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Jenny Garcia Arias

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**UNIVERSITÉ PARIS 1 PANTHÉON SORBONNE**

École Doctorale de Géographie

Centre de recherche de l'Institut de démographie de Paris CRIDUP

**THÈSE**

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**Jenny GARCIA ARIAS**

**DISPARITÉS DE MORTALITÉ PAR CAUSES EN AMÉRIQUE LATINE:**

**L'HYPOTHÈSE DU « BIAIS URBAIN »**

**Sous la direction de: Dr. France MESLÉ**

**JURY:**

Directrice de Thèse: **Dr. France MESLÉ**, Directrice de recherche, Institut National d'études Démographiques (INED)

Co-directrice: **Dr. Aline DESESQUELLES**, Directrice de recherche, Institut National d'études Démographiques (INED)

Président du Jury: **Dr. Claude GRASLAND**, Professeur, Université Paris 7 Denis Diderot

Rapporteur: **Dr. Hiram BELTRÁN-SANCHÉZ**, Professeur agrégé de l'Université de Californie, Los Angeles.

Rapporteur: **Dr. Mark MONTGOMERY**, Chercheur, Programme Pauvreté, genre et jeunesse, de Population Council et Professeur de l'Université Stony Brook.



**DISPARITÉS DE MORTALITÉ PAR CAUSES EN AMÉRIQUE LATINE:**

**L'HYPOTHÈSE DU « BIAIS URBAIN »**

## Résumé

En 1977, Michael Lipton a présenté le concept de biais urbain comme cadre pour comprendre comment la plupart des politiques macroéconomique et microéconomique ont profité au surdéveloppement des zones urbaines et au sous-développement des zones rurales, en raison du biais historique dans la réaffectation des ressources. En Amérique latine, l'urbanisation et la baisse de la mortalité sont historiquement liées positivement : la transition sanitaire dans la région a été amorcée dans les principales villes et s'est poursuivie plus rapidement dans les pays à urbanisation plus élevée. Cette recherche s'inscrit dans ce cadre et s'intéresse à deux phénomènes: la persistance d'un avantage urbain dans la mortalité d'une part; et d'autre part des traces d'un «biais urbain» dans les schémas des causes de décès dans la région. En étudiant plusieurs pays d'Amérique latine sur la période 2000-2010, j'applique des méthodes de décomposition de l'espérance de vie à la naissance pour analyser les disparités dans les schémas de mortalité et les causes de décès lorsque les zones urbaines et rurales sont considérées séparément. En définissant l'urbain comme un continuum au lieu d'un concept dichotomique, trois groupes spatiaux sont reconnaissables dans chaque pays: les capitales et autres grandes villes (plus de 500 000 habitants); les moyennes et petites villes (20 000 à 499 000 habitants) et les villages et autres zones purement rurales (moins de 20 000 habitants). Les pays analysés sont le Brésil, le Chili, la Colombie, l'Équateur, le Mexique, le Pérou et le Venezuela. Dans la mesure où une comparabilité dans le temps et entre les pays est nécessaire, deux questions majeures sont considérées pour garantir la qualité des données: les erreurs de couverture évaluées en termes de niveau de sous-déclaration et les erreurs de déclaration pour l'âge, le sexe, la résidence et les causes de décès. Les résultats indiquent que l'avantage urbain est persistant et que les écarts de mortalité entre les zones rurales et urbaines ont toujours favorisé les villes. Il n'y a pratiquement aucune baisse de la mortalité chez les adultes plus âgés en dehors des capitales et autres grandes villes. Cet avantage urbain en matière de mortalité résulte de la baisse de la mortalité pour les causes qui se prêtent à des interventions primaires rendues possibles par l'existence d'infrastructures publiques ainsi que par la fourniture de biens et services sociaux. Les pays et les sous-populations bénéficient différemment des progrès: dans les pays les plus urbanisés, les schémas de mortalité des groupes spatiaux convergent, tandis que des écarts subsistent dans les pays les moins urbanisés.

**Mots-clés:** urbanisation, croissance urbaine, avantage urbain, sur-urbanisation, baisse de la mortalité, transition sanitaire, causes de décès évitables.

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## INTRODUCTION

Au cours du siècle passé, les profils de mortalité ont été profondément modifiés dans les pays latino-américains : dans la plupart des pays, il y a eu une rapide diminution de la mortalité tandis que les maladies dégénératives et les maladies de société devenaient prépondérantes dans la structure des causes de décès. La période au cours de laquelle la mortalité a diminué le plus rapidement - à partir des années 1930 - fut marquée par des contrôles sanitaires considérables, des campagnes de vaccination massives, l'élimination des vecteurs de maladies, la distribution d'antibiotiques, la construction à grande échelle de réseaux d'eau potable et d'eaux usées et l'expansion du système de santé (Arriaga and Davis 1969; Preston 1976). Ces mesures ont significativement réduit les décès par maladies infectieuses et parasitaires, dans tous les pays et particulièrement au sein de la population infantile. Ainsi, l'espérance de vie moyenne de la région a augmenté de 6,4 ans au cours des années 1950 et de 8,6 ans au cours des deux décennies suivantes (ECLAC 2016). Après les années 1970, la baisse a commencé à ralentir et il y a eu une augmentation de la prévalence des décès dus aux maladies cardiovasculaires et à des causes externes (Frenk, Frejka et al. 1991; ECLAC 2007; Sabino, Regidor et al. 2007). Dans la littérature, le ralentissement des progrès de l'espérance de vie est lié à plusieurs causes : 1) les taux élevés persistants de mortalité infantile, dus des maladies infectieuses encore importantes dans certains pays (Schkolnik and Chackiel 1997); 2) l'échec qui a consisté à passer à côté de la "révolution cardiovasculaire" ; 3) l'existence d'importants différentiels entre les population sub-nationales (Frenk, Bobadilla et al. 1991); ; et 4) l'incidence des morts violentes qui soit persiste soit augmente (Di Cessare 2011).

Quand une étude de la mortalité porte sur différents pays, l'approche la plus traditionnelle considère le contexte national, dans la mesure où les politiques d'intervention sont souvent indubitablement inhérentes aux Etats. Cependant, il est également vrai que l'analyse des indicateurs de mortalité pris à un niveau national peut dissimuler des différentiels entre des groupes de population en particulier. Des écarts de conditions de vie ont historiquement été corrélés avec toutes sortes de facteurs (race, ethnicité, revenus, éducation, profession, etc.) qui ne correspondent pas nécessairement à des catégories spatiales. Cependant, dans le cas de l'Amérique latine, de nombreuses études sur les conditions de vie ont souligné leur développement inégal en fonction de lignes spatiales. Une concentration élevée de biens et de services dans les villes a laissé les zones rurales à la traîne (Prata 1992; Curto 1993; Schkolnik and Chackiel 1997).

C'est en 1977 que Michael Lipton a introduit la Thèse du Biais Urbain (TBU) comme cadre théorique pour comprendre les singularités socio-économiques dans les pays en voie de développement. Il a mis en lumière comment la plupart des initiatives politiques macro et microéconomiques ont conduit à un surdéveloppement des zones urbaines et à un sous-développement des zones rurales (Lipton 1977). La TBU affirme que les zones rurales dans les pays en voie de développement souffrent de trop peu de dépenses en aide sociale et des différences en matière de taxation, de salaires et de prix de la nourriture, qui ont créé des écarts inéquitables au sein de la population et un manque d'efficacité dans la distribution des ressources (Varshney 1993). On peut retrouver la trace du biais urbain dans la façon dont l'économie rurale-urbaine se manifeste dans les stratégies de moyens de subsistance (Jones and Carbridge 2010). Bien qu'il y ait des raisons de penser qu'un biais urbain continue de

gangrener les politiques de prix et de dépenses et l'allocation de ressources totale dans les pays en voie de développement, son ampleur demeure inconnue" (National Research Council 2003).

A la suite de cette idée, ce projet de recherche cherche à répondre aux questions suivantes. Peut-on trouver la trace du "biais urbain" à travers les différences urbaines-rurales de la mortalité ? Et est-ce que prendre en compte ces différences met en lumière les moteurs de la transition sanitaire dans la région ? Dans ce sens, je pose les hypothèses suivantes : l'urbanisation et le développement sont étroitement liés en Amérique latine, parce que la concentration de biens et de services dans les zones les plus urbanisées - le biais urbain en matière d'allocation de ressources - résulte invariablement en ce que les ressources soient stratégiquement utilisées pour promouvoir un rapide déclin de la mortalité et pour mener la transition de santé à un niveau national, dans un contexte d'urbanisation rapide.

Plus spécifiquement, je cherche à savoir : est-ce que les pays latino-américains ont des modèles de mortalité différents lorsque l'on considère les zones urbaines et rurales séparément ? Est-ce que les différences entre les cadres ruraux et urbains proviennent de niveaux et de tendances spécifiquement liés à la cause de décès et à l'âge ? Est-ce que le biais urbain dans l'allocation de ressources peut être perçu à travers la structure des causes de décès dans les pays latino-américains ? De même, je pose l'hypothèse que :

-Il y a un avantage urbain persistant dans la mortalité en Amérique latine. Cet avantage se concentre principalement dans les plus grandes villes. L'avantage urbain demeure, en dépit du niveau d'urbanisation et de mortalité atteints par ces pays.

-L'avantage urbain est perceptible à travers les différences dans les tendances de mortalité spécifiques à l'âge. Dans les plus grandes villes, la réduction de la mortalité adulte conduit à une rectangularisation de la courbe de survie, alors que dans les autres villes et les zones rurales, la baisse de la mortalité infantile demeure la principale contributrice aux changements.

-L'avantage urbain provient principalement de l'impact différentiel des causes de décès évitables, dans la mesure où leurs taux d'incidence sont plus élevés dans les zones rurales que dans les zones urbaines. Cela signifie que l'analyse des causes de décès rend possible de suivre le biais urbain dans les allocations de ressources à travers le territoire national, parce que les décès dus à certaines causes évitables ne se produiraient pas si des interventions efficaces étaient réalisées dans les temps.

Pour répondre à toutes ces questions et tester les hypothèses de cette recherche, j'ai sélectionné les données de sept pays latino-américains. Ceux-ci représentent des situations diverses en termes d'espérance de vie et de pourcentage de population urbaine (voir tableau ci-dessous). La période d'analyse, de 2000 à 2010, couverte par la 10<sup>e</sup> révision de la Classification Internationale des Maladies (CIM), est déterminée par la disponibilité des données dans les sept pays.

% Population urbaine en 1995	Espérance de vie en 1995	
	Supérieure (>69 years)	Inférieure (<69 years)
Elevée (>80%)	Chili	Brésil
Moyenne (60% to 80%)	Venezuela	Colombie
Basse (<60%)	Mexique	Pérou
	Équateur	

Cette recherche emploie le terme “urbain” en tant que continuum de catégories plutôt que comme un concept dichotomique, appliquant ainsi trois types de groupes spatiaux reconnaissables pour tous les pays : les capitales et grandes villes (plus de 500 000 habitants) ; les villes moyennes et petites (de 20 000 à 499 000 habitants) ; et les villages et zones rurales (moins de 20 000 habitants). J'utilise des bases de données sur les causes de décès provenant des statistiques démographiques publiées par les Ministères de la Santé au Pérou et au Venezuela, et par les Instituts Nationaux des Statistiques au Chili, en Colombie, en Equateur et au Mexique, et des estimations de population faites par les Instituts Nationaux des Statistiques de chaque pays. J'ai ensuite pris en considération deux problèmes majeurs en estimant les taux de mortalité par âge : les erreurs de couverture, identifiées en tant que niveaux sous-déclarés ; et les erreurs de déclaration pour l'âge, le sexe, le département de résidence et les causes de décès. Des estimations corrigées et comparables sont analysées en utilisant des méthodes de décomposition de l'espérance de vie. Cette recherche se décompose en quatre parties. La première résume le cadre théorique et contextuel de la recherche ; la seconde indique brièvement la méthode utilisée pour l'analyse. Les résultats sont présentés dans la troisième partie et les conclusions dans la quatrième.

## 1. CONTEXTE

Les théories de la modernisation qui prévalent dans les études démographiques reposent sur l'idée que le développement est un processus unidirectionnel dans lesquelles les sociétés doivent passer d'un état primitif de famille rurale, élargie et à la vie courte, à un état idéal de famille urbaine, réduite et à la vie longue (Tabutin 1999). Cette approche dichotomique des cadres rural-urbain a servi comme cadre analytique pour les sociétés modernes autour du globe, dans lequel l'espace urbain industrialisé est vu comme une version évoluée de l'espace rural agricole. Il est vrai que l'augmentation des taux d'instruction et le déclin des taux de fécondité et de mortalité (prévalant en tant que valeurs séculières et rationnelles) ont eu lieu dans les villes européennes industrielles (Notestein 1945; Notestein 1953). Cependant, les récents déclin de la mortalité et de la fécondité dans les pays en voie de développement remettent en question les tentatives d'interprétation précédentes. Plusieurs exemples de croissance élevée d'urbanisation, combinée à des fécondité et mortalité en déclin, ont été relevés en l'absence d'industrialisation, dans le monde entier (Dyson 2011).

Depuis le début du vingtième siècle, la population d'Amérique latine et des Caraïbes a été multipliée par dix : elle est d'abord passée de 60 millions en 1900 à 161 millions en 1950, puis à 622 millions en 2018. La région représente de nos jours 8,5% de la population mondiale totale (ECLAC 2011; UN-Habitat 2012). La croissance s'est principalement concentrée dans les zones urbaines ; et en l'espace d'environ 50 ans, l'Amérique latine est passée de majoritairement rurale à majoritairement urbaine. A la même période, deux phénomènes démographiques se sont produits : 1) une baisse plus rapide des taux de mortalité que des taux de fécondité, ce qui a conduit à une croissance naturelle de la population ; et 2) une forte migration rurale-urbaine qui a concentré les populations dans les villes.



## 1.1 Processus ancien et récent d'urbanisation

A partir d'une revue de la littérature, l'espace urbain est défini en utilisant plusieurs critères. Les définitions varient au cours du temps et elles peuvent émerger comme fonctions des frontières politiques, de la taille ou de la densité de population, des activités du territoire économique, du paysage ou des structures physiques, des services fournis, ou peut-être d'autres critères qu'il reste à mettre en avant. Dans tous les cas, la définition repose sur un contour commun et spécifique : l'espace urbain est non-rural. L'idée de définir l'urbain et le rural de façon dichotomique suppose qu'il y ait en effet suffisamment de caractéristiques opposées pour distinguer les deux cadres (Hugo 1987). Du fait de la nature de cette analyse, l'urbain est supposé être simplement une dimension démographique dans laquelle la taille de la population est utilisée comme un indicateur. Un espace urbain ou une population urbaine est ainsi caractérisée par sa densité, et le processus d'un espace rural devenant urbain consiste simplement à croître en densité. Au moins une distinction doit être faite au sujet du processus d'urbanisation. Est-ce que l'urbanisation récente dans les pays en voie de développement est comparable à l'urbanisation ancienne en Europe ? Est-ce que les différences sont liées aux décalages dans le temps ou bien impliquent-elles un processus complètement différent ? Comprendre l'urbanisation ancienne et récente en fonction d'un cadre analytique différent peut être le premier pas pour démêler le rôle joué par les processus de développement et d'urbanisation et leurs relations avec la baisse de la mortalité.

La première région à avoir été urbanisée fut l'Europe. La croissance accélérée de la population urbaine s'est produite en parallèle du processus d'industrialisation. Jusque-là, les villes étaient des endroits mortels pour qui y vivait, en raison de leurs taux de mortalité élevés. La croissance préindustrielle urbaine fut restreinte par deux facteurs : leur capacité à fournir de la nourriture et à contrôler les maladies infectieuses et parasitaires (De Vries 1984). Alors que la mortalité baissait, la population totale croissait et, par conséquent, la population urbaine augmentait. De plus, la migration rurale-urbaine fut conduite par un développement économique conséquent, associé à l'urbanisation (Fox 2012). Le parallélisme de ces deux processus, dans l'histoire européenne, a conduit à ce que l'urbanisation émerge comme résultat d'une croissance économique soutenue, bien qu'il y ait probablement de très bonnes raisons d'interpréter une causalité inversée. Cela signifie que la croissance économique soutenue a résulté de l'urbanisation. Il est sans aucun doute difficile de concevoir que ce développement économique, politique et social se produirait dans les zones européennes rurales sans l'existence des villes (Keyfitz 1996). Tout au long du processus d'urbanisation européenne, un changement significatif, dans les tendances de mortalité, a été enregistré. Dans le cas européen, les liens entre urbanisation et développement économique semblent être incontestables. Loin des généralisations mondiales, la récente expérience des pays en voie de développement autour du monde pourrait remettre en question ces liens entre urbanisation et développement économique. L'urbanisation sans véritables signes de développement économique ou de modernisation est observée partout (Bairoch 1996).

Le processus d'urbanisation dans les pays en voie de développement n'a pas été exceptionnellement rapide du point de vue des standards historiques ; c'est plutôt la croissance des taux de population urbaine qui représente un phénomène sans précédent (Preston 1979). En échelle absolue, l'urbanisation contemporaine tout autour du monde est bien plus grande qu'au 19<sup>e</sup> siècle, pendant que l'augmentation proportionnelle de la population urbaine est

similaire à celle observée en Europe et en Amérique du Nord pour la période 1875-1925 (Cohen, Montgomery et al. 2003). Les changements dans les pays en voie de développement furent généralement mis en mouvement par une introduction plus rapide des technologies, telles que les méthodes agricoles industrielles, les antibiotiques et les vaccins, le tout facilitant les baisses de la mortalité et augmentant la disponibilité des réserves de nourriture après la 2e Guerre Mondiale (Fox, 2012). Par conséquent, le taux de changement a été plus rapide et plus élevé que la croissance de la population. Les gains en espérance de vie et les réserves de nourriture ont cru plus rapidement que le développement économique, et l'écart entre le moment où la mortalité et la fécondité ont commencé à décliner est plus grand dans certains pays en voie de développement, par rapport au cas européen (Reher 2011). Cet écart a permis à des populations de continuer à croître plus vite, dans les zones urbaines comme rurales (Bairoch 1985). Entre 1950 et 1990, la population urbaine dans les pays en voie de développement a augmenté de 4,5% chaque année, plus de 2,5 fois n'importe quel taux jamais enregistré dans les pays européens. A ce rythme, on estime que le processus d'urbanisation -au lieu de prendre 150 ans (ce qui fut le cas dans les pays européens)- prendrait seulement 50 ans (Pumain 2006).

## **1.2 Biais urbain contre sur-urbanisation en matière de mortalité**

Le processus d'urbanisation rapide et non-contrôlé a renforcé l'incapacité des pays en voie de développement à fournir des biens et services publics à toutes les populations ; et un biais en faveur ou au détriment des zones urbaines a été identifié comme l'une des principales inégalités spatiales. Selon que la relation entre urbanisation et mortalité est linéaire et causale ou pas, deux scénarios sont possibles quand on lie les deux processus de façon transversale : une relation inversée (ou avantage urbain) ou bien une relation directe (ou désavantage urbain). Ces deux scénarios antagonistes sont bien connus dans les théories économiques, géographiques ou sociales, où on les qualifie de biais urbain (avantage urbain) et sur-urbanisation (désavantage urbain).

### **1.2.1 La thèse de la sur-urbanisation**

Le terme de « sur-urbanisation » a été introduit pour la première fois par Davis et Golden (1954) pour décrire les pays dans lesquels le taux d'industrialisation a cru plus lentement que leur taux d'urbanisation. A partir d'un paradigme de développement clair, il a pour but d'expliquer la rapide croissance urbaine dans des cadres de pauvreté continue et de stagnation économique. Le flagrant défaut des économies en voie de développement est qu'elles sont centrées sur l'industrialisation et biaisées en faveur des stratégies pour développer un secteur urbain moderne (Todaro and Stilkind 1981). Quand on étudie la mortalité, la thèse de la sur-urbanisation a été utilisée pour expliquer l'excès de mortalité dans les zones urbaines de certains pays en voie de développement. Les spécialistes ont montré que même si les pays en voie de développement du monde entier ont construit, approvisionné et pourvu en personnel leurs écoles, structures de santé et cliniques de planification familiale tout en fournissant des services de logement et de transport avec des degrés de succès variés, certaines zones rurales demeurent plus pauvres que jamais, pendant que différentes zones urbaines sont devenues des espaces de pauvreté centrés sur des bidonvilles et en proie au crime.

Les populations urbaines actuelles sont confrontées, d'un côté, à une exposition à des environnements physiques malsains en proie aux maladies transmissibles, et, d'un autre côté, au problème croissant des maladies non-transmissibles associées à l'instabilité sociale, aux maladies mentales, à la violence, aux accidents et aux maladies chroniques. La co-existence de ces deux profils épidémiologiques différents contredit l'idée généralement admise selon laquelle les zones urbaines de certains pays en voie de développement pourraient prendre la tête dans la transition de la mortalité de nos jours. Les analyses de la mortalité infantile et adulte par causes de décès à Nairobi, au Kenya, et au Burkina Faso, fournissent suffisamment d'illustrations de l'inconvénient urbain auquel font face de nombreuses populations urbaines pauvres (Rossier, Bassiahi Soura et al. 2014). Leon (2008) arrive au même résultat dans une analyse de l'hypertension en Afrique sub-saharienne, dans laquelle il a montré que les taux étaient constamment plus élevés dans les zones urbaines plutôt que rurales (Leon 2008).

### **1.2.2 La Thèse du Biais Urbain**

En 1977, Michael Lipton a introduit pour la première fois la Thèse du Biais Urbain comme cadre pour comprendre les inégalités sociales et économiques dans les pays avec des économies en voie de développement. Il a montré comment la plupart des initiatives politiques macro et microéconomiques ont abouti à un surdéveloppement des zones urbaines et à un sous-développement des zones rurales, en tant que produit des économies capitalistes (Lipton 1977). La surconcentration des zones urbaines est l'exact résultat d'un biais urbain dans les politiques publiques qui a conduit à des taux excessifs d'urbanisation. Les pays avec des économies en voie de développement sont incapables de satisfaire les besoins fondamentaux au-delà des zones urbaines, en raison d'une concentration élevée de biens et de services dans les villes, et particulièrement dans les capitales. De ce fait, le cadre urbain tient un avantage en termes de niveaux de vie et d'accès aux services (Cohen 2006).

On peut également trouver la trace d'un avantage urbain en termes de santé, dans certains pays en développement, au cours du 19<sup>e</sup> siècle, quand les villes ont commencé à fournir des services sociaux aux colons immigrants (Gould 1998). Cela est demeuré constant dans de nombreux pays où les villes ont profité de la concentration des infrastructures, des programmes de prévention et des établissements médicaux (Oris and Fariñas 2016). Les avantages résultent d'une combinaison de facteurs. Tout d'abord, la pauvreté extrême et le manque de services tendent à être principalement des phénomènes ruraux. Ensuite, les populations urbaines disposent de taux plus élevés de couverture de santé publique que leurs équivalentes rurales. Enfin, en raison de leur proximité, de leur dissémination et de leur assimilation des interventions de santé publique, elles sont susceptibles d'être plus efficaces dans un cadre urbain (Leon 2008). De plus, les individus avec des revenus plus élevés et un niveau d'instruction plus élevé (des facteurs considérés comme de robustes indicateurs de santé et déterminants de modes de vie) sont plus susceptibles de se regrouper dans les villes (Sastry 1997). Les différences sous-jacentes dans les caractéristiques socioéconomiques et comportementales, entre les cadres urbain et rural, au niveau de l'individu et du foyer, n'aboutissent en effet pas à des résultats de santé particuliers, mais la concentration des facteurs aboutit à de meilleurs résultats dans les villes (Phillimore and Reading 1992; Sastry 1997; Haines 2001; Reher 2001; Zimmer, Kaneda et al. 2007).

### 1.3 Le processus d'urbanisation en Amérique latine

Tout au long du 19<sup>e</sup> siècle, les niveaux d'urbanisation en Amérique Latine et dans les Caraïbes étaient plus bas qu'en Amérique du Nord, en Europe et en Océanie. La minorité de la population vivant dans les villes était concentrée dans les capitales des pays (Merrick 1995). Par la suite, on estime que la population urbaine latino-américaine a été multipliée par cinq entre les années 1920 et 1960. Au cours de cette période, alors que les populations rurales et des petites villes (moins de 20 000 habitants) ont juste été multipliées par deux et demi (Rowley 1976), la population vivant dans les villes de plus de 500 000 habitants est passée d'une estimation de 12 millions à 35 millions. Entre 1950 et 2000, la région a cru de 314 à 1851 villes de plus de 20 000 habitants, celles-ci étant le plus souvent concentrées dans les régions côtières. Durant la première décennie du 21<sup>e</sup> siècle, les niveaux d'urbanisation ont finalement rattrapé ceux d'Amérique du Nord ainsi que ceux de nombreux pays européens (Cohen 2006).

Différents paradigmes sociaux et économiques ont arbitré la relation entre l'urbanisation et le développement au travers de la politique publique directe et des changements sociaux qui se sont produits durant le 20<sup>e</sup> siècle. Dans un contexte où les processus d'industrialisation, d'urbanisation, de modernisation et de développement se sont entremêlés, la littérature souligne au moins trois grandes étapes des politiques socioéconomiques qui ont façonné le rôle de la ville latino-américaine : 1) la période qui a imposé des politiques de remplacement des importations au milieu du 20<sup>e</sup> siècle ; 2) les politiques économiques néolibérales dans les années 1980 ; et 3) la montée du nationalisme populiste au début du 21<sup>e</sup> siècle.

1) L'imposition de politiques de remplacement des importations et le développement de secteurs industriels naissants parmi les plus grandes économies de la région ont caractérisé les deux décennies qui ont suivi la fin de la 2<sup>e</sup> Guerre Mondiale en Amérique latine (Frankman 1971). Les théories économiques formulées entre les années 1950 et les années 1960 étaient censées moderniser les pays, plaçant l'industrialisation au centre, indépendamment de l'orientation idéologique ou du régime politique. Une industrialisation rapide était considérée comme le seul modèle pour le développement économique, et une part inévitable de ce processus d'industrialisation était l'urbanisation. L'explosion urbaine, dans la plupart des pays latino-américains, fut due à un développement industriel nouveau, à l'expansion du secteur secondaire, et à la faiblesse du secteur agricole. Ces changements étaient au début principalement conduits par les gouvernements nationaux. En fait, 40% de l'investissement en capital fixe, dans toute la région, au cours des années 1950, fut fait par le secteur public. Le rapide processus d'urbanisation durant la période des politiques de remplacement des importations conduisit à la dépopulation des zones rurales et à une concentration encore plus grande de populations dans les plus grandes des grandes villes, généralement les capitales (Baeninger 2002).

Les limites du modèle de remplacement des importations, dans le plein développement du secteur industriel de la région, ont conduit à la croissance des bidonvilles et à une culture de la marginalité qui a accompagné la migration de la campagne à la ville. La croissance rapide des bidonvilles est considérée comme une réponse à la croissance urbaine dans des conditions historiquement sans précédent (Rowley 1976). La croissance initiale démesurée des villes,

principalement grâce à des logements de fortune, est devenue une préoccupation publique, et les Etats ont commencé à développer des stratégies pour améliorer la qualité des logements et pour étendre les équipements publics à l'intérieur des bidonvilles existants. Que ce soit en créant de nouvelles constructions ou en remplaçant des logements précaires, les quartiers pauvres se sont formalisés. Le principal rôle du gouvernement, dans de tels plans de logement, était de créer un environnement favorable pour le plein développement d'initiatives d'autoconstruction pour les pauvres des villes, ce qui est devenu une caractéristique des années 1970 et de la plus grande partie des années 1980. Cela impliquait une rupture majeure avec la période précédente, quand les interventions de l'Etat signifiait l'éviction des habitants de leurs installations spontanées et la destruction de leurs cabanes provisoires (van Lindert 2018).

2) *Les politiques économiques néolibérales* sont apparues comme une recommandation non seulement en raison de la stagnation économique de la région durant la "décennie perdue" des années 1980 mais aussi de l'échec des politiques de remplacement des importations. En réponse au discours économique régional, dans lequel les interventions inefficaces de l'Etat dans la vie économique conduisaient à la stagnation économique, les Etats furent forcés à réduire les investissements publics, à entamer une vague de privatisation d'envergure, à éliminer les taxes, et à réduire les taux d'inflation. Dans certains pays, les politiques fonctionnèrent, quand dans d'autres elles augmentèrent les taux de pauvreté. Les politiques économiques néolibérales ont eu un effet particulièrement dur sur les plus grandes villes de la région. Des coupes budgétaires dans les investissements sociaux et dans les services publics employés à réduire les inégalités socioéconomiques, particulièrement dans les villes, furent mises à exécution durant cette période. L'impact fut tel que, à la fin des années 1980 et au début des années 1990, les niveaux de pauvreté urbaine avaient augmenté considérablement et un grand nombre de villes étaient confrontées à un état critique (Da Cunha 2002; Rodríguez 2002). Plusieurs pays de la région ont procédé à des réformes qui ont transféré l'exécution de certaines étapes de la mise en œuvre des politiques sociales à la sphère privée.

Les plus grandes villes continuèrent à être mieux positionnées en moyenne, mais étaient sous la menace d'être confrontées à des disparités sociales et de revenus plus profondes. La tendance vers une importance décroissante des capitales - définie par leur contribution proportionnelle au PIB national - soit inversé dans la plupart des pays (Cuervo Gonzalez 2017). Les périphéries des plus grandes villes commencèrent à perdre tout avantage, aux dépens d'une consolidation des métropoles industrielles secondaires et des régions agro-industrielles ; mais la plupart de ces régions ont, finalement, subi de graves revers à cause de la désindustrialisation accélérée et des vagues de privatisation des années 1980 et 1990 (Piña 2014). Les modèles de primauté de la capitale demeurent importants dans seulement quelques pays tels que l'Argentine, le Chili, le Panama et l'Uruguay, où plus de 40% des populations vivent dans les aires métropolitaines de la capitale, alors que dans d'autres pays de la région, des réseaux urbains bien plus complexes couvrent les territoires nationaux.

3) *Le nationalisme populiste* : le mécontentement provoqué par le modèle économique néolibéral de développement et de mondialisation a encouragé la montée du nationalisme populiste dans de nombreux pays durant la première décennie du 21<sup>e</sup> siècle (Baeninger 2002). Au cours de cette étape, d'importants changements structurels ont eu lieu en Amérique latine.

Les économies nationales se sont intégrées à l'économie mondiale et des programmes publics ont été mis en œuvre de façon à réduire les niveaux de pauvreté et à améliorer les infrastructures et à contribuer au rétablissement économique, toutes ces mesures étant particulièrement remarquables, en comparaison avec la décennie précédente. Une aubaine économique aboutit à l'augmentation des prix du pétrole et du gaz, ainsi qu'à de nouveaux partenariats commerciaux à des niveaux internationaux. La teneur économique et les fonctions du capital furent profondément transformés. La tendance prédominante consista à réduire les activités économiques industrielles et à consolider les fonctions tertiaires de la grande ville (Da Cunha and Rodríguez 2009; Cuervo Gonzalez 2017).

La baisse des inégalités devint assez répandue après 2000. En termes généraux, la période précédente d'inégalités croissantes (1990 et 2002) fut inversée entre 2002 et 2010 (ECLAC 2014). Cette réduction fut fortement influencée par des programmes publics à grande échelle de transferts directs d'argent liquide aux ménages et par une réduction des inégalités de revenus liés au travail, ce dernier étant associé à un accès plus égalitaire à la scolarisation (Lopez-Calva and Lustig 2010). La majeure partie de la croissance observée dans les populations urbaines l'a été dans des villes de petite et moyenne taille et dans des villes de moins d'un million d'habitants. Les plus grandes villes de la région demeurent double, divisées, et ségréguées aussi bien spatialement que socialement parce que les initiatives pour combattre la pauvreté n'ont pas éliminé les inégalités.

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#### **1.4 La baisse de la mortalité en Amérique latine**

L'espérance de vie moyenne en Amérique latine et dans les Caraïbes est passée de 29 ans en 1900 à 74 ans en 2010. La même année, 98% des enfants atteignaient leur premier anniversaire, contre seulement 75% cent ans plus tôt. Pour mettre cela en perspective, l'espérance de vie à la naissance en Amérique du Nord en 1900 était de 48 ans, presque vingt ans de plus que dans la région latino-américaine prise dans son ensemble ; et en 2010 la différence n'était plus que de quatre ans, avec une espérance de vie à la naissance nord-américaine de 78 ans (PAHO 2012). Cette progression fut influencée principalement par les changements démographiques qui ont eu lieu durant les années 1950 et 1960, une période de croissance explosive qui a propulsé la population d'Amérique latine bien au-dessus des autres régions à faible revenu (Schultz 1993). ). L'Amérique latine était la région à faible revenu qui présentait la meilleure santé du monde, et l'espérance de vie a continué à progresser jusqu'à augmenter de plus de 20 ans au cours des 50 années suivantes dans la plupart des pays de la région, la baisse constante de la mortalité infantile étant le principal moteur de cette augmentation de l'espérance de vie. La baisse de la mortalité s'est opérée de façon continue, même durant les périodes de croissance économique lente et versatile et en dépit du fait que les taux de pauvreté durant la première décennie du 21<sup>e</sup> siècle étaient aussi élevés que ceux du début des années 1980 (Butterworth and Chance 1981).

### **1.4.1 Les facteurs du progrès sanitaire**

A l'exception de l'Argentine et de l'Uruguay, les progrès les plus importants de l'espérance de vie ont débuté en Amérique latine après la 2<sup>e</sup> Guerre Mondiale. L'impact du développement économique sur la baisse de la mortalité fut décisif seulement au début du 20<sup>e</sup> siècle, au moment où le progrès sanitaire s'amorçait. De 1900 à 1930, la baisse de la mortalité est restée très lente et l'augmentation moyenne de l'espérance de vie à la naissance était seulement de 0,21 an par année calendaire (Arriaga 1970). Des années 1930 aux années 1960, quand la baisse a commencé à accélérer dans la plupart des pays, les principaux facteurs de la baisse de la mortalité, ont été, d'un côté, les contrôles sanitaires appliqués sur la base de notions élémentaires d'hygiène personnelle et, d'un autre côté, l'intégration des progrès médicaux dans les pratiques de santé standard (Arriaga and Davis 1969; Preston 1976). La plupart des pays latino-américains ont promulgué des politiques de santé efficaces, telles que la vaccination des populations à grande échelle, l'élimination des vecteurs de maladie, la distribution d'antibiotiques et la construction à grande échelle de systèmes de fourniture d'eau potable et du tout-à-l'égout (Palloni and Pinto-Aguirre 2011).

Durant les années 1980, alors que les stratégies de développement économique fondées sur le remplacement des importations s'épuisaient progressivement d'elles-mêmes dans tous les pays, la crise de la dette de 1982 a conduit au renforcement de mesures d'austérité drastiques et à des coupes budgétaires (Imbusch, Misse et al. 2011). La plupart des pays de la région ont diminué les dépenses dédiées à la santé, mis un terme à l'expansion des infrastructures de santé publique et réduit les campagnes de vaccination. Il est devenu courant de voir des vagues de privatisation dans les systèmes de santé, dans la mesure où les services étaient sous-traités, dans toute la région. Après les années 1990, la baisse de la mortalité s'est ralentie et une quasi-stagnation de l'espérance de vie a été observée dans la plupart des pays (Di Cessare 2011). Ce ralentissement peut être attribué à des causes bien connues historiquement, telles que la pauvreté et les inégalités, pendant que de nouvelles causes sont apparues, telles que des changements rapides de mode de vie incluant mais ne se limitant pas à des régimes alimentaires plus pauvres et plus industrialisés, une augmentation du tabagisme, une augmentation de l'obésité, et la soi-disant «épidémie de violence». Selon ce scénario, les facteurs les plus importants dans la réduction de la mortalité ont été les suivants : améliorations des niveaux de vie, des logements, de l'alimentation, des transport et de l'accès aux soins médicaux (Palloni and Pinto-Aguirre 2011).

### **1.4.2 L'évolution des causes de décès**

Jusqu'à la 2<sup>e</sup> Guerre Mondiale, la caractéristique principale de la région était un profil épidémiologique dominé par les maladies infectieuses et une mortalité infantile élevée. Le paludisme était la première cause de décès dans presque tous les pays de la région, suivi par la fièvre typhoïde, la dysenterie et la tuberculose. La réduction initiale de ces maladies infectieuses peut être expliquée par deux types d'intervention : premièrement, quelques pays pionniers (le Panama et Cuba) ont initié des campagnes pour éradiquer les maladies transmises par un vecteur ; et, deuxièmement, la plupart des pays à la traîne ont intégré dans leurs systèmes de santé les nouvelles technologies médicales, les antibiotiques et les vaccinations (Palloni and Pinto-Aguirre 2011). Entre 1930 et 1960, la baisse rapide de la mortalité dans la

région est principalement due à la réduction du paludisme et de la tuberculose, particulièrement dans les pays où les taux étaient les plus élevés (Palloni 1981).

Actuellement, les maladies infectieuses et parasitaires continuent de diminuer en Amérique latine, mais à des niveaux et avec des rythmes de baisse différents entre les pays et les sous-populations. Cependant, des maladies déjà éradiquées resurgissent et reviennent dans la région occasionnellement. La plus grande épidémie de choléra durant la dernière décennie du 20<sup>e</sup> siècle s'est produite de façon inattendue en Amérique latine en 1991, après une absence de près de cent ans. De leur côté, la dengue, la dengue par fièvre hémorragique et d'autres maladies transmissibles sont encore apparues à des taux épidémiques dans de nombreux pays de l'hémisphère (PAHO 2012). Le fait que la partie pauvre de la population a continué à vivre sans conditions sanitaires adéquates peut être la principale raison des épidémies (Taucher, Albala et al. 1996).

Après la diminution des maladies transmissibles, une nouvelle vague d'augmentation puis de diminution des décès dus aux maladies circulatoires s'est répandue à travers la région. Dans les années 1960, déjà, les maladies circulatoires concurrençaient les maladies infectieuses pour devenir la première cause de décès dans la population âgée de 45 ans et plus. Entre les années 1970 et 1980, la baisse des maladies circulatoires dans les pays pionniers a joué un grand rôle dans le déclin de la mortalité adulte. Depuis les années 1980, la mortalité adulte suit différents modèles de causes de décès, selon l'âge : les maladies chroniques non-transmissibles dominent les 15 ans et plus mais les maladies de l'appareil circulatoire, qui avaient été cause de décès la plus importante, ont été remplacées par les cancers. Dans cette période, la plus grande diminution de la mortalité a été observée dans le groupe d'âge 15-44 ans pour la plupart des pays, à l'exception de Cuba, du Venezuela et du Guatemala. A la fin du 20<sup>e</sup> siècle, le diabète a commencé à émerger dans la plupart des pays latino-américains, en particulier au Mexique.

Une attention particulière doit être accordée aux causes de décès liées à la violence. Ce qui était un problème naissant dans les années 1950 devint une « épidémie » dans plusieurs pays latino-américains, dans la mesure où elle touchait les jeunes hommes d'une façon disproportionnée. On trouve une haute incidence de la criminalité dans la région : la prolifération de gangs de jeunes violents et la forte prévalence de la violence domestique émergent au sommet de formes de violence plus historiques, telles que les guerres civiles persistantes, les mouvements de guérilla, les escadrons de la mort, le terrorisme d'Etat, les dictatures, les soulèvements sociaux et les révolutions violentes (Imbusch, Misse et al. 2011). L'augmentation des homicides est la dimension la plus alarmante de cette violence, dont les moteurs primaires peuvent être la diffusion des armes à feu, la consommation d'alcool, le trafic de drogues, le blanchiment d'argent et les guerres civiles.

### **1.4.3 La transition sanitaire en Amérique Latine**

Dans leur analyse des causes de décès en Amérique Latine, Frenk et al. (1991) ont adopté l'idée de la transition sanitaire pour expliquer les changements des modèles et des causes de la mortalité (Frenk, Bobadilla et al. 1991). Ils ont proposé un cadre théorique qui décrit les transitions sanitaires dans la baisse de la mortalité en Amérique latine, ainsi que leurs déterminants ainsi que l'évolution de la morbidité existante et des schémas de mortalité caractérisant le profil épidémiologique de la région (Frenk, Frejka et al. 1991). En reliant les



évolutions de la mortalité au processus de modernisation, ils ont montré que des différences dans les modèles de mortalité persistent à cause des différents processus de modernisation sociale et économique rencontrés par les pays, mais aussi à cause de la modernisation inégale de leurs systèmes de santé.

Frenk et al. (1996) ont évalué cinq principaux attributs de la transition épidémiologique afin d'expliquer les changements dans les modèles de mortalité des pays latino-américains : 1) les changements dans la structure par âge de la mortalité ; 2) les changements dans la prédominance des causes de décès ; 3) la durée et l'époque des changements ; 4) la distribution sociale des profils de santé ; et 5) l'ordre des ères épidémiologiques (Frenk, Bobadilla et al. 1996). Ils concluent que les transitions latino-américaines contrastent avec les étapes classiques de la transition épidémiologique initialement proposée, de différents points de vue :

-une superposition des étapes avec un effet simultané sur les maladies infectieuses et les maladies de nature chronique et dégénérative.

-une contre-transition, caractérisée par la réapparition de maladies infectieuses précédemment sous contrôle, telles que le paludisme, la dengue ou le choléra.

-une longue transition, dans laquelle il n'y a pas de lecture claire du processus de transition 10 mais plutôt une stagnation continue dans la dualité des profils épidémiologiques.

-une polarisation épidémiologique, dans laquelle les étapes se chevauchent en raison d'écart dans le développement socio-économique urbain et rural ; cela signifie que les contextes inégaux déterminés par la classe sociale génèrent différents profils épidémiologiques (Frenk, Frejka et al. 1991).

### **1.5 Le biais urbain en Amérique Latine**

L'avantage historique des zones urbaines -en particulier dans les capitales- a été bien établi en Amérique latine. On peut trouver la trace du favoritisme envers les villes, dans la distribution des dépenses publiques pour les biens et services, en analysant l'expansion des programmes d'allocations pour la santé durant la deuxième moitié du 20<sup>e</sup> siècle. Bien que la dépense totale soit fortement similaire à celle des pays développés, sa répartition semble loin d'être une réponse aux besoins de la population. Des groupes urbains plus riches bénéficient de façon disproportionnée de services publics au coût élevé (souvent subventionnés) pendant que la majeure partie de la population de ces pays manque de services et de biens basiques. La répartition inadaptée des dépenses publiques a historiquement eu un effet clair sur les résultats en termes de niveau de vie des pays et d'autres inégalités visibles au sein des territoires et des groupes sociaux.

Durant la première décennie du 21<sup>e</sup> siècle, les études montrent qu'environ 53% de la population rurale vit dans la pauvreté (ECLAC 2012), et la différence entre le pourcentage de la population vivant sous le seuil de pauvreté dans les zones urbaines et rurales est tristement célèbre (Montero and Garcia 2017). De nos jours, deux types distincts de pauvreté doivent être considérés. D'abord, il y a la pauvreté rurale qui est associée à l'agriculture familiale et paysanne et les terres indigènes, que l'on pourrait appeler *pauvreté persistante*. Ensuite, l'indéniable forme de pauvreté urbaine dans laquelle il y a une immense économie grise de

travailleurs pauvres dans les villes de tous les pays latino-américains. Ils pâtissent de conditions de travail précaires et de logements rudimentaires, mais simultanément, ils peuvent bénéficier d'un meilleur investissement dans la scolarisation et dans les soins de santé (Ramirez, Silva et al. 2009).

Comme prévu, les différentiels de mortalité peuvent aussi être affectés par ce biais urbain, même si peu de progrès ont été faits dans l'analyse de cet aspect. Le principal défi est qu'une comparaison inter-pays et inter-villes est nécessaire afin de pouvoir monter en généralité. De nombreuses études sur la mortalité infantile ont comparé les écarts urbains-ruraux dans les différents pays, alors que les problèmes de couverture et de qualité des données ont rendu difficile l'évaluation des différentiels urbains-ruraux aux âges adultes, à une échelle régionale en Amérique Latine. Des différentiels spatiaux apparaissent au début du processus d'urbanisation, quand certaines zones se sont développées plus rapidement que d'autres. Sur le long terme, ces zones particulières bénéficient plus rapidement d'une baisse de la mortalité qu'un pays ne le fait en entier. Une variété de facteurs associés aux niveaux de mortalité sont introduits par l'hétérogénéité régionale du développement dans un pays, ses niveaux d'urbanisation et l'importance proportionnelle de ses plus grandes villes dans la distribution totale de la population.

Les différentiels de mortalité urbains-ruraux peuvent agir de façon dissemblable sur la mortalité adulte. Les inégalités sociales sont identifiées comme l'une des principales causes de violence, de même que le comportement délinquant en général. Dans ce sens, la mortalité des jeunes peut être expliquée différemment de la mortalité infantile. De plus, la vulnérabilité de la population en âge de travailler est exacerbée par les différences entre les centres urbains et leurs périphéries, particulièrement en termes de manque d'accès aux services et d'exposition aux facteurs de risque environnementaux. La croissance désordonnée du secteur industriel influence directement la pollution biologique, chimique et physique, ce qui affecte la santé de la population en retour, particulièrement de ceux vivant dans des villes industrialisées plus grandes (PAHO 2007) et de ceux qui travaillent dans le secteur manufacturier ou industriel.

## 2. MÉTHODES ET DÉFINITIONS

Sept pays ont été sélectionnés pour étudier l'avantage urbain de la mortalité persiste en Amérique latine. Ils ont été choisis en fonction de leurs processus d'urbanisation et de leurs étapes dans la transition de la mortalité. Ce sont le Brésil, le Chili, la Colombie, l'Équateur, le Mexique, le Pérou et le Venezuela. Chacun d'eux définit différemment la «population urbaine» dans ses bases de données démographiques. Le défi a été de parvenir à la comparabilité en adoptant un concept non dichotomique de relation urbain-rural, appelé degré d'urbanisation (*urbaness*). Ce terme implique une approche continue de l'espace urbain-rural. L'urbanisation est capturée dans cette recherche comme indicateur d'un gradient urbain en ordonnant les villes en fonction de la taille de leur population. Trois groupes spatiaux ont été identifiés dans chaque pays: le groupe des capitales et grandes villes de plus de 500 000 habitants, le groupe des villes moyennes et petites entre 20 000 et 500 000 habitants et le groupe des villages et des zones rurales de moins de 20 000 habitants. Les groupes spatiaux sont suivis à travers différentes bases de données démographiques par les divisions administratives mineures

(MIAD) attachées officiellement aux villes par les bureaux nationaux de statistique dans chaque pays analysé.

Cette section décrit les méthodes utilisées pour évaluer si l'Amérique latine a un (dés) avantage urbain en matière de mortalité qui affecte également tous les âges et tous les sexes. Afin de rechercher les comparaisons les plus précises possibles, les chiffres de décès et de population sont regroupés comme suit: moins d'un an; un à quatre ans; et de là en tranches d'âge de cinq ans jusqu'à une tranche d'âge ouverte de 80 ans et plus. Toutes les estimations du nombre de décès utilisées dans cette recherche ont été corrigées des erreurs de déclaration de l'âge, du sexe et du lieu de résidence, ainsi que du sous-enregistrement, séparément pour les décès des enfants et des adultes.

## 2.1 Taux et ratios de mortalité

1) *Le taux de mortalité par âge* est un rapport occurrence / exposition indiquant le risque de mortalité d'une population à un âge et à un moment précis. Ces deux caractéristiques - occurrence et exposition - sont respectivement le nombre de décès survenant dans une période de temps définie et le nombre de personnes dans la population soumises au risque pendant la période, connue sous le nom de nombre de personnes-années- (Preston, Heuveline et al. 2001).

2) *Taux standardisés de mortalité par causes*: Étant donné que les sous-populations diffèrent dans leur taille et leur distribution par âge et sexe, des indices bruts ne permettent pas de contrôler les effets des différences de composition et ne garantissent pas la comparabilité. Pour éliminer cet effet, les taux de mortalité par cause spécifique pour chaque sous-population sont directement standardisés

3) *Ratios proportionnels de décès par rapport à la population*: le rapport de la distribution des nombres de décès à la distribution des de la population par sexe et par âge est calculé pour chaque sous-population. Le rapport proportionnel décès / population d'une sous-population au temps t est le quotient de la proportion de décès entre l'âge x et x + n, par rapport à la proportion de la taille de la sous-population entre l'âge x et x + n.

## 2.2 Tables de mortalité

Des tables abrégées de mortalité du moment sont construites annuellement pour chaque sous-population, le quotient de mortalité par âge est estimé à partir des taux de mortalité par âge. La moyenne d'années-personnes vécues dans un intervalle d'âge ( ${}_n a_x$ ) est reprise des travaux de Coale et Demeny (1983) pour  ${}_1 a_0$  et  ${}_4 a_1$  tandis que pour les valeurs de  ${}_n a_x$  entre 5 et 79 ans, les décès sont supposés être répartis également dans les intervalles d'âge et donc  ${}_n a_x = n/2$  (Preston, Heuveline et al. 2001). Enfin, le nombre moyen de personnes-années dans l'intervalle d'âge ouvert (80 ans et plus) est calculé comme la valeur inverse du taux de mortalité par âge, ce qui rend  ${}_{\infty} a_{80}$  égal à  ${}_{\infty} e_{80}$  (Land, Yang et al. 2005). De même, dans un cadre de table de mortalité par période, j'applique  ${}_n a_x$  dans l'intervalle x to x+n aux taux de mortalité observés  ${}_n M_x$  afin d'obtenir la probabilité de mourir  ${}_n q_x$  dans l'intervalle d'âge. Cette recherche porte sur toutes les fonctions de la table de mortalité pour une analyse

comparative des niveaux de mortalité des sous-populations, en utilisant les principaux indices synthétiques:

- 1) *L'espérance de vie à l'âge x* est calculée comme le rapport entre le nombre de personnes-années à partir de l'âge x et le nombre de survivants à l'âge x (Preston, Heuveline et al. 2001). Ici, l'analyse porte sur l'espérance de vie à la naissance, ses tendances, ses changements et ses différences entre sous-populations et pays. L'espérance de vie à la naissance ( $e_0^0$ ) est la somme de toutes les personnes-années-divisée par le nombre total de membres de la cohorte. En d'autres termes, l'espérance de vie à la naissance est l'âge moyen au décès d'une cohorte hypothétique.
- 2) *Quotient de mortalité* : le risque de mourir entre l'âge x et x + n est calculé comme la probabilité de mourir entre deux âges. Cela signifie que la survie des âges précédents est une condition implicite pour le calcul. Dans cette étude, j'ai calculé un quotient de mortalité aux âges adultes jeunes (entre 15 et 45 ans (30q15)) et aux âges adultes élevés (entre 45 et 75 ans (30q45)).
- 3) *Disparité de durée de vie*: plusieurs indicateurs sont utilisés pour mesurer la disparité de durée de vie dans une population (par exemple le coefficient de Gini, les années de vie perdues et la variance de l'âge au décès, entre autres). Ici, l'évolution de la dispersion de la mortalité est calculée en utilisant l'écart type de la distribution des décès et ses changements. L'avantage de cet indicateur par rapport à d'autres est que l'écart-type de la répartition par âge des décès est comparable à l'espérance de vie, car les deux sont exprimés en années, ce qui facilite son interprétation.

### 2.3 La décomposition de l'espérance de vie à la naissance

La décomposition des différences d'espérance de vie à la naissance permet de savoir quelle dimension contribue à ses évolutions dans le temps et laquelle est responsable des différences entre deux populations. J'utilise ces deux méthodes pour décomposer les différences d'espérance de vie à la naissance:

- 1) *The stepwise replacement decomposition method*: L'espérance de vie à la naissance étant fonction du vecteur des taux de mortalité par âge, la décomposition pas à pas modifie les taux un âge à la fois, puis recalcule l'espérance de vie en remplaçant les éléments d'un vecteur des taux de mortalité par âge, avec les éléments respectifs d'un autre vecteur (Andreev, Shkolnikov et al. 2002). La méthode est appliquée dans cette recherche en utilisant le package R DemoDecomp, développé par Riffe (2018).
- 2) *Algorithm of contour replacement decomposition method*: L'algorithme de la méthode de décomposition par « remplacement de contour » est une extension de la méthode de remplacement par étapes. Il prend les différences initiales dans les taux d'événements de la mesure agrégée et les différences de tendances et les divise en composants additifs. La méthode divise la différence totale des contributions, entre ce qui est dû aux différences initiales entre les espérances de vie et ce qui revient aux changements des espérances de vie au fil du temps (Jdanov and Shkolnikov 2014). La méthode de décomposition par remplacement de contour et son algorithme sont

(jusqu'à présent) le seul moyen d'estimer les différences d'espérance de vie en divisant les effets des tendances spécifiques à l'âge sur une période donnée tout en contrôlant les différences initiales des niveaux de mortalité par âge.

## 2.4 Classification des causes de décès

L'objectif de l'étude des causes de décès est d'identifier les pathologies qui sont les principaux moteurs de l'évolution de la mortalité dans une population donnée. Plusieurs regroupements ont été suggérés par des recherches qui analysent la mortalité au cours de l'histoire. Ici, les analyses s'appuient sur deux regroupements des causes de décès. Le premier repose sur les causes de décès les plus courantes dans la région, tandis que le second distingue la mortalité évitable, sensible aux politiques de santé.

1) Regroupement des causes principales: onze groupes de causes de décès sont construits à partir des rubriques de la 10<sup>e</sup> révision de la Classification internationale des maladies (CIM-10). Cette liste de causes de décès est la suivante : tumeurs, maladies circulatoires, diabète, maladies infectieuses, maladies respiratoires, maladies digestives, accidents de la route et autres accidents, homicides et suicides, affections périnatales, affections maternelles et autres maladies.

2) Mortalité évitable: Tobias et Jackson ont affiné la notion de «mortalité évitable» et classifié les maladies ou affections comme «entièrement évitables» par la prévention primaire ou secondaire ou tertiaire (Tobias and Jackson 2001). Leurs catégories ont été redéfinies comme suit :

- Prévention primaire ou prévention du développement de la maladie: Ce groupe comprend les affections liées aux maladies infectieuses, à l'anémie, aux tumeurs facilement détectables, aux accidents de voiture, aux accidents dus à un dysfonctionnement de l'équipement public et aux suicides, entre autres.
- Prévention secondaire : une détection et une intervention précoces peuvent retarder la progression de la maladie ou la rechute. Les affections telles que le diabète, les complications liées à la grossesse et les tumeurs curables font partie de ce groupe.
- Prévention tertiaire : des traitements médicaux ou chirurgicaux peuvent réduire la létalité de la maladie, tels que l'appendicite, les affections congénitales et les tumeurs bénignes.

## 2.5 Analyse de classification

Dans cette recherche, deux analyses statistiques sont utilisées afin de caractériser, résumer et classer les tendances de la mortalité dans les sous-populations : l'analyse en composantes principales (ACP) et l'analyse hiérarchique de grappes (AHG). Elles permettent de définir différents profils de mortalité parmi les sous-populations.

1) Analyse en composantes principales: L'analyse en composantes principales (ACP) est l'une des méthodes d'analyse multivariée les plus connues qui utilise la décomposition

spectrale d'un coefficient de corrélation, également connu sous le nom de matrice de covariance (Yanai and Ishii 2010). Elle est appliquée lors de la poursuite de la réduction de la dimensionnalité des données, et utilise une transformation orthogonale pour convertir un ensemble d'observations de variables éventuellement corrélées en un ensemble de valeurs de variables linéairement non corrélées appelées composantes principales (Wallisch 2014). Les principales composantes qui en résultent sont inférieures ou égales au nombre de variables d'origine, et elles sont exprimées en termes de proportion de la variance totale qu'elles expliquent. Dans cette recherche, les variables soumises à l'ACP sont précédemment mises à l'échelle par normalisation et un seuil de 70% de la variance cumulée expliquée est retenu pour indiquer un nombre acceptable de composantes principales.

- 2) Analyse hiérarchique de grappes : pour mettre en évidence les similitudes entre les profils de sous-population, on identifie des groupes qui rassemblent les sous-populations qui partagent le plus grand nombre de caractéristiques similaires, au point que ces caractéristiques les différencient (ou ne sont pas liées) aux sous-populations des autres groupes. L'analyse hiérarchique de grappes est une méthode statistique pour constituer des groupes de cas relativement homogènes en fonction des dissemblances ou des distances entre les objets (Serra and Tagliaferri 2019). Elle considère les distances entre les cas afin de placer des groupes dans l'espace dimensionnel non corrélé précédemment établi par ACP. Le résultat est un arbre de classification hiérarchique. Cette recherche applique l'analyse d'agrégation hiérarchique en grappes en utilisant la méthode de variance minimale de Ward.

### **3. RESULTATS**

Les premiers résultats de cette recherche portent sur les tendances générales de mortalité pour la période 2000-2010, à l'exception du Pérou, pour lesquelles les données couvrent les années 2003-2013. Etant donné le niveau de qualité de ses estimations, l'Equateur n'est pas pris en compte dans l'étude de mortalité exposée ci-après. De même, au vue du manque de fiabilité des déclarations de causes de décès, le Pérou est exclu de l'analyse des causes de décès.

Dans le but d'examiner l'existence de différences introduites par l'urbanisation dans les tendances de mortalité en Amérique Latine, j'utilise comme indicateurs clés: les évolutions de l'espérance de vie à la naissance ainsi que les évolutions des quotients de mortalité pour des tranches d'âge spécifiques. Ensuite, j'applique une méthode de décomposition pour établir avec précision les contributions d'une cause de décès donnée aux écarts de mortalité entre groupes spatiaux dans chaque pays.

### 3.1 Différences de l'espérance de vie à la naissance

La figure 1 illustre l'espérance de vie à la naissance par groupe spatial et sexe, mettant en évidence leurs évolutions. J'utilise ici des nuages de points afin de montrer les niveaux d'espérance de vie pour l'année de référence 1 ( $t_1$ , en abscisse) par rapport aux niveaux d'espérance de vie pour l'année de référence 2 ( $t_2$ , en ordonnée). Pour des raisons de comparaison,  $t_1$  correspond à l'année 2000 dans chaque pays (à l'exception du Pérou, pour lequel l'année initiale est 2003). Chaque estimation parmi le nuage de points représente une unique sous-population, chacune regroupée par pays (couleurs distinctes) et par groupe spatial (formes distinctes). L'espérance de vie des hommes et celle des femmes sont présentées séparément, et les lignes pointillées du graphique représentent l'espérance de vie moyenne des premières et dernières années de référence.

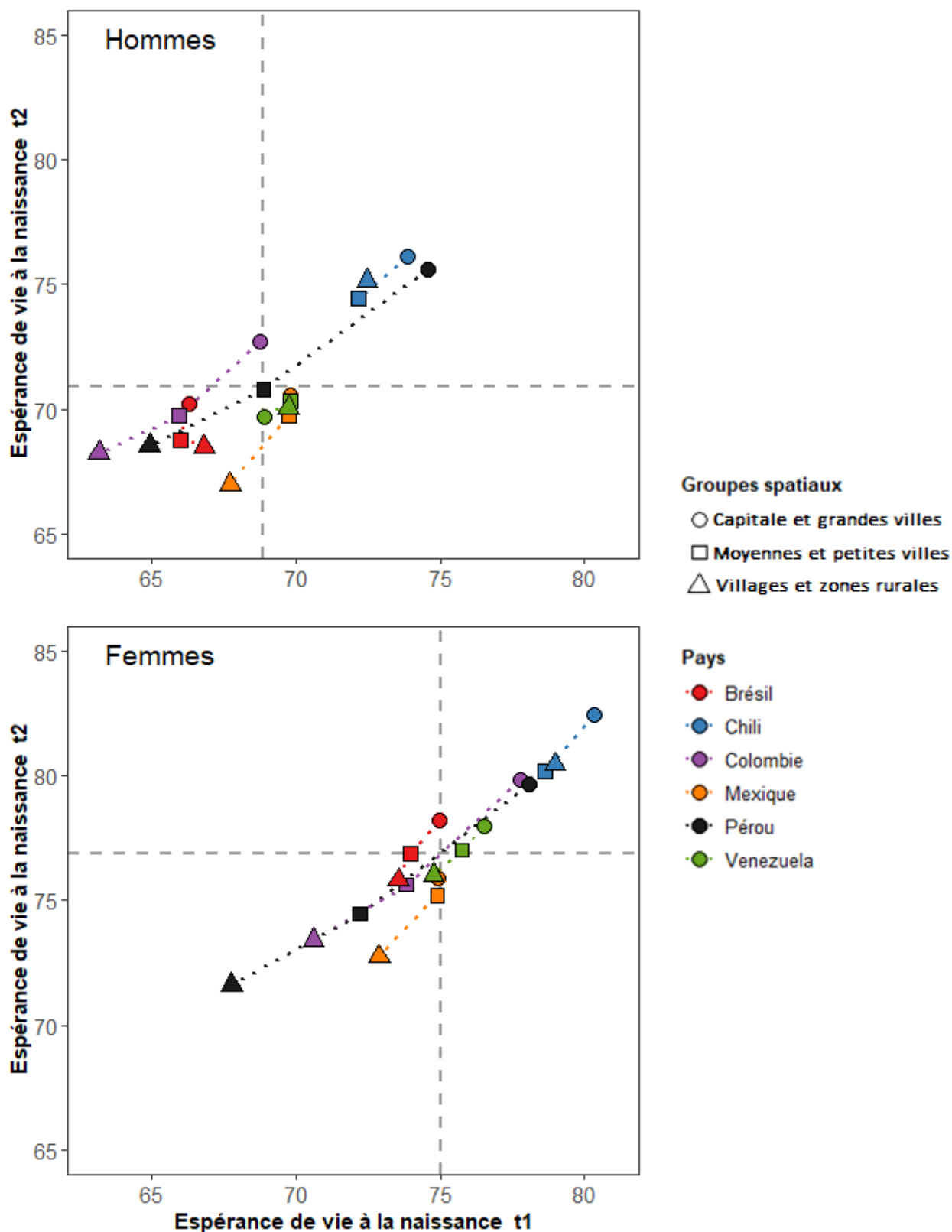
De toutes les populations étudiées, ce sont les sous-populations du Chili qui connaissent les meilleures évolutions de l'espérance de vie à la naissance. De plus, le groupe « capitale et grandes villes » de ce pays présente l'espérance de vie la plus élevée. En plus d'avoir la meilleure performance, le Chili et le Venezuela connaissent les plus petits écarts entre leurs sous-populations, en comparaison des autres pays de la sélection. Seuls les niveaux d'espérance de vie des femmes des groupes « capitale et grandes villes » du Pérou et de la Colombie se rapprochent des niveaux d'espérance de vie chiliens. Ce schéma d'espérance de vie la plus élevée pour le groupe « capitale et grandes villes » est avéré pour tous les pays, à l'exception des hommes au Brésil en début de période et au Venezuela pour les deux années de référence.

Le fait que le groupe « capitale et grandes villes » ait l'espérance de vie la plus élevée ne signifie pas pour autant que toutes les capitales et grandes villes sont situées dans le quadrant « meilleure performance ». Pour les hommes, seules les capitales et grandes villes chiliennes et péruviennes ont obtenu la meilleure performance sur la période. En revanche, pour les femmes, les niveaux d'espérance de vie de tous les groupes « capitale et grandes villes » sont situés dans le quadrant « meilleure performance », à l'exception de celui du Mexique, qui présente une performance détériorée, inférieure à la moyenne en fin de période.

### 3.2 Ecart de mortalité selon l'âge

Trois intervalles d'âge ont été retenus afin d'analyser les écarts de mortalité entre les groupes de villes en fonction de l'âge : enfants de moins d'un an, adultes jeunes (entre 15 et 45 ans) et adultes plus âgés (entre 45 et 75 ans). Les nuages de points sont utilisés pour examiner les changements d'indicateurs pour toutes les sous-populations durant la période d'analyse. Les changements entre l'année initiale ( $t_1$ ) et l'année finale ( $t_2$ ) sont affichés en ordonnée et le niveau de l'indicateur pour l'année initiale ( $t_1$ ) est indiqué en abscisse. Une ligne bleue en trait fin a été ajoutée au nuage de points afin de distinguer les sous-populations dont le risque de mourir à  $t_2$  est plus élevé qu'à  $t_1$  (en dessous de la ligne bleue) et les sous-populations dont le risque de mourir à  $t_2$  est plus faible qu'à  $t_1$  (au-dessus de la ligne bleue). Plus une sous-population est située au-dessus de la ligne bleue, plus la réduction du risque de mourir durant la période est grande. Contrairement à l'analyse, présentée dans la section 3.1, de la distribution des sous-populations en fonction de leurs performances, je me suis attachée ici à caractériser pour chaque sous-population le processus de rattrapage du déclin de la mortalité.

Figure 1 Espérance de vie à la naissance au temps1 versus temps2 par sexe et groupe spatial



\*Temps 1 correspond à l'année 2000 et Temps2 à l'année 2010 – à l'exception du Pérou, pour lequel la période considérée est 2003 – 2013. Les lignes pointillées représentent l'espérance de vie moyenne pour les deux temps Temps1 et Temps2.



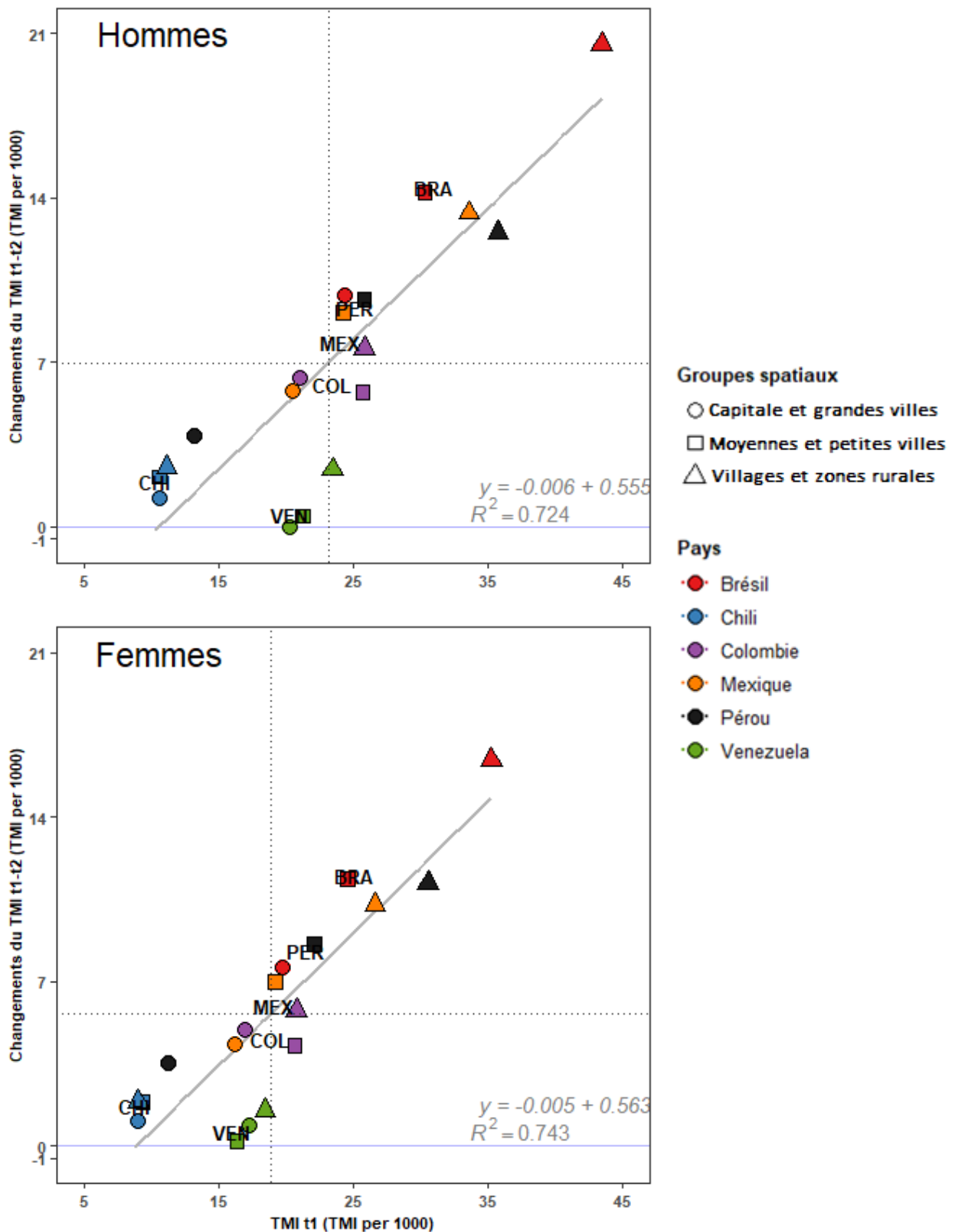
En plus des estimations pour toutes les sous populations, sont incluses dans les figures des estimations au niveau du pays, ainsi qu'un modèle de régression linéaire pour indiquer l'existence ou non de convergence parmi toutes les sous populations. Les résultats pour la mortalité infantile sont présentés à la figure 2, et ceux pour la mortalité des adultes à la figure 3.

Une convergence est observée dans les taux de mortalité infantile (TMI) à la fois au niveau des pays et de leurs sous-populations. Cela signifie que les pays avec les niveaux les plus élevés du TMI en t1 ont les gains les plus importants car la mortalité infantile y diminue pendant toute la période. Les niveaux de TMI pour la période sont négativement corrélés à l'urbanisation, car les pays les plus urbanisés ont le TMI le plus bas les groupes des capitales et grandes villes présentent les TMI les plus bas dans tous les pays par rapport aux autres groupes. Le Venezuela est le seul pays à ne pas suivre cette tendance. D'un autre côté, la dispersion du TMI des sous-populations dans chaque pays est positivement liée au niveau national. Le Chili et le Venezuela, les pays ayant le TMI le plus faible, ont le plus petit différentiel dans le TMI de leurs sous-populations, tandis que le Pérou et le Brésil, les pays ayant les TMI nationaux les plus élevés, présentent les écarts les plus importants.

La représentation graphique de la mortalité adulte suit la même logique que la représentation de la mortalité infantile. Étant donné que l'écart de mortalité en fonction du sexe dans ce groupe d'âge est important, et afin de rendre visibles les estimations des sous-populations et leurs changements, j'utilise différentes échelles par sexe dans la figure 3A pour les jeunes adultes alors que la mortalité des adultes plus âgés est présentée dans la figure 3B par sexe en conservant la même échelle. Les pays convergent dans la mortalité des jeunes adultes pour les deux sexes, à l'exception du Mexique et de la population masculine au Venezuela. Les améliorations les plus importantes sont enregistrées en Colombie, pays où le risque de décès est le plus élevé en t1, tandis que le Chili, le pays où le risque de décès est le plus faible, affiche de légères réductions au cours de la période. Les sous-populations au sein des pays se comportent différemment : elles montrent un processus mixte de convergence et de divergence dans leur risque de mourir à âge adulte jeune, selon les pays. La convergence entre les sous-populations est claire dans toutes les sous-populations au Chili et dans les sous-populations masculines en Colombie et au Pérou. Cette convergence est principalement due au fait que les groupes des villages et zones rurales rattrapent les gains obtenus précédemment par les villes.

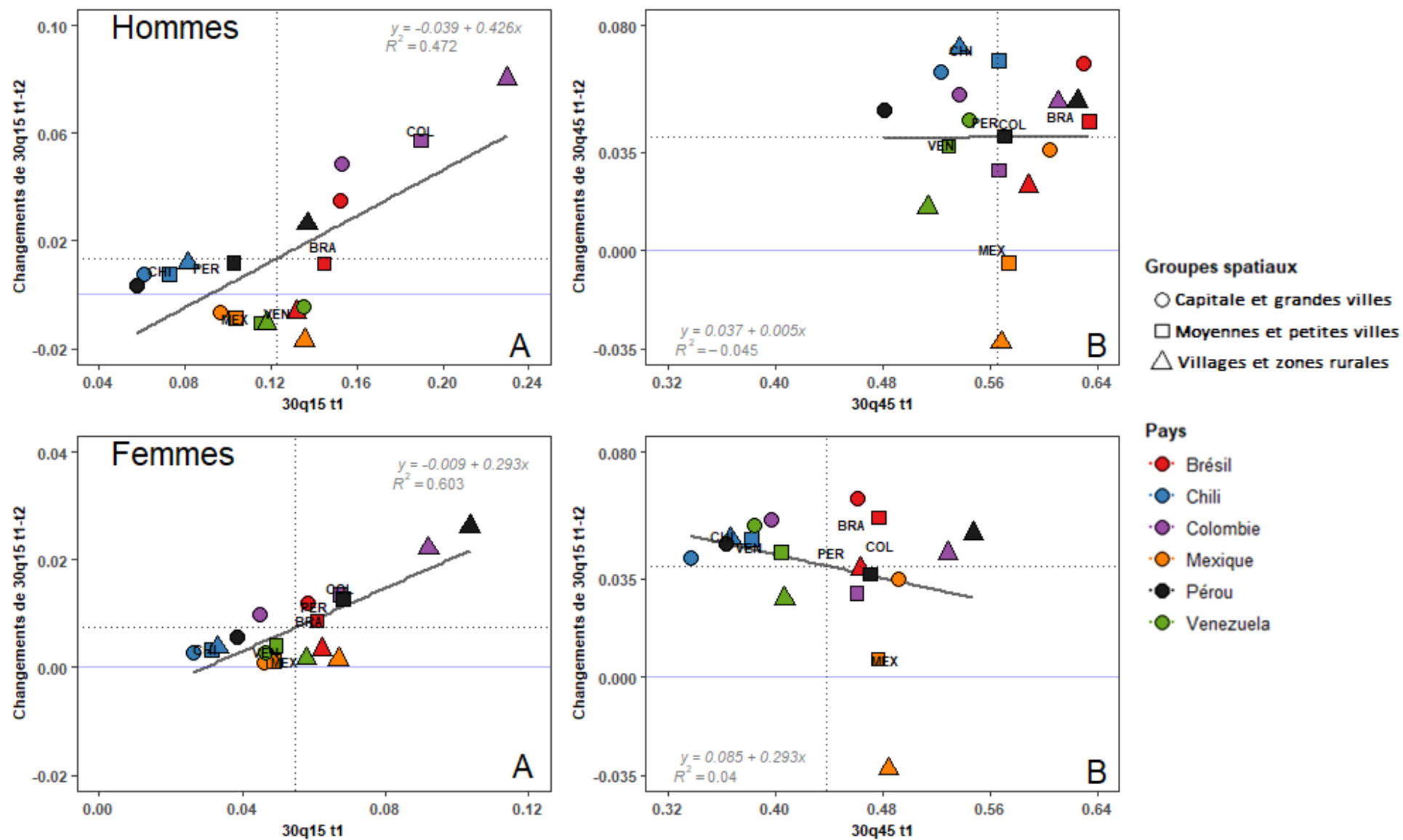
En ce qui concerne la mortalité des personnes âgées, les pays montrent des divergences dans leurs changements. Cette divergence est facilement perçue dans les populations féminines au niveau du pays et des sous-populations. Le Brésil et la Colombie affichent des améliorations toujours plus élevées que des pays comme le Chili et le Venezuela, où les progrès s'étaient déjà produits avant la période d'analyse. Ces deux derniers pays sont les précurseurs pour la mortalité des personnes âgées. Le Mexique, pour sa part, est une fois de plus le pays où la mortalité des personnes âgées est la plus dégradée. Contrairement à ce qui est vu pour la mortalité des jeunes adultes, il n'y a pas de différence de sexe dans la répartition des sous-populations pour la mortalité des personnes âgées, bien que, comme prévu, les femmes présentent généralement des risques plus faibles. Presque toutes les sous-populations féminines âgées de 45 à 70 ans vivant dans les groupes des capitales et grandes villes sont identifiées comme des précurseurs dans la réduction du risque de mourir.

Figure 2. Taux de mortalité infantile au temps 1 versus gains en TMI entre temps 1 et temps 2, par groupe spatial et sexe.



\* Temps 1 fait référence à l'année 2000 et temps 2 à 2010, à l'exception du Pérou, dont la période de référence est 2003-2013. Le TMI moyen au temps 1 et le gain moyen en TMI sont représentés par les lignes pointillées.

Figure 3 Risques de décès entre 15 et 45 ans ( $A=_{30q15}$ ) et entre 45 et 75 ans ( $B=_{30q45}$ ), par groupe spatial et sexe



En résumé, les meilleures performances en matière de réduction des risques de décès se trouvent dans le groupe des capitales et grandes villes pour tous les pays. Même au Mexique, où la pire performance est enregistrée dans toutes ses sous-populations, le groupe des capitales et grandes villes est le moins affecté par la tendance à la détérioration de la mortalité adulte. Comme on peut le voir, la mortalité adulte ne suit pas le même schéma d'amélioration que la mortalité infantile. En fait, il y a des sous-populations montrant une mortalité infantile décroissante parallèlement à un risque croissant de mourir aux jeunes âges adultes et à un risque décroissant de mourir aux âges adultes plus élevés. Il n'y a pas de sous-population qui pourrait être considérée comme un précurseur ou un retardataire pour les trois indicateurs, ce qui signifie qu'il n'y a pas de sous-population qui enregistre uniformément une amélioration ou une détérioration constante dans tous les groupes d'âge sur la période.

### **3.3 Évolution des causes de décès selon les groupes spatiaux**

Dans cette section, l'analyse des tendances nationales et sous-nationales des causes de décès de 2000 à 2010 par sexe est effectuée en utilisant les taux de mortalité standardisés des dix principales causes. Dans la figure 4 pour les hommes et la figure 5 pour les femmes, les taux standardisés par causes en 2000 (t1) se situent en abscisse tandis que les taux standardisés en 2010 (t2) se situent en ordonnée. La diagonale des figures sépare les taux croissants (au-dessus de la ligne pointillée) des taux décroissants (sous la ligne pointillée).

Des progrès sont perçus dans tous les pays si l'on suit l'évolution des maladies infectieuses et circulatoires parmi les sous-populations et celle des tumeurs parmi les sous-populations féminines. À la fin de la période, l'avantage détenu par le groupe des capitales et grandes villes sur les sous-populations restantes du pays est dû aux différences introduites par les accidents, les maladies circulatoires et les tumeurs. Ce n'est qu'au Mexique que les capitales et grandes villes continuent de voir des améliorations des conditions périnatales, d'autres causes et - dans une moindre mesure - des maladies circulatoires. L'avantage du groupe des capitales et grandes villes n'est affecté que par l'augmentation du diabète parmi les sous-populations masculines dans tous les pays et par celle des homicides chez les hommes au Venezuela et au Brésil. L'avantage des capitales et grandes villes sur les autres groupes spatiaux est supérieur à la différence entre les villes moyennes et petites et les villages et zones rurales. Ces deux groupes partagent la plupart des désavantages de mortalité.

La mortalité maternelle diminue au cours de la période pour toutes les sous-populations, à l'exception des capitales et grandes villes du Venezuela et du Brésil, et des villages et zones rurales du Venezuela et du Chili. La mortalité maternelle contribue aux différences spatiales entre les sous-populations en Colombie et au Mexique, même à la fin de la période d'analyse. Dans les autres pays, les taux déjà bas en début de période continuent d'agir en faveur du groupe des capitales et grandes villes.

Figure 4 Taux de mortalité standardisés pour les hommes (pour 1000 habitants) par cause spécifique de décès au t1 vs TMS au t2

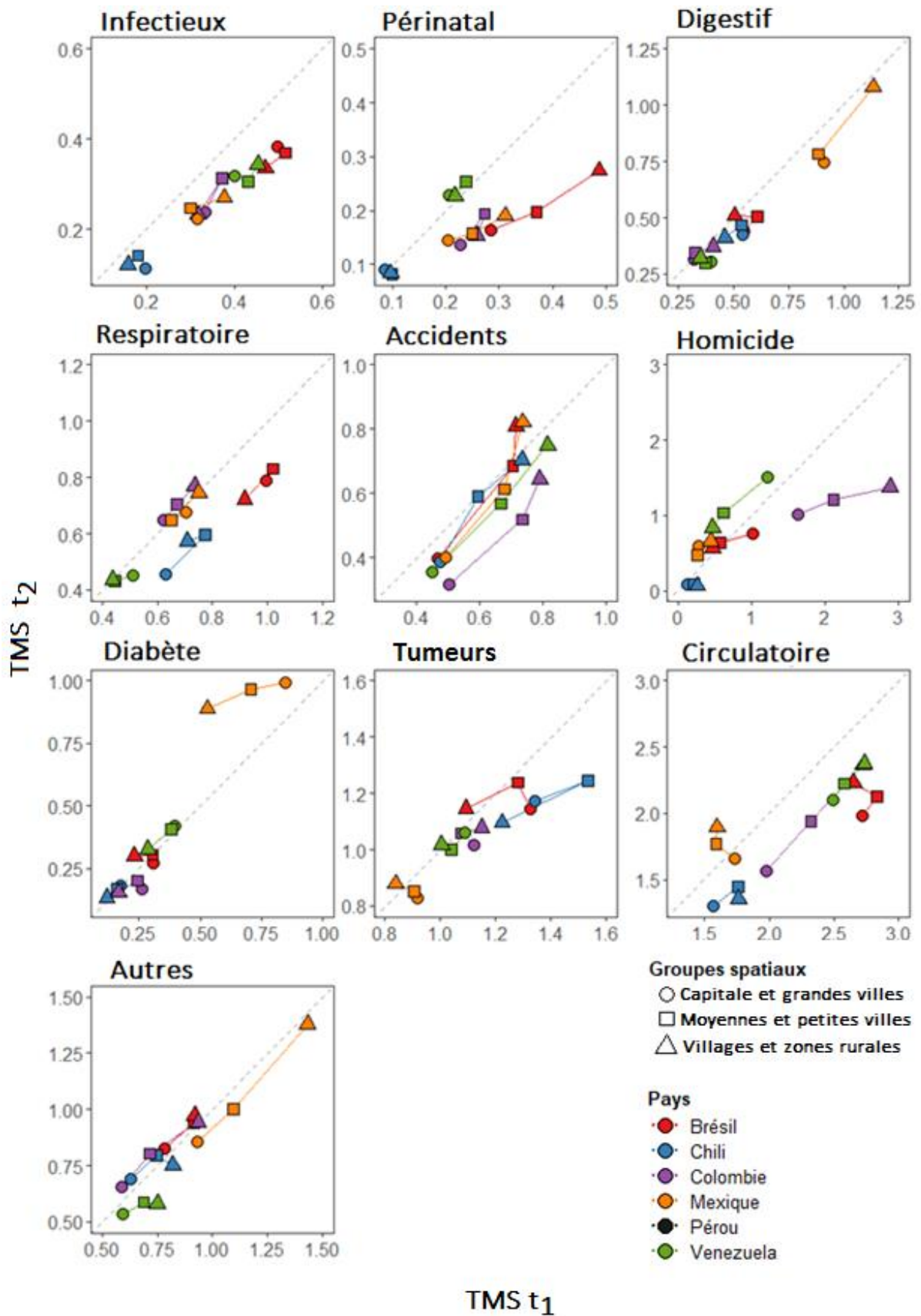
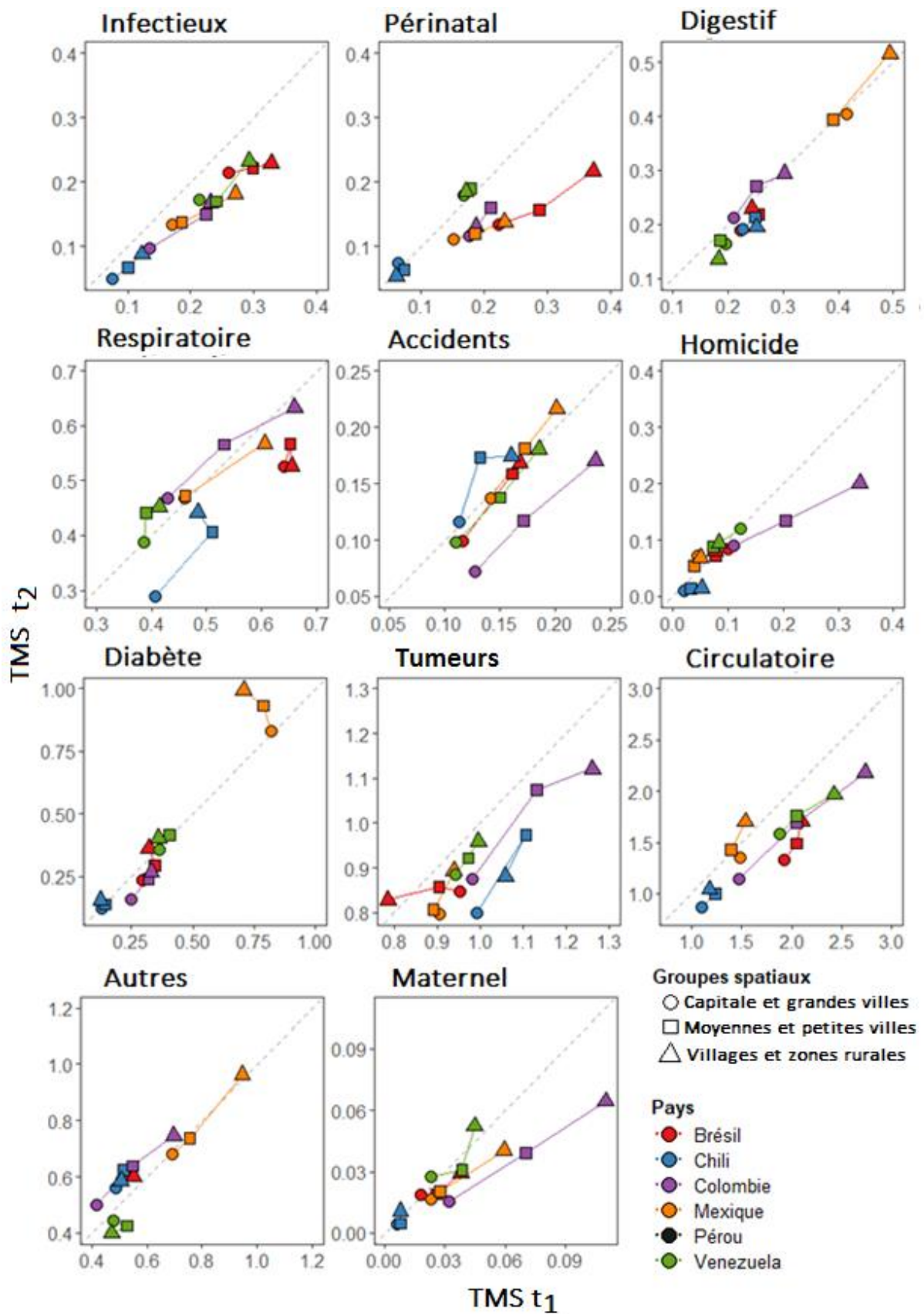


Figure 5 Taux de mortalité standardisés pour les femmes (pour 1000 habitants) par cause spécifique de décès au t1 vs TMS au t2



### 3.4 Contributions des causes de décès aux évolutions de l'espérance de vie

Les contributions des causes de décès à l'évolution de l'espérance de vie à la naissance entre 2000 et 2010 sont ici décomposées à l'aide de la *stepwise replacement decomposition method*. Cinq groupes de causes de décès sont considérés en fonction de leur importance dans les écarts entre groupes spatiaux. Ce sont les maladies circulatoires, les tumeurs, les morts violentes (homicides, accidents de la circulation et autres accidents, tous ensemble), les maladies infectieuses, digestives et respiratoires (I.D & R.); et un dernier groupe d'autres causes, dont le diabète (voir la figure 6 pour les hommes et la figure 7 pour les femmes). Toutes les échelles sont similaires, sauf pour les morts violentes.

Au cours de la période d'analyse de 2000 à 2010 dans tous les pays à l'exception du Mexique, les changements dans l'espérance de vie sont dus à une diminution des maladies circulatoires à l'âge adulte et à une diminution du groupe I.D. & R. et des autres maladies chez les enfants. La plupart des années d'espérance de vie gagnées grâce à la baisse des maladies circulatoires se concentrent à 60 ans et plus. Ce n'est qu'en Colombie que les gains se produisent aussi entre 30 et 70 ans. La mortalité adulte diminue principalement grâce à la réduction des homicides chez les jeunes adultes et à la réduction des maladies circulatoires aux âges plus avancés. Les maladies circulatoires contribuent à maintenir la différence de mortalité entre les groupes spatiaux selon le gradient d'urbanisation. Le Mexique est le pays qui a connu le moins de progrès au cours de la période d'analyse, et le seul qui perd des années d'espérance de vie à la naissance en raison de l'augmentation des maladies circulatoires et d'autres causes à un âge adulte avancé, en particulier dans les villages et les zones rurales. Les gains d'espérance de vie à la naissance dus à la contribution des 80 ans et plus au cours de la période proviennent principalement de la réduction des maladies circulatoires. Les jeunes femmes adultes (moins de 30 ans) est le groupe d'âge négligé dans tous les pays, et seules quelques améliorations mineures sont enregistrées au Brésil et en Colombie.

Figure 6 Contributions de l'âge (en années) à l'évolution de l'espérance de vie à la naissance des hommes par cause de décès, 2000 à 2010

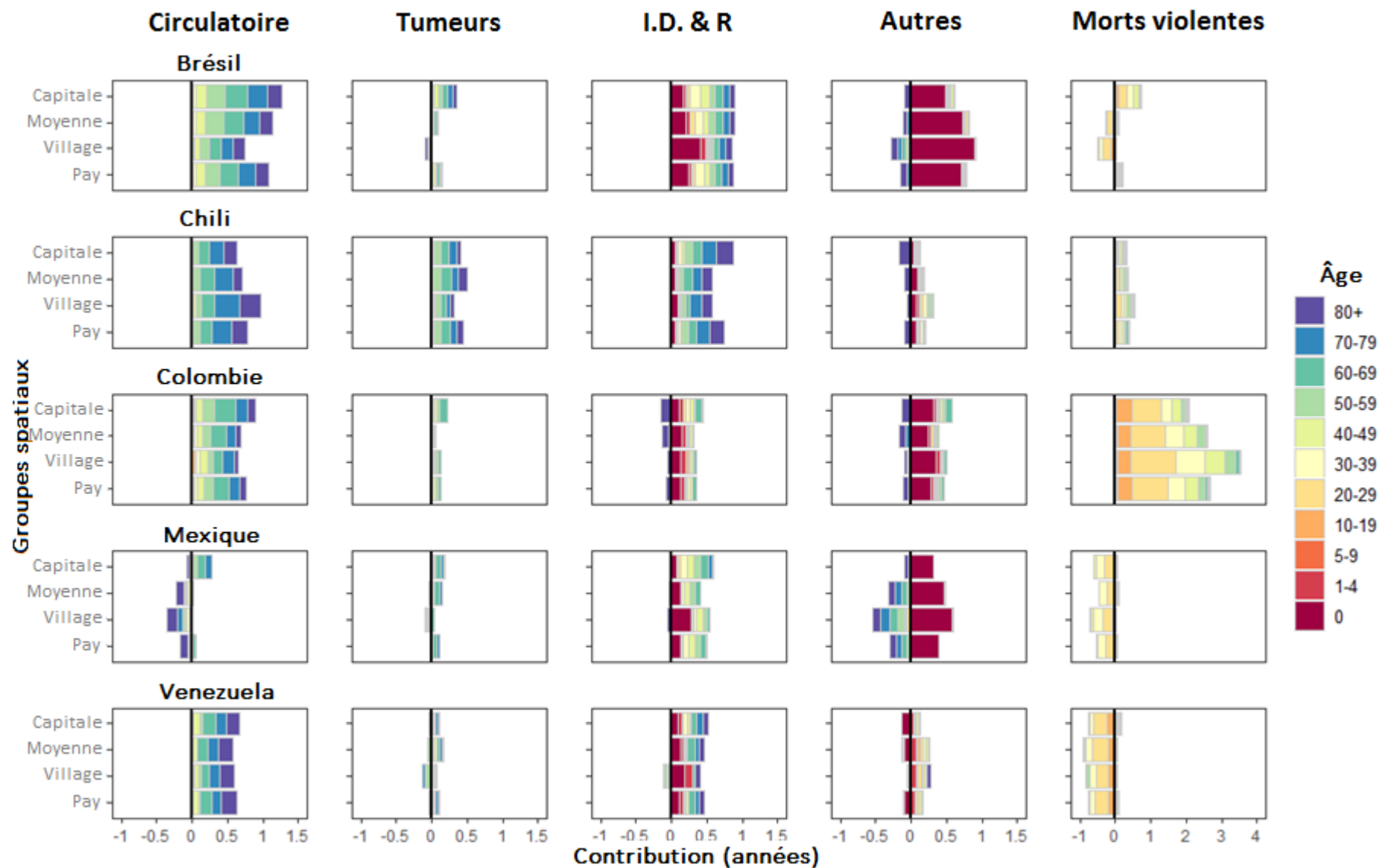
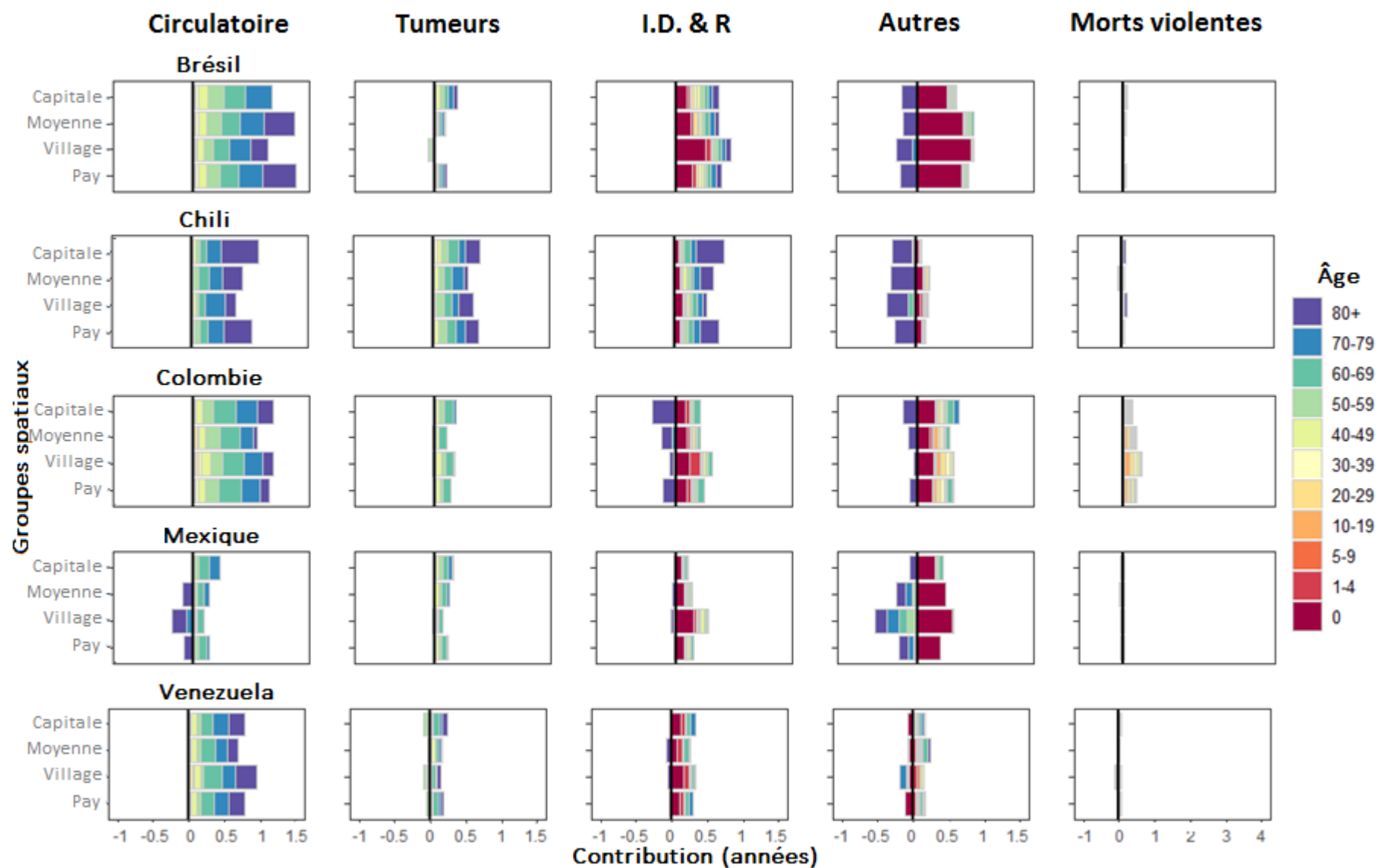




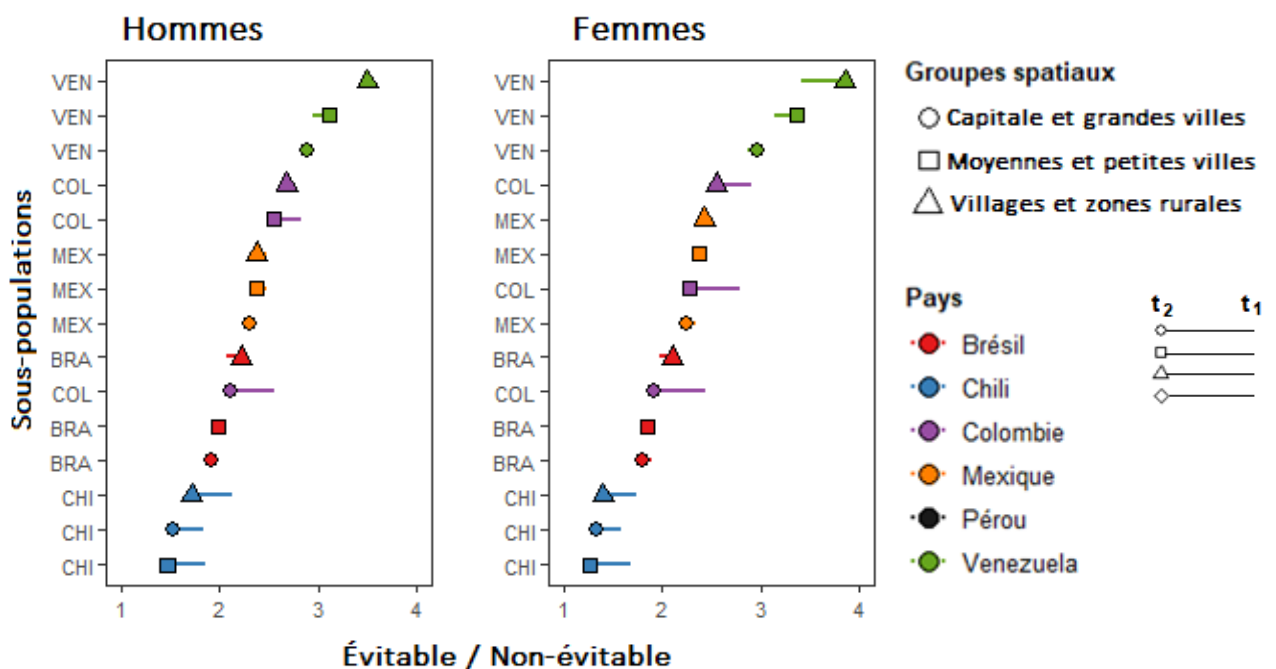
Figure 7 Contributions de l'âge (en années) à l'évolution de l'espérance de vie à la naissance des femmes par cause de décès, 2000 à 2010



### 3.5 Causes de décès évitables par groupes spatiaux

La contribution des soins de santé peut jouer un rôle important dans la baisse de la mortalité en Amérique latine. L'augmentation la plus importante de l'espérance de vie au niveau national s'est produite parallèlement à l'expansion du système de santé et au processus d'urbanisation. Ici, les causes de décès pouvant être évitées par des soins médicaux / de santé sont analysées dans le contexte du gradient urbain, en mettant l'accent sur le rôle joué par les interventions de santé publique dans les écarts de mortalité par groupe spatial. On distingue d'abord les décès évitables des décès non évitables. Les homicides ont été exclus de ces groupes car, comme on l'a vu dans les sections précédentes, ils affectent significativement des sous-populations spécifiques. La figure 8 montre le rapport des causes évitables aux non évitables en 2000 et 2010 par sexe, pays et groupe spatial.

Figure 8 Ratio des causes de décès évitables / non évitables par pays, sexe et groupe spatial, 2000 et 2010



Les ratios plus faibles indiquent des poids proportionnels plus élevés des causes non évitables dans le taux de mortalité total. Les sous-populations sont listées en ordonnée en fonction de leurs ratios en 2010. Pour les deux sexes, seules les villes colombiennes de taille moyenne et les petites villes affichant des proportions plus importantes de décès dus plus à des causes évitables que non évitables. Cependant, les groupes de capitales et grandes villes dans tous les pays ont moins de décès évitables que de non évitables pour les deux périodes. Seul le Chili ne suit pas ce schéma général. Cela est dû au fait que les contributions négatives à l'augmentation de l'espérance de vie dans les villes moyennes et petites au cours de la période proviennent de causes de décès non évitables à 80 ans et plus. En ce qui concerne les changements au cours de cette période, les villages et les zones rurales du Brésil ainsi que toutes les sous-populations

vénézuéliennes voient une augmentation du ratio de cause évitables / non évitables, alors qu'il reste stable ou diminue dans toutes les autres sous-populations.

Les principales interventions pouvant jouer sur les causes évitables sont les suivantes : mesures de sécurité routières, sécurité des logements, eau potable, systèmes d'évacuation des eaux usées, politiques de santé axées sur la vaccination à grande échelle des populations, élimination des vecteurs de maladies, distribution d'antibiotiques, et accès aux premiers soins d'urgence et de traumatologie. Tous ces éléments sont reconnus par la littérature comme les principaux déterminants de la baisse historique de la mortalité en Amérique latine et sont identifiés dans cette recherche comme les principaux moteurs des écarts entre groupes spatiaux, même dans les pays les plus urbanisés comme le Chili. Cela signifie que la répartition inégale des infrastructures sanitaires de base et l'accès aux services de base continuent d'introduire des écarts de mortalité dans la région.

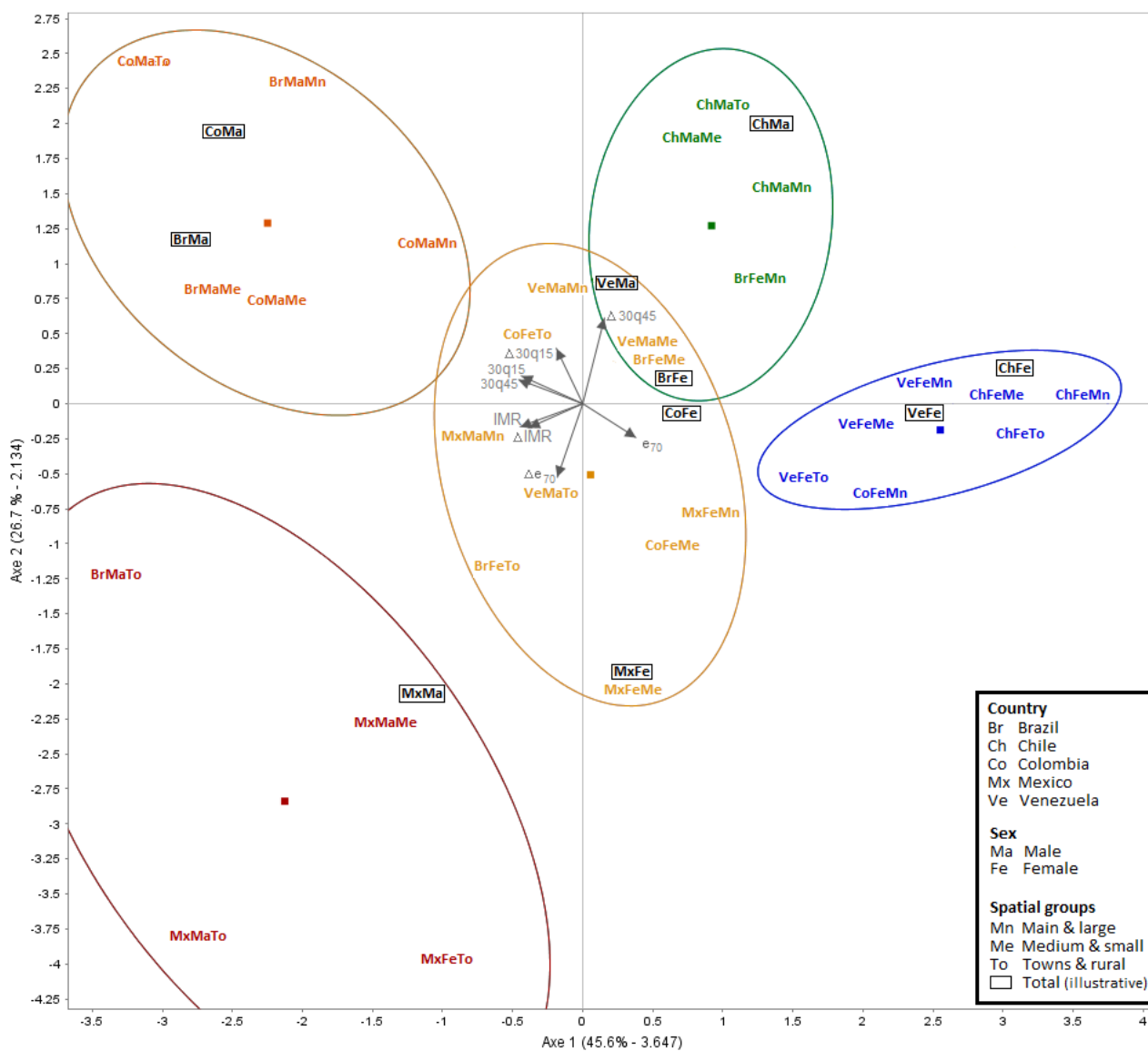
### **3.6 Regroupement des profils de mortalité des sous-populations**

Cette section regroupe tous les indicateurs précédemment utilisés afin de catégoriser les sous-populations en fonction de leurs profils généraux de mortalité. En ce qui concerne la qualité des données, l'analyse en composantes principales (ACP) et l'analyse hiérarchique (AH) sont utilisées pour fournir une vue synthétique des profils de mortalité dans les sous-populations au-delà de leurs niveaux nationaux. L'objectif est de classer les 30 sous-populations (plus 10 populations nationales à titre d'illustration) sur la base de niveaux et d'évolutions (dis)similaires au cours de la période de dix ans en matière de mortalité infantile (taux de mortalité infantile), mortalité des jeunes adultes (30q15), mortalité des personnes âgées (20q45) et espérance de vie à 70 ans. Les deux analyses sont effectuées avec le programme statistique SPAD.

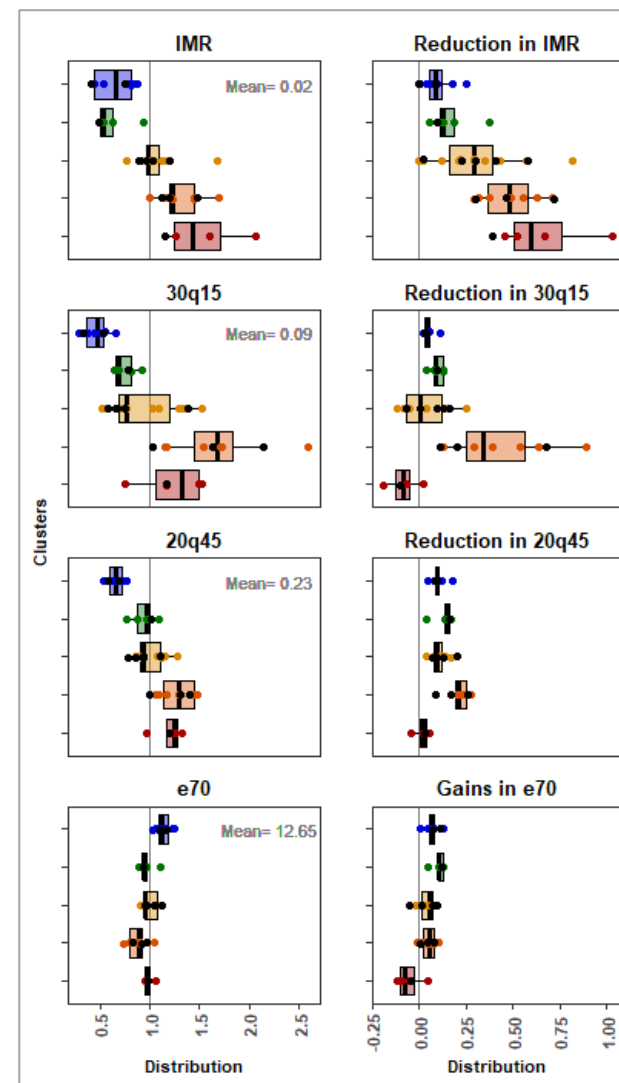
Les résultats de l'ACP sont présentés sous forme de diagramme de dispersion de sous-espace à composante principale sur la figure 9. Les deux premiers axes expliquent 72,3% de la variance: l'axe 1 a une valeur propre de 3,647, soit 45,6%; tandis que la valeur propre de l'axe 2 est égale à 2,134 et équivalente à 26,7%. Un troisième axe, avec une valeur propre de 0,9, indique que 11,6% de la variance sont ignorés. Ce troisième axe a les contributions les plus fortes de la variable «changements dans 30q15» (le seul changement qui est introduit lorsque l'on considère le troisième axe est de diviser les sous-populations en sept grappes en divisant la grappe jaune en deux). Les schémas de mortalité sont résumés en deux grandes dimensions - Premièrement, la rectangularisation de la courbe de survie sur l'axe 1 représente le passage d'une large dispersion des décès à une concentration du nombre de décès autour d'un âge modal plus élevé, qui est le produit d'une amélioration de l'espérance de vie à tous les âges. Deuxièmement, l'axe 2 résume le rétrécissement de la bosse de mortalité. Les deux dimensions expriment l'idée de changements dans les schémas de mortalité. La typologie des sous-populations permet: 1) d'approfondir les (dis)similitudes entre les sous-populations au-delà de leur pays; et 2) de résumer leurs performances antérieures et actuelles.

Les sous-populations sont regroupées en cinq grappes qui ne représentent pas nécessairement des niveaux de mortalité différents, mais plutôt des différences dans les tendances de mortalité par groupe d'âge au cours de la période d'analyse.

Figure 9. Sous-espace de la composante principale bidimensionnelle et regroupement des profils de mortalité dans les sous-populations



Répartition des clusters dans les variables actives ( $t_1$  valeurs moyennes centralisées)



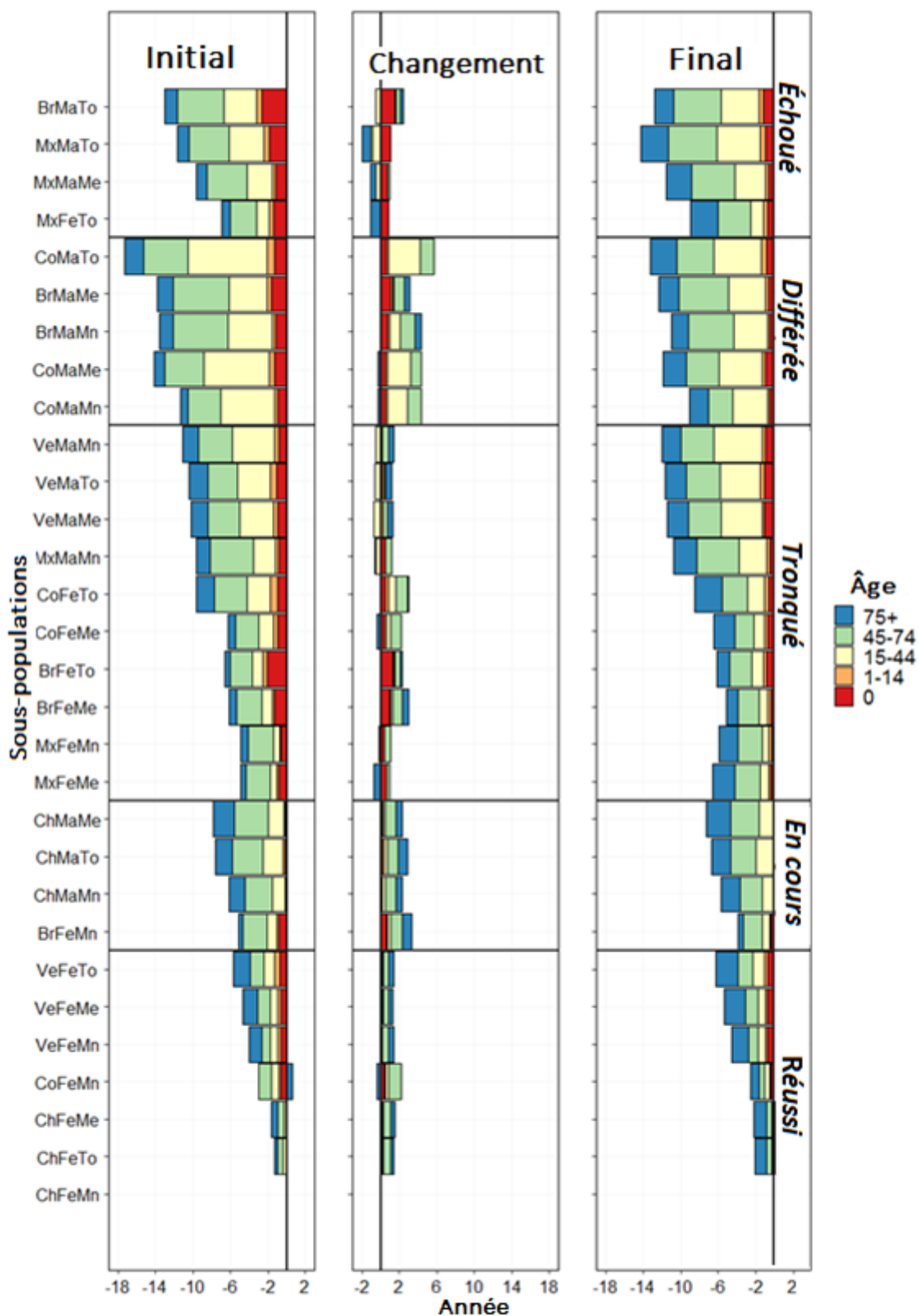
À la figure 10, les contributions de l'âge (en années) aux différences d'espérance de vie à la naissance entre chaque sous-population et la sous-population la plus performante (les femmes chiliennes habitant la capitale ou les grandes villes) ont été décomposées afin d'identifier les causes de décès et les groupes d'âge qui pèsent le plus dans ces différences. Les sous-populations, classées par grappe puis au sein de chaque grappe en fonction de leur niveau de mortalité, sont identifiées sur l'axe des y par un acronyme formé en combinant le pays, le sexe et le groupe spatial. Les grappes traduisent la façon dont la transition sanitaire se produit parmi les sous-populations. L'algorithme de remplacement de contour est la méthode utilisée pour décomposer les contributions des différents âges aux différences d'espérance de vie à la naissance. Trois ensembles de résultats sont présentés ici : les contributions d'âge à la différence finale d'espérance de vie à la naissance de toutes les sous-populations par rapport à la sous-population la plus performante, elle-même divisée en deux composantes additives, la contribution des âges à la différence initiale d'espérance de vie à la naissance et la contribution des âges aux changements intervenus au cours de la période de dix ans dans chaque sous-population.

Les baisses de la mortalité adulte sont plus importantes dans les sous-populations regroupées dans le cluster transition sanitaire *en cours* par rapport à celles qui ont déjà *réussi* la transition sanitaire. Le cluster *en cours* comprend des sous-populations féminines et masculines en retard qui rattrapent les avantages initiaux de leurs homologues féminines dans le cluster *réussi*. Ce cluster *en cours* aurait besoin d'une plus grande réduction des maladies circulatoires au-delà de 45 ans pour réduire le désavantage restant par rapport au cluster *réussi*. Il est possible que les sous-populations de ce groupe soient toujours en train de diminuer le poids proportionnel des décès dus aux maladies circulatoires chez les jeunes adultes.

Le cluster transition *interrompue (ou inachevée)* combine des sous-populations avec différents profils épidémiologiques au début de la période et dont les causes de décès présentent des tendances différentes. Les progrès modestes réalisés par cette grappe concernent principalement les populations âgées de 45 à 74 ans, mais ce n'est en aucun cas ce à quoi l'on pourrait s'attendre compte tenu de leur niveau de mortalité encore élevé par rapport aux sous-populations les plus performantes. Il y a quelques petites améliorations dues aux maladies du groupe I. D. & R. dans les populations infantiles, mais pratiquement aucun changement ne se produit à 75 ans et plus pendant la période. Ce groupe regroupe les sous-populations qui, d'une part, maintiennent des niveaux persistants de maladies I. D. & R. aux jeunes âges tout en ne bénéficiant pas correctement de la révolution cardiovasculaire et, de l'autre, ceux qui souffrent déjà des conséquences des homicides et du diabète. Il n'y a pas un processus clair de transition, mais plutôt une stagnation continue dans la dualité des profils épidémiologiques.

Contrairement aux sous-populations de la grappe *inachevée*, les sous-populations étiquetées comme étant en transition sanitaire *différée* présentent les progrès les plus importants à tous les âges, en particulier à l'âge adulte entre 15 et 74 ans. Ces sous-populations rattrapent leur retard sur les sous-populations plus performantes. Ces sous-populations n'ont pas manqué de bénéficier de la transition sanitaire, mais leurs progrès se sont produits plus tard.

Figure 10. Contributions de l'âge (en années) aux différences d'espérance de vie à la naissance entre les sous-populations et la sous-population la plus performante (ChFeMn), 2000-2010.



Enfin, les sous-populations qui ont *échoué* dans la transition sanitaire n'avaient pas nécessairement les niveaux de mortalité les plus élevés en 2000. Soit elles ont augmenté leurs écarts par rapport à la sous-population la plus performante, soit l'écart est resté stable en raison de la combinaison de contributions négatives et positives des différentes causes de décès. L'augmentation des maladies circulatoires, du diabète et des morts violentes empêche la baisse de la mortalité adulte de cette grappe. Ses sous-populations souffrent d'une détérioration générale de la mortalité adulte. , La réduction de la mortalité infantile, encore élevée en début de période, est le seul moteur des améliorations dans ce groupe. Les contributions de ce groupe d'âge au progrès de l'espérance de vie proviennent principalement de la diminution des maladies IDR & M. Compte tenu des âges et des causes de décès à l'œuvre, il est possible de dire que ce groupe n'a pas achevé son chemin vers un profil épidémiologique dominé par les maladies non transmissibles.

#### 4. Conclusions

Dans un contexte de croissance démographique rapide - comme celui qui sous-tend les récents processus d'urbanisation dans le monde - la relation entre l'urbanisation et la baisse de la mortalité ne dépend pas nécessairement du développement économique. Deux schémas d'évolution de la mortalité peuvent résulter des récents processus d'urbanisation : un effet de sur-urbanisation, qui est considéré comme une pénalité urbaine ou un effet de biais urbain, comme en témoigne l'avantage urbain persistant en matière de mortalité. Cela signifie qu'une urbanisation rapide pourrait être préjudiciable ou bénéfique pour les populations vivant dans les espaces urbains, et sa relation avec le développement détermine le différentiel urbain-rural de mortalité à long terme.

L'urbanisation et le développement ont indéniablement eu une relation positive en Amérique latine. La concentration des biens et des services dans les grandes villes se traduit systématiquement par une utilisation stratégique des ressources pour développer la région dans un contexte de croissance démographique rapide exceptionnelle. Il ne faut pas oublier que si l'Amérique latine est présentée comme l'une des régions les plus urbanisées du monde, elle est également l'une des moins peuplées. La période d'expansion de la ville dans la région coïncide avec une baisse rapide de la mortalité et une réduction des maladies infectieuses au niveau national. Des écarts de mortalité spatiale urbaine-rurale sont apparus au début du processus d'urbanisation, lorsque certaines zones se sont développées plus rapidement que d'autres. Les capitales et les grandes villes ont été les premières à voir l'introduction de contrôles sanitaires, les avancées médicales, la vaccination à grande échelle des populations, l'élimination des vecteurs de maladies, la distribution d'antibiotiques et la construction à grande échelle de systèmes d'eau potable et d'évacuation des eaux usées. Tous ces éléments ont été identifiés comme jouant le rôle le plus important dans la modification du profil épidémiologique de la région.

L'avantage urbain de la mortalité peut être considéré comme le résultat de stratégies de réaffectation des ressources et de moyens d'existence qui ont favorisé les villes, en particulier les capitales et les grandes villes. Le privilège accordé aux capitales et toutes les stratégies macroéconomiques adoptées dans la région jouent un rôle clé dans la compréhension de l'écart urbain-rural de baisse de la mortalité. L'urbanisation accrue et la baisse de la mortalité ne peuvent être dissociées, car le biais urbain dans l'allocation des ressources a été transversal dans les macro-politiques de développement de la région. Cela pourrait être la raison pour laquelle la baisse de la

mortalité a tendance à se produire plus rapidement dans les pays avec des niveaux d'urbanisation plus élevés, ainsi que la raison pour laquelle la transition sanitaire a progressé plus régulièrement dans les capitales et les grandes villes.

Ce contexte constitue le point de départ de la période d'analyse de cette recherche. Grâce à l'analyse des causes de décès, j'ai pu comprendre le niveau de (sous) développement des villes d'Amérique latine en fonction de leur taille. En outre, j'ai expliqué comment leurs différents niveaux pouvaient être traduits en schémas épidémiologiques divers et coexistants, généralement cachés lors de l'analyse du contexte national. Sept pays ont été initialement sélectionnés pour mener ces recherches. Ils ont été choisis en fonction de leurs processus d'urbanisation (mesurés en pourcentage de la population urbaine) et de leurs étapes de transition de la mortalité (mesurés à travers leur espérance de vie). Toutes les villes ont été séparées en trois groupes spatiaux en fonction de leur taille et de la dynamique de leur démographie historique : le groupe des capitales et grandes villes (500 000 habitants ou plus), le groupe des villes moyennes et petites (entre 20 000 habitants et 499 999 habitants) et le groupe des villages et des zones rurales (moins de 20 000 habitants). Après une évaluation approfondie de la qualité des données au niveau du groupe spatial pour les sept premiers pays sélectionnés, il a été possible de mener une analyse des tendances de mortalité sur seulement six d'entre eux, et à la fin, seuls cinq pays disposaient de données suffisamment précises pour estimer les causes de décès par groupes spatiaux. Cela signifie qu'une analyse des causes de décès a été réalisée pour le Brésil, le Chili, la Colombie, le Mexique et le Venezuela, tandis que le Pérou n'a été pris en compte que pour l'analyse des tendances de la mortalité par âge et l'Équateur a été complètement ignoré.

Cette recherche a confirmé la persistance de l'avantage urbain en matière de mortalité au cours de la première décennie du 21<sup>e</sup> siècle, comme on l'a constaté historiquement tout au long de la revue de la littérature. La mortalité urbaine conserve une position avantageuse en termes de niveaux initial et final pendant la période d'analyse. Toutes les zones urbaines sont mieux loties que les villages et les zones rurales, et le groupe des capitales et grandes villes a le taux de mortalité le plus bas. L'avantage urbain se retrouve dans tous les pays, quels que soient leurs niveaux de mortalité et leurs proportions de population urbaine. Cependant, le fait que le groupe des capitales et grandes villes ait l'espérance de vie la plus élevée ne signifie pas que toutes les capitales et grandes villes ont une performance exceptionnellement bonne en matière de baisse de la mortalité. Ils présentent simplement les meilleures performances dans leurs pays respectifs. Cet avantage affecte inégalement les sexes: les femmes bénéficient largement de l'avantage urbain par rapport aux populations masculines de tous les pays. À l'exception du Mexique, toutes les populations féminines vivant dans les capitales et les grandes villes ont à la fois les meilleures performances dans leurs pays respectifs et une augmentation continue de l'espérance de vie pendant la période d'analyse. Pour les populations masculines, ce n'est pas toujours le cas. L'effet de l'augmentation de la violence est associé aux inégalités sociales que l'on trouve principalement dans les agglomérations urbaines et les «bidonvilles», et il a profondément affecté les sous-populations masculines du Brésil et des capitales et des grandes villes du Venezuela.

Les résultats généraux montrent qu'il n'y a pas de groupe spatial qui enregistre des améliorations ou des détériorations constantes pour tous les groupes d'âge au cours de la période. Le groupe spatial le plus performant en termes de réduction du risque de mourir à un âge avancé est sans aucun doute le groupe des capitales et grandes villes pour tous les pays, alors que ce sont les



villages et les zones rurales qui enregistrent la baisse la plus importante du taux de mortalité infantile encore relativement élevé. Il n'y a pratiquement aucune amélioration de la mortalité aux âges adultes avancés en dehors des capitales et grandes villes. En fait, la réduction de la mortalité des adultes est liée à l'urbanisation et façonnée par un gradient urbain. Le ralentissement de l'augmentation de l'espérance de vie au niveau national est principalement dû aux efforts infructueux pour réduire la mortalité des populations âgées de 45 ans et plus en dehors des capitales et grandes villes. En ce sens, comme les contributions de chaque groupe spatial aux tendances nationales de mortalité varient d'un pays à l'autre (selon le poids respectif de ces groupes dans la population totale), ce sont les pays les plus urbanisés qui affichent la survie la plus élevée. Le Chili, le pays avec la courbe de survie la plus rectangulaire, est non seulement le plus urbanisé mais aussi celui avec les niveaux les plus élevés de métropolisation et de primauté de la capitale. Un effet de composition de la répartition de la population urbaine / rurale favorise la dominance des capitales et grandes villes dans le schéma de mortalité national.

Une autre question posée dans cette recherche porte sur les rôles joués par le biais urbain dans l'allocation des ressources et dans la formation des modèles de mortalité, en particulier à travers une analyse des causes de décès évitables. Puisque les décès susceptibles d'être évités sont largement liés à l'existence d'infrastructures, de biens et de services publics, on peut utiliser les modèles de mortalité pour confirmer l'influence du biais urbain dans l'allocation des ressources sur les résultats sanitaires régionaux. Étant donné que les causes de décès pouvant faire l'objet d'une intervention primaire comprennent les maladies et les affections susceptibles de prévention, ce groupe comprend les affections liées aux maladies infectieuses, à l'anémie, aux tumeurs facilement détectables, aux accidents de voiture et aux accidents dus à un dysfonctionnement de l'équipement public, entre autres.

Enfin, le principal résultat de cette recherche concerne le rôle du biais urbain dans la relation entre l'urbanisation et la transition sanitaire en Amérique latine. Passant en revue les changements épidémiologiques survenus dans la région, Frenk et al. (1991) ont développé l'hypothèse que les changements dans la structure des causes de décès ne se produisent pas selon un processus linéaire en suivant les étapes successives de la transition épidémiologique, comme cela avait été initialement proposé par Omran (1971). En revanche, la baisse de la mortalité en Amérique latine s'est produite dans le cadre d'un modèle de transition «polarisé-prolongé», ce qui signifie que des progrès ont été réalisés en même temps que les écarts se maintenaient de façon durable entre les sous-populations. Cette polarisation résulte de la coexistence de proportions importantes de causes transmissibles et non transmissibles dans tous les pays (Frenk et al. 1991). Pendant la période d'analyse de cette recherche, les maladies transmissibles semblent avoir joué un rôle négligeable dans la définition des schémas de mortalité. En termes de maladies transmissibles et non transmissibles dans les profils épidémiologiques nationaux, ce qui est plus pertinent que la «polarisation», c'est la «stagnation» en dehors des capitales et grandes villes, en particulier dans la lutte contre les maladies circulatoires à l'âge adulte. La révolution cardiovasculaire vécue par les pays développés se retrouve uniquement dans l'évolution de la mortalité des capitales et grandes villes d'Amérique latine, quel que soit le niveau d'urbanisation du pays.

En général, les pays et les sous-populations bénéficient différemment du progrès, et les généralisations sur le rythme du changement sont difficiles. Dans des pays comme le Chili et le Venezuela, les progrès se produisent à travers des cycles de convergence / divergence entre les

groupes spatiaux, mais à différents stades. Au Chili, l'écart entre le groupe « capitale et grandes villes » et le reste du pays est plus important que la simple distinction urbaine-rurale, car la primauté de sa capitale s'impose dans le schéma de mortalité au niveau national. Au Venezuela, en revanche, l'écart entre les zones urbaines et rurales est toujours important car les différences de mortalité entre les grandes, moyennes et petites villes ne sont pas aussi importantes qu'au Chili mais très marquées avec les villages et les zones rurales. Dans les deux pays, la différence entre les sexes semble être plus pertinente dans l'analyse des profils de mortalité que dans celle des écarts spatiaux.

Inversement, au Brésil, au Mexique et en Colombie, le différentiel urbain-rural dans les structures des causes de décès reste dans le même gradient tout au long du processus de baisse de la mortalité. Les schémas de mortalité des trois groupes spatiaux sont largement différents, ce qui donne l'idée de trois scénarios de développement distincts. Cela signifie que les stratégies de développement axées sur les zones urbaines conservent un avantage urbain persistant car les sous-populations urbaines bénéficient de manière significative et plus rapide de tout changement favorable à une baisse de la mortalité. De plus, les capitales et grandes villes restent pionnières de la transition sanitaire. Même lorsque les villages et les zones rurales de ces pays connaissent des progrès rapides, il ne leur est pas possible de rattraper l'avantage urbain initial et des profils parallèles coexistent au niveau national.



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**THÈSE**

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**Jenny GARCIA ARIAS**

**URBAN BIAS IN LATIN AMERICAN CAUSES OF DEATH PATTERNS**

**Sous la direction de: Dr. France MESLÉ**

**JURY:**

Directrice de Thèse: **Dr. France MESLÉ**, Directrice de recherche, Institut National d'études Démographiques (INED)

Co-directrice: **Dr. Aline DESESQUELLES**, Directrice de recherche, Institut National d'études Démographiques (INED)

Président du Jury: **Dr. Claude GRASLAND**, Professeur, Université Paris 7 Denis Diderot

Rapporteur: **Dr. Hiram BELTRÁN-SANCHÉZ**, Professeur agrégé de l'Université de Californie, Los Angeles.

Rapporteur: **Dr. Mark MONTGOMERY**, Chercheur, Programme Pauvreté, genre et jeunesse, de Population Council et Professeur de l'Université Stony Brook.



*To Alberto Gruson who taught me the relevance of the urban bias  
and to my dear friend Marie from being who she is*

## ABSTRACT

In 1977, Michael Lipton introduced the Urban Bias Thesis as a framework for understanding how most macro- and microeconomic policy initiatives have historically benefited the overdevelopment of urban areas and the underdevelopment of rural areas, as a result of the historical urban bias in resource reallocation. In Latin America, urbanization and mortality decline have historically been positively related: the health transition in the region has been initiated in the main cities and has tended to proceed more rapidly in countries with higher levels of urbanization. Given this context, this research looks for evidence on two phenomena: the persistence of an urban advantage in mortality; and traces of an “urban bias” in the causes of death patterns in the region. Using a sample of Latin American countries over the period 2000-2010, I apply decomposition methods on life expectancy at birth to analyze the disparities in mortality patterns and causes of death when urban and rural areas are considered separately. Urban is defined as a continuum category instead of a dichotomous concept. Hence, three types of spatial groups are recognizable in each country: main and large cities (more than 500,000 inhabitants); medium-sized and small cities (20,000 to 499,000 inhabitants); and towns and purely rural areas combined (less than 20,000 inhabitants). The countries under analysis are Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela. Because comparability across time and countries is needed, I ensure a high standard of data quality by addressing two major issues: coverage errors identified as underreporting levels; and quality errors in reported age, sex, residence and causes of death. The results indicate that the urban advantage is persistent and that rural-urban mortality differentials have consistently favored cities. Hardly any improvement in declining mortality exists in older adult ages outside the main and large cities. This urban advantage in mortality comes as an outcome of lower rates for causes of death that are amenable to primary interventions, meaning they are made amenable by the existence of basic public infrastructures as well as by the provision of basic goods and services. Countries and subpopulations are benefiting differently from progress: in the most urbanized countries, spatial-group mortality patterns are converging; while differentials remain in the least urbanized countries.

**Keywords:** urbanization, urban growth, urban advantage, over-urbanization, mortality decline, Health Transition, amenable causes of death.

## Résumé

En 1977, Michael Lipton a présenté le concept de biais urbain comme cadre pour comprendre comment la plupart des politiques macroéconomique et microéconomique ont profité au surdéveloppement des zones urbaines et au sous-développement des zones rurales, en raison du biais historique dans la réaffectation des ressources. En Amérique latine, l'urbanisation et la baisse de la mortalité sont historiquement liées positivement : la transition sanitaire dans la région a été amorcée dans les principales villes et s'est poursuivie plus rapidement dans les pays à urbanisation plus élevée. Cette recherche s'inscrit dans ce cadre et s'intéresse à deux phénomènes: la persistance d'un avantage urbain dans la mortalité d'une part; et d'autre part des traces d'un «biais urbain» dans les schémas des causes de décès dans la région. En étudiant plusieurs pays d'Amérique latine sur la période 2000-2010, j'applique des méthodes de décomposition de l'espérance de vie à la naissance pour analyser les disparités dans les schémas de mortalité et les causes de décès lorsque les zones urbaines et rurales sont considérées séparément. En définissant l'urbain comme un continuum au lieu d'un concept dichotomique, trois groupes spatiaux sont reconnaissables dans chaque pays: les capitales et autres grandes villes (plus de 500 000 habitants); les moyennes et petites villes (20 000 à 499 000 habitants) et les villages et autres zones purement rurales (moins de 20 000 habitants). Les pays analysés sont le Brésil, le Chili, la Colombie, l'Équateur, le Mexique, le Pérou et le Venezuela. Dans la mesure où une comparabilité dans le temps et entre les pays est nécessaire, deux questions majeures sont considérées pour garantir la qualité des données: les erreurs de couverture évaluées en termes de niveau de sous-déclaration et les erreurs de déclaration pour l'âge, le sexe, la résidence et les causes de décès. Les résultats indiquent que l'avantage urbain est persistant et que les écarts de mortalité entre les zones rurales et urbaines ont toujours favorisé les villes. Il n'y a pratiquement aucune baisse de la mortalité chez les adultes plus âgés en dehors des capitales et autres grandes villes. Cet avantage urbain en matière de mortalité résulte de la baisse de la mortalité pour les causes qui se prêtent à des interventions primaires rendues possibles par l'existence d'infrastructures publiques ainsi que par la fourniture de biens et services sociaux. Les pays et les sous-populations bénéficient différemment des progrès: dans les pays les plus urbanisés, les schémas de mortalité des groupes spatiaux convergent, tandis que des écarts subsistent dans les pays les moins urbanisés.

**Mots-clés:** urbanisation, croissance urbaine, avantage urbain, sur-urbanisation, baisse de la mortalité, transition sanitaire, causes de décès évitables.

## Resumen

En 1977, Michael Lipton introdujo la tesis del sesgo urbano como un marco para comprender cómo la mayoría de las iniciativas macro y microeconómicas en los países en desarrollo han beneficiado a las áreas urbanas sobre las áreas rurales, a través del sesgo en la distribución de recursos. En América Latina, la urbanización y la disminución de la mortalidad están históricamente ligadas: la transición de la salud en la región comenzó en las principales ciudades y ha tendido a avanzar más rápidamente en los países más urbanizados. En este sentido, esta investigación busca evidencia sobre dos fenómenos: la continuidad de la ventaja urbana en la mortalidad; y rastros del "sesgo urbano" en los patrones de causas de muerte en la región. Utilizando una muestra de países latinoamericanos durante el período 2000-2010, se aplican métodos de descomposición en la esperanza de vida al nacer para analizar las disparidades en los patrones de mortalidad y las causas de muerte cuando las áreas urbanas y rurales se consideran por separado. Urbano se define como una categoría continua en lugar de un concepto dicotómico. Por lo tanto, tres tipos de grupos espaciales son reconocibles en cada país: ciudades principales y grandes (más de 500,000 habitantes); ciudades medianas y pequeñas (20,000 a 499,000 habitantes); y pueblos y áreas puramente rurales combinadas (menos de 20,000 habitantes). Los países analizados son Brasil, Chile, Colombia, Ecuador, México, Perú y Venezuela. Debido a que la comparabilidad a través del tiempo y los países es necesaria para garantizar un alto estándar de calidad de los datos, se tienen en cuenta dos cuestiones principales: errores de cobertura identificados como niveles de sub-registro; y errores en la declaración de la edad, sexo, residencia y causas de muerte. Los resultados indican que la ventaja de las áreas urbanas es persistente y que los diferenciales de mortalidad urbana-rural han favorecido a las ciudades. Casi ninguna mejora en la disminución de la mortalidad existe en adultos mayores fuera de las ciudades principales y grandes. Esta ventaja de las áreas urbanas en la mortalidad se produce como resultado de tasas más bajas de causas de muerte que son evitables a través de intervenciones primarias, lo que significa que no hubiesen ocurrido ante la existencia de infraestructuras públicas básicas, así como por la provisión de bienes y servicios básicos. En general, los países y las subpoblaciones se benefician de manera diferente del progreso: en los países más urbanizados, los patrones de mortalidad de los grupos espaciales convergen; mientras que en los países menos urbanizados los diferenciales permanecen.

**Palabras clave:** urbanización, crecimiento urbano, ventaja urbana, sobre-urbanización, disminución de la mortalidad, transición de la salud, causas evitables de muerte, causas prevenibles de muerte.



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## List of Abbreviations

ADR	Age-specific Death Rates
DHS	Demographic and Health Survey
ICD	International Classification of Diseases
CDR	Crude Death Rate
CBR	Crude Birth Rate
GDP	Gross Domestic Product
UNODC	United Nations Office on Drugs and Crime
WHO	World Health Organization
PAHO	Pan-American Health Organization
UNICEF	United Nations Children's Fund
ECLAC	Economic Commission for Latin America and the Caribbean
CELADE	Centro Latinoamericano de Demografía
CEPALSTAT	Economic Commission for Latin America and the Caribbean's statistics database
REDATAM	REtrieval of DATa for small Areas by Microcomputer
MAD	Major Administrative Division
MIAD	Minor Administrative Division
Sub-MIAD	Sub-Minor Administrative Division
IMILA	International Migration in Latin America database
MIALC	Internal migration in Latin America database
PIAALC	Indigenous and Afro-descendant populations in Latin America database
OECD	Organization for Economic Co-operation and Development
IPUMS	Integrated Public Use Microdata Series
IAC	International American Conference
IASI	Inter-American Statistic Institute
COTA	Americas Census Program
VSPI	Vital Statistics Performance Index
PRODEM	DEMographics PROjections
ABACUS	the projection programs
RUP	Rural-Urban Projections
CONAPO	Consejo Nacional de Población (México)
WHOSYS	World Health Organization Statistical Information System data
PCA	Principal Component Analysis
HCA	Hierarchical Cluster Analysis
UNASA	United Nations Age-Sex Accuracy Index
SR	Sex Ratio
IRA-h	Mean Age Deviation for men
IRA-m	Mean Age Deviation for women
MBI	Myers Blended index
IMR	Infant Mortality Rate
UN IGME	United Nations Inter-agency Group for Child Mortality Estimation
URR	Under-Registration Ratio
CI	Coverage Index
SBH	Summary Birth History

CEB	Children Ever Born
CSA	Children Still Alive
DDM	Death Distribution Method
GGB	General Growth Balance method
BGB	Brass Growth Balance
SEG	Synthetic Extinct Generations method
PCM	Preston and Coale Method
LAMBdA	Latin American Mortality Database
DESA	United Nations Department of Economic and Social Affairs
SDR	Standardized Death Rate
DPR	Death-to-population Proportional Ratio
DR	Death Ration
NR	Population Ratio
PAM	Primary Avoidable Mortality
SAM	Secondary Avoidable Mortality
TAM	Tertiary Avoidable Mortality
ID&R	Infectious, Digestives and Respiratory diseases
IDR&M	Infectious, Digestives Respiratory diseases and Maternal conditions

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## INTRODUCTION

In most regions of the world, decreasing mortality has been unstoppable since the twentieth century. Despite some setbacks due to the HIV/AIDS epidemic in Africa, trends in mortality reduction have been overwhelmingly positive worldwide. Several attempts have been made to construct analytical frameworks that synthesize explanations for the decline and its determinants. One aspect they have in common is the assumption that factors determining the likelihood of death are related to population and cultural characteristics, such as health services, lifestyles, medical progress, and environmental and sanitary conditions, among others.

During the last century, Latin American countries also showed accelerated changes in mortality patterns: a fast decrease in mortality rates and a cause-of-death structure in which degenerative and man-made diseases became prevalent in most countries. This process has been characterized as reversible, discontinuous and dissimilar to those patterns presented by developed countries (Palloni 1981). The consensus among experts is that the impact of economic development on the decline in the region's mortality was relevant only until the early twentieth century, when the reduction was still incipient. The faster decreasing mortality period – from the 1930's onward – was marked by substantial sanitary controls, mass vaccinations, the elimination of disease vectors, the distribution of antibiotics, large-scale construction of potable water and sewage disposal systems, and the expansion of the health system (Arriaga and Davis 1969; Preston 1976). These measures significantly reduced deaths for infectious and parasitic diseases in all countries, especially among the infant population. Thus, the region's average life expectancy increased by 6.4 years during the fifties and by 8.6 years in the next two decades (ECLAC 2016). After the 70's, the drop began to slow down and there was an increase in the prevalence of deaths due to cardiovascular disease and external causes (Frenk, Frejka et al. 1991; ECLAC 2007; Sabino, Regidor et al. 2007). Since then, the decline has been related to improvements in the population's quality of life and individual living standards, e.g.: nutrition, housing, and access to medical care, among others (Palloni and Pinto-Aguirre 2011).

Mortality decline in Latin America has not been observed as a homogeneous process among a region that is mainly characterized by its heterogeneity. A clear divergence-convergence cycle in life expectancy has taken place since the beginning of the decline. Divergence was evident during the fifties, when Argentina, Uruguay and Cuba were ahead of the rest of the region in their levels of life expectancy at birth (Palloni and Pinto-Aguirre 2011). Later on, a convergence stage began and all the countries managed to more or less rapidly catch up with the initial advantage. The convergence in life expectancy was related to the homogeneous post-transition phase that occurred after overcoming most deaths due to infectious diseases.

Since then, only a few countries have continuously accelerated their increases in life expectancy. Among these are Chile and Costa Rica, whose constant increases have initiated a new cycle of divergence in life expectancy for the region. The divergence this time results from the success of these countries in reducing death due to circulatory diseases. Besides the exceptional improvements in Chile and Costa Rica, the increases in life expectancy is observed to be somewhat stagnating in most Latin-American countries. The stagnation in the increases in life expectancy has been linked in the literature to many reasons: 1) the still persistent high levels of infant mortality due to the remaining importance of infectious diseases in some countries (Schkolnik and Chackiel 1997); 2) their failure in passing by the "cardiovascular revolution"; 3) the existence of important

differentials between sub-national populations (Frenk, Bobadilla et al. 1991); and 4) the incidence of violent deaths that are either persisting or increasing (Di Cessare 2011).

When a mortality study takes into consideration different countries, the most traditional approach is through the national context, since intervention policies are often undoubtedly inherent to national states. However, it is also true that the analysis of composite mortality indicators and indexes at the national level as a whole could obscure differentials related to particular population groups. When inequality takes on importance like it does in the Latin American case, country level averages hardly reflect the broad range of co-existent sub-population patterns (Metzger 2002). To get a closer view of any phenomenon that is made biased by great inequalities, some distinctions have to be made. Since diseases and causes of death do not always appear by chance, but rather correspond to a defined pattern of social organization and structure, living conditions play a major role.

Inequalities in mortality across socio-economic groups have been widely studied over recent years through income, educational attainment, or other indicators (Wagstaff, 2002). However, socio-economic stratification predicts only a small proportion of the variation in mortality (Pradhan, Sahn et al. 2003), and more environmental characteristics should also be considered (Montgomery and Hewett 2005). Gaps in living conditions have been historically correlated with all kinds of factors (race, ethnicity, income, education, occupation, etc.) that do not necessarily correspond to spatial categories. However, in the case of Latin America, many studies on living conditions have highlighted their unequal development along spatial lines. A high concentration of goods and services in cities have left rural areas behind (Prata 1992; Curto 1993; Schkolnik and Chackiel 1997). Therefore, it is possible to locate and distinguish the central differences in living conditions in Latin America just by spatially differentiating the urban from the rural areas.

This is not in fact a new idea. It was in 1977 that Michael Lipton introduced the Urban Bias Thesis<sup>1</sup> (UBT) as a framework for understanding economic and social singularities in developing countries. He identified how most macro- and microeconomic policy initiatives have led to the overdevelopment of urban areas and the underdevelopment of rural areas (Lipton 1977). This bias is a continuation of distortions resulting from trade relationships of natural resource exploitation by colonial powers (Preston 1979). In its first iteration, the UBT asserts that rural areas in developing countries suffer from: too little spending on welfare and differences in taxation, salaries and food prices, which have created unfair gaps among the population and inefficiency in the distribution of resources (Varshney 1993). Since then, different views and criticisms have been published in regard to this theory. What is more, other authors have studied how the urban bias can be traced to the way that rural-urban economics manifest itself into livelihood strategies (Jones and Carbridge 2010). Although there is some reason to think that “an urban bias continues to plague pricing, expenditure policies and overall resource allocation in developing countries, its magnitude remains unknown” (National Research Council 2003).

With the strong favoritism given to urban areas in Latin American countries, it is no surprise to find large disparities in the capacity of populations to satisfy their basic needs. What has been said is that if quality of life is closely linked to urban development (ECLAC 2009), in their own way, cause of death analysis could provide an insight into the level of (under)development of the regions. In addition, causes of death could be used as an outcome to indicate how strategies for gaining access to health, sanitation and so on could be translated into different epidemiological patterns.

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<sup>1</sup> Recently revisited as a hypothesis by the author (Lipton, 2005).

Following this idea, it is possible to find in the literature not only signs of the relationship between urban bias and mortality in Latin America countries, but also how cause-of-death structure differs between urban and rural populations. For example, Frenk et al. (1991) brought attention to an extended-polarized model in the case of the Latin American epidemiologic transition, using it as a framework to explain the coexistence of a significant proportion of deaths from communicable and non-communicable causes in the national context. They claimed that this polarized characteristic of the epidemiological profile would be partially diluted when considering separate urban/rural patterns.

From that point forward, few advances have been made in ascertaining how specific causes of death contribute to the urban-rural gap in the region. To that end, this research proposal seeks to answer the following questions. Can the “urban bias” be traced through urban-rural differences in mortality? And does taking these differences into account shed light on the drivers of the health transition in the region? In this sense, I mainly hypothesize the following: Urbanization and development are tightly linked in Latin America because concentrating goods and services in the most urbanized areas –urban bias in resource allocation- consistently results in resources being strategically used to promote a rapid mortality decline and to drive the health transition at the national level, in a context of rapid urbanization.

More specifically, I inquire: Do Latin American countries have different mortality patterns when considering urban and rural areas separately? Do differences between urban and rural settings come from specific cause-of-death and age-specific mortality levels and trends? Can the urban bias in resource allocation be perceived through the amenability of causes of death in Latin American countries? Likewise, I hypothesize that:

-There is a persistent urban advantage in mortality in Latin America. This advantage is concentrated mostly in the largest cities. Thus, their initial level and trends during the period of analysis are the most advanced in terms of mortality decline in comparison with the rest of the country. The urban advantage remains, regardless of the level of urbanization and mortality maintained by these countries.

-The urban advantage is perceivable through differences in age-specific mortality trends. In the largest cities, the reduction in adult mortality is moving toward a rectangularization of the survival curve; whereas in towns and rural areas, decreasing infant mortality is still the main contributor to changes.

-The urban advantage comes mainly from the differential impact of amenable causes of death, as their incidence rates are higher in rural areas than in urban areas. This means that using causes of death as an outcome makes it possible to follow the urban bias in resource allocations across the national territory, because amenable causes imply that deaths from certain causes would not occur if timely and effective interventions were given.

To answer all these questions and test the hypotheses of this research, I selected data from seven Latin American countries: Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela. These represent diverse situations in terms of life expectancy at birth and percentages of urban population (see table below). The aim is to characterize both the urban-rural mortality differential in the region and the cause-of-death patterns that could explain the gap. The 2000-2010 period of analysis adheres to the commonly used 10th Revision of the International Classification of Diseases (ICD) and the data availability of the seven countries, both of which facilitate the comparative analysis.

% Urban Population in 1995	Life Expectancy in 1995	
	Higher (>69 years)	Lower (<69 years)
<b>High</b> (>80%)	Chile Venezuela	Brazil
<b>Medium</b> (60% to 80%)	Mexico	Colombia Peru
<b>Low</b> (<60%)	Ecuador	

Source: CEPALSTAT. Databases and statistical publications, at [http://estadisticas.cepal.org/cepalstat/web\\_cepalstat/estadisticasIndicadores.asp?idioma=i](http://estadisticas.cepal.org/cepalstat/web_cepalstat/estadisticasIndicadores.asp?idioma=i) consulted 04.02.2019.

There is no commonly used unified threshold to separate urban from rural areas in these countries; each country has adopted different criteria and limits for distinguishing urban from rural areas, such as political boundaries (political-administrative hierarchy); population size or density (thresholds vary among countries); economic function; landscape; number of urban facilities and services; and so on. The definitions adopted may also vary over time in a single country. Thus, this research employs “urban” as continuum categories instead of a dichotomous concept, thereby applying three types of recognizable spatial groups for all countries: main and large cities (more than 500,000 inhabitants); medium-sized and small cities (20,000 to 499,000 inhabitants); and towns and rural areas (less than 20,000 inhabitants).

The data are used to compute mortality rates by causes of death and decedents’ place of residence. This means that on the one hand we have mortality data: cause-of-death databases from vital statistics published by the Ministries of Health in Peru and Venezuela, and by the National Statistics Institutes in Chile, Colombia, Ecuador and México. They contain the information provided on death certificates, whenever a death is reported to the health service, whether or not it took place in a healthcare Institution. On the other hand, we have adjusted population estimates made by the National Statistics Institutes in each country under the supervision of the Population Division at the United Nations Economic Commission for Latin America and the Caribbean (ECLAC). These data are matched by clustering the minor administrative units (MIAD) assigned to the cities by each national statistical office. The MIAD is the equivalent of a *county* in the United States of America and of a *département* in France

In summary, 10,777 counties from the seven countries are split into the three spatial groups. Because comparability across time and countries is also needed to ensure a high standard of data quality, I subsequently took two major issues into consideration when estimating age-specific mortality rates: coverage errors, identified as underreporting levels; and quality errors in reported age, sex, MIAD of residence, and cause of death. Comparable and accurate estimates are analyzed using a life expectancy decomposition methods, specifically the stepwise decomposition and the algorithm of contour replacement, developed by Jdanov and Shkolnikov (Jdanov and Shkolnikov 2014). The aim is to decompose the difference in life expectancy at birth in order to evaluate differential contributions by age and cause of death.

This research is described in ten chapters. Throughout the first chapter, I revisit population theories linking demographic phenomena and urbanization, as well as the role played by mortality in the urban transition. Here, I take a demographic approach to explore the contrast between “urban bias” and “over-urbanization”, specifically by looking at the urban advantage and urban penalty in mortality.

The second chapter summarizes key elements in my literature review to help understand the urbanization process in Latin America, the current city system, and the effect that the historical urban bias on resource allocation has on population’s quality of life and private living standards. For its part, the third chapter is dedicated to summarizing historical mortality patterns in Latin America with a focus on the existing gaps found among countries, geographical areas, and sub-populations, especially regarding the mortality differentials introduced by the urbanization process.

The fourth chapter describes the core of this research, its geographical and temporal framework, and the technical arrangements made to divide the national territory into units in order to guarantee reliable comparison within data sources over time. In Chapter Five, I provide a description of the available demographic data on the region and its historical assessment. Chapter Six examines in detail the quality of the demographic data at the spatial group level for the seven selected countries. This chapter ends by classifying the data quality of all spatial groups and summarizing the arrangements needed to achieve comparability. Chapter Seven describes all the methods and indexes used in this research to properly assess the urban (dis)advantage in Latin American mortality patterns.

The results of this research are presented in the following three chapters. In Chapter Eight, I explore the existence of differentials introduced by urbanization in Latin American mortality patterns using age-specific mortality trends and their contributions to changes. In the ninth chapter, I enrich this exploration by analyzing the cause –of-death structure in Latin American countries when considering the urban-rural gradient. The aim of the ninth chapter is to identify the main causes of death driving age-specific mortality trends and their contribution to spatial-group differentials during the period of analysis.

The last chapter of this research, Chapter Ten, focuses on determining which subpopulations are leading changes in the region’s mortality and which causes of death are responsible for the subpopulations’ divergence/convergence processes in their mortality decline beyond the country level. Finally, the manuscript ends by providing general conclusions, limitations, and some views toward future research.

## 1. URBANIZATION AND MORTALITY

Underlying all demographic transitional ideals, it is urbanization and industrialization that are used not only as proxies for development, but as one of the main determinants of changes. Their parallel occurrences in European history have made them hard to disentangle from the explanatory processes found in most population theories. The processes of modernization, industrialization and urbanization tend to be confused with each other when development is viewed as a homogenous and irreversible process of universal convergence (Huntington 1971). What is more, the modernization theories that prevail in demographic studies have set the idea of development as a unidirectional process in which societies must pass from a primitive state of the rural, enlarged, short-lived family to an ideal stage of the urban, small, long-lived family (Tabutin 1999). This dichotomous approach to urban-rural settings has served as an analytical framework for modern societies around the globe, in which the urban industrialized space is viewed as an evolved version of an agricultural rural one. In this way, comparing “city” and “countryside” is continuously used as an attempt to engage modern versus traditional representations (Veron 2006).

It is true that increasing levels of education, fertility and mortality decline (prevailing as secular and rational values) took place in industrial European cities (Notestein 1945; Notestein 1953). However, recent declines in mortality and fertility in developing countries challenge previous interpretative attempts. Several examples of high urbanization growth combined with declines in fertility and mortality in the absence of industrialization have been occurring all over the world (Dyson 2011). This chapter is dedicated to, first, exploring the role given to the urbanization process within population theories and, second, to displaying the analytical framework for understanding the relationship between urbanization and mortality — which I later apply to the case of Latin America. The chapter is divided into five sections. The first section summarizes the basic concepts and historical framework of urbanization processes. Here, historic and recent urbanization processes around the world are distinguished.

The second section aims to revisit population theories linking demographic phenomena and urbanization. The third section is dedicated to describing the Urban Transition and the role played by mortality in this process. The fourth section delves deeper into the opposition between “urban bias” and “over-urbanization”, with the former describing the framework for understanding the advantages found in the urban setting, where development and urbanization process go hand-in-hand; whereas the latter describes the dissociation between the urbanization process and development. Finally, I provide a brief conclusion that puts into perspective the relationship between mortality and urbanization in this research project.

### 1.1 Urbanization process

Some preliminary remarks must be necessarily made about the concept of urbanization before providing a comprehensive analysis on its relationship with demographic phenomena. To begin, a proper definition of *urban* must be established. Through a literature review, the urban space is defined using several criteria. Definitions vary over time and they might emerge as functions of political boundaries, population size or density, territorial economic activities, landscape or physical structures, services provided, or perhaps some other criteria that have yet to be put forth. In all cases, the definition relies on one common and specific delineation: the urban space is non-rural.



The idea of dichotomously defining urban and rural assumes that there are indeed enough opposite characteristics to distinguish the two frameworks (Hugo 1987). Thus, both demographic and non-demographic dimensions are used to draw a line between urban and rural populations. Because of the nature of this analysis, urban is assumed merely as a demographic dimension in which population size is used as an indicator. An urban space or an urban population is then indicated by its density, and the process of a rural space becoming urban is simply one of increasing density.

### **1.1.1 Urbanization and urban growth**

Urbanization always implies a process of social transformation over time. Without regard to the time element, its use employs a diachronic perspective to analyze the process of becoming urban (Butterworth and Chance 1981). A set of phenomena has been identified as urbanization: structural urbanization, behavioral urbanization and demographic urbanization (De Vries 1990). In order to avoid misconceptions about the concept of urbanization, this document uses a quite restricted meaning of the term, one that is attached purely to its demographic conception. It refers to the process in which a population goes from a mostly dispersed pattern of human settlement to one that is concentrated mostly in cities (Rogers 1982). In other words, it indicates a process of increasing the proportion of the total population of a country or living area into relatively permanent points of high density (Browning 1967). Urbanization occurs in a given country or large limited geographical area, and it strictly involves the shift of a society from having 10 percent of an urban population or less to having 70 percent or more of an urban population (Dyson 2011).

This process could be measured through an urbanization rate (proportion of people living in cities), total urban inhabitants (absolute number of people living in cities) and/or urban growth (increase in urban population in a temporal framework). These three indicators cover different but complementary ideas of the urbanization process itself. Urbanization and urban growth may occur together, but they do not measure the same attribute in a population. Indeed, urban growth could happen with or without urbanization, because the number of people in an urban population may grow at the same time as that in a rural one — without augmenting its proportion of the total population. In contrast, urbanization necessarily implies urban growth. Equally, a high urban growth rate will be a consequence of the high population growth rate (Veron 2006).

At least one distinction has to be made regarding the urbanization process. Is recent urbanization in developing countries comparable to historic urbanization in Europe? Are differences linked to delays or do they indeed involve a completely different process? Understanding historic and recent urbanization within a different analytic framework may be the first step in disentangling the role played by the development and urbanization process and their relationships with demographic phenomena.

### **1.1.2 Historic and recent urbanization processes**

Urban settlements have existed around the world since even before the nineteenth century. However, it is from this period on that the urbanization process began. The first region to be urbanized was Europe. The accelerated urban population growth occurred in parallel to the process of industrialization. Up to that point, cities were deadly places to live in, due to their high mortality rates. Preindustrial urban growth was restricted by two factors: their ability to supply food and to control infectious and parasitic diseases (De Vries 1984). The combination of technological and

institutional innovations achieved during the industrialization process constituted key factors in both mortality decline (through the controls of diseases and energy surplus) and economic development. As mortality declined, the total population grew and, consequently, urban population increased. In addition, rural-urban migration was driven by the substantial economic development associated with industrialization (Fox 2012).

The parallelism of both processes in European history led to urbanization emerging as a result of sustained economic growth, although there are probably very good reasons for interpreting a reverse causality. This means that sustained economic growth resulted from urbanization. Undoubtedly, it is difficult to conceive that economic, political and social development would occur in rural European areas without the existence of cities (Keyfitz 1996). The Dutch Republic, England and France were the first countries to be properly urbanized. The growth of urban populations was not simultaneous: the port cities in these three countries tended to grow rapidly and concentrated the largest numbers of the population. For example, during the entire eighteenth century, “England’s share of Europe’s total urban growth was 70 percent, while the total English population was less than 8 percent of the entire European population throughout the century” (Wrigley 1990).

Throughout the European urbanization process, a significant shift in mortality trends was recorded. At the beginning of the nineteenth century, mortality varied directly with population density while by the early twentieth century mortality it varied inversely. At the same time, the impact of the industrial revolution during the nineteenth century led to increases in agricultural productivity, which drove unemployed farmers to the cities. These migrations were responsible for one-half to two-thirds of the subsequent urban growth (Pumain 2006). In the European case, the links between urbanization and economic development seem to be inarguable. Far from global generalizations, the recent experience of developing countries around the world could be calling into question these links between urbanization and economic development. Urbanization without real signs of economic development or modernization is observed everywhere (Bairoch 1996).

First, the most important issues to be addressed regarding the studies of the urbanization process in developing countries is that most of the countries do not have long-term vital statistics that allow us to follow historic trends (beyond those estimated by the United Nations after the 1950s). Using these estimates makes it possible to observe the patterns for the most recent period, and this may allow in some cases a glimpse of their demographic transition (Dyson 2011) as well as ongoing urban growth.

Second, the urbanization process in developing countries has not been exceptionally rapid by historical standards; rather, it is the growth of urban population rates that represent an unprecedented phenomenon (Preston 1979). At the absolute scale, contemporary urbanization all over the world is far greater than in the 19th century, while the proportional increase in the urban population is similar to that seen in Europe and North America in the period 1875–1925 (Cohen, Montgomery et al. 2003). The accelerated increase in urban populations is also related to the rise in natural growth rates and net urban in-migration, but not along the same lines as the European experience. Changes in developing countries were generally set in motion by a more rapid introduction of technologies, such as industrial agricultural methods, antibiotics and vaccines, all of which facilitated mortality declines and increased the availability of surplus food supplies after World War II (Fox, 2012). Therefore, the rate of change has been faster and higher than the population growth.

Gains in life expectancy and food supplies increased more rapidly than economic development, and the gap between the point at which mortality and fertility began to decline is larger in some developing countries than when compared with the European case (Reher 2011). This gap has allowed populations to keep growing faster in both urban and rural areas (Bairoch 1985). In this case, rural-urban migration partially accounts for the urban growth. Between 1950 and 1990, the urban population in developing countries increased 4.5 percent each year, more than 2.5 times the rate of any that was ever recorded in European countries. At that pace, it is estimated that the urbanization process — instead of taking 150 years (as was the case in European countries) — would only take 50 years (Pumain 2006).

The diverse experiences in which urbanization and development are determined by industrialization have generated questions regarding the interdependency of these processes. Both theoretical arguments and the empirical evidence gathered from countries point in different directions: urbanization and development could be positively or negatively related, depending on the context and the historical period. Social and economic transformations introduced by the industrialization process are observed in all urban areas, even in the absence of significant improvements in the population's economic well-being. This is because modern economic growth has undoubtedly played an important role in stimulating urbanization — although not an indispensable one — whereas changes in population patterns that lead to increasing their size are indeed indispensable for urbanization.

## **1.2 Urbanization and population theories**

Urbanization itself has received marginal attention in the field of demography. Only a few studies associate urban population growth to the vital transition dynamics of mortality and fertility changes. This is indeed because it is difficult to talk about the vital transition without talking about urbanization. The transition itself implies population growth that irremediably leads to a growing urban population (Dyson 2011).

Landry (1934), Kirk (1944), Davis (1945) and Notestein (1945) initially described their conceptualizations of the demographic transition by pointing out the influence of the urban industrial society on the demographic changes. In general, the demographic transition covered the process in which pre-industrial populations — sometimes referred to as Malthusian populations — experienced a shift in their fertility and mortality patterns, specifically from high levels to relatively low and stable ones. Mortality begins to decline and fertility is expected to follow, leading to changes in population growth rates and structure (Notestein 1945). The pace of mortality decline surpassed fertility decline for decades. Urban child mortality was the first to decrease and then a more gradual reduction in adult mortality was recorded. At first, reductions were related to increased knowledge regarding child care, feeding practices, a rise in living standards and better nutrition (Mc Keown 1976; Ripley 2005). Rural-urban migration, for its part, contributes to increasing the number of inhabitants in the cities, especially in the reproductive age group.

Broadly speaking, three different approaches are taken to linking urbanization with the demographic transition. They all underline the importance of the urban space, but differ in their explanations of the process. As said before, the urbanization process could be historically associated with different economic and social transformations all over the world, just as theoretical frameworks call upon specific connotations that are associated with the urbanization process. The

urban space is viewed throughout population theories as: 1) an environment of industrialization and economic growth; 2) a cradle of secular values and modernization, which the literature later refers to as Westernization; and 3) the cause/consequence of the demographic transition.

### **1.1.3 Industrialization and economic growth**

Economic theories link the occurrence of structural economic changes to labor market spatial dynamics. Thus, urbanization is the result of changes in the structure of employment resulting from modern economic growth, and it was driven by the rural-urban migration stimulated by a wage gap between the two areas (Fox 2012). Employment opportunities increased due to the concentration of industries and manufacturing companies in the cities and, consequently, the urban population grew (Jones and Marjit 2003).

The idea in which urbanization and economic growth go together can be traced to Adam Smith (1776). For Smith, bigger and more concentrated markets led to greater economic benefits and possible specialization (Spengler 1976). The cities are places for innovation, opportunity and political transformation (Friedmann 1969), which themselves are grounded in the industrialization process.

In more recent times, the unified growth theory by Galor and Weil (2000) combines the process of economic development with population regimes. This theory synthesizes the historical evolution of the population's response to technology. In its initial conceptualization, it disregarded the spatial aspect in which changes occur (Galor and Weil 2000). However, similar approaches by Zhang (2002), Behrens (2004), and Sato and Yamoto (2005) constructed models in which urbanization plays a major role in the pursuit of development, together with the demographic transition. Economic growth promotes urbanization, and urbanization fosters economic growth.

The direct links between economic development, urbanization and the vital transition came into doubt once countries with developing economies began to experience similar demographic changes in their historical transitions at a much faster pace though without achieving economic development.

### **1.1.4 Modernization and secular values**

In pursuit of other explanations that link urbanization and the demographic transition, cultural and technological diffusion theories have become common in population studies since the seventies. In this view, the urban space is merely a place for developing and concentrating innovation and education, and the urbanization process serves to help both spread. In this framework, Caldwell's wealth-flow (1976) approach and Lesthaeghe's cultural-flow (1977), among others, focused more on "cultural modernization" rather than the material aspects, that were initially used to explain secular shifts in fertility and mortality patterns. Values and behaviors were modified by technological inventions in the cities and later on spread across the whole world (Caldwell 1976). In this sense, changes in demographic patterns are not due to industrialization, but are instead driven by modernization (or Westernization) through the extension of the public education system.

Pichet and Porier (1995) also relied on diffusion theories to point out the importance of the urban areas as places where the industrial classes gather. Diffusion in this sense is through a class

domination system that empowers industrial capitalists, and the city is the privileged space of capitalism (Piche and Poirier 1995).

Another influential approach to population studies was institutionalism, especially around the decades of the eighties and nineties. Analyses made via the institutionalism approach rejected macro-level generalizations linked to demographic transition. In order to establish causation in population patterns, it relied not only on the particularities of institutional, cultural and political structures, but also on how these structures interchange processes and relationships at the macro and micro levels (Greenhalgh 1990; Mc Nicoll 1994). Through this approach, it is possible to see demographic changes at an aggregated international level across various levels of urbanization, once education is considered (Bongaarts and Watkins 1996). To summarize both the diffusion and institutionalism theories, urbanization does not seem to have an important link to demographic transition but instead it does link to the expansion of a public education system that propagates modern ideals

### **1.1.5 Causes and consequences of the vital transition**

Different demographic components have been identified as elements that foster urbanization around the world, depending on the period of time and region. Regardless of the different outcomes found when linking levels of urban growth rates to demographic flows, the occurrence of the urbanization process itself is undeniable.

A first attempt is Wrigley's "urban natural decrease model" (1969). He summarizes how deaths were more numerous than births in European cities, making them graveyards always in need of rural immigrants to maintain their growth. The so-called "paradox of growth" implies that European cities absorbed the demographic growth of rural areas, which otherwise would have become overpopulated rural slums (Oris and Fariñas 2016). Thereby, the starting point of an initial phase in the urbanization process has been linked to two main demographic flows: rural-urban migration and a natural increase in population (Cohen 2006). The importance given to one or the other depends on the context and period of analysis.

Studies influenced by Malthusian theory are more likely to rely on rural-urban migration as the main explanation for urban growth. The rapid population growth in rural areas that resulted in declining living standards acted as a "push" factor (Malthus 1809), and populations thus constantly flowed to the cities. Scholars like Todaro (1979) focused not just on the importance per se of rural-urban migration's added effect on population size, but also on its long-term impact on the general structure of the population through fertility (Todaro 1979).

Conversely, Davis (1965) claimed that the rapid expansion of urban populations is driven by its natural increase (Davis 1965). In this sense, some robust empirical evidence was found by Preston (1979), who pointed out the strong correlation between total population growth and urban growth (Preston 1979), as well as the important role played by the urban natural increase when compared to rural-urban migration. Thus, the onset of the demographic transition itself could be responsible for the overall urbanization process.

More recently, Lee and Reher have argued in favor of demographic changes as a cause rather than a consequence of social and economic changes (Lee and Reher 2011; Reher 2011). They revisited the comprehensive theory of "the urban transition" formulated by De Vries (1990), in which there is causation between demography and urbanization around the world. Following this idea, Dyson

(2011) and Fox (2012) establish urbanization as a consequence of the demographic transition and argue that the orthodox explanation for urbanization is based on economic factors, with migration being viewed only through studies on exceptional cases. Through this approach, they explain how the faster pace of the demographic transition in developing countries — characterized by population growth rates that are higher than historic transitions — ended in higher levels of urbanization. No population has experienced transition from high to low death rates without resulting in urbanizing; and once these populations have urbanized, sustained economic growth may or may not occur (Dyson 2011; Fox 2012). Their hypothesis is that vital transition and not economic growth explains urban transition, since urbanization over recent decades has been happening in places where there is little or no economic growth.

### 1.3 The urban transition and mortality

In an attempt to define a universal model of the spatial distribution of the population, urbanization could be analyzed within a transitional framework in which it is possible to identify successive stages regarding the specific demographic phenomena behind its causation (Moriconi-Ebrard 1993). In its initial connotation, Zelinsky (1971) defined the urban transition as a combination of the demographic transition and the mobility revolution in a particular spatial interaction (Zelinsky 1971). Accelerated urban growth is driven by rural-urban migration that later on will decrease, thus making way for a second stage of increasing natural growth in urban areas. Both process will contribute to the urbanization process (Rogers 1979).

De Vries (1990) argued in his original proposal that the urban transition continues to conflate into a single process what are actually three different processes: urbanization, modernization and industrialization. This is because the original conceptualization assumes the universality of the existing pull and push factors of the labor market, which were introduced by industrialization. In this sense, the model would be suitable only for explaining a one-time phenomenon related to urbanization in Europe. What is more, it implies an equal spatial spreading of the secular values that are responsible for changes in fertility and mortality patterns, without accounting for differentials in urban-rural demographic patterns. Instead, De Vries proposed a “*stylized*” version of the urban transition, which is more in line with diffusion theories and in which the secular values promoting the shift in fertility and mortality patterns may have been mediated by a spatial diffusion gradient. Then, urban and rural differentials in demographic patterns could be explained by the time-paths of their changes within the same country or society (De Vries 1990).

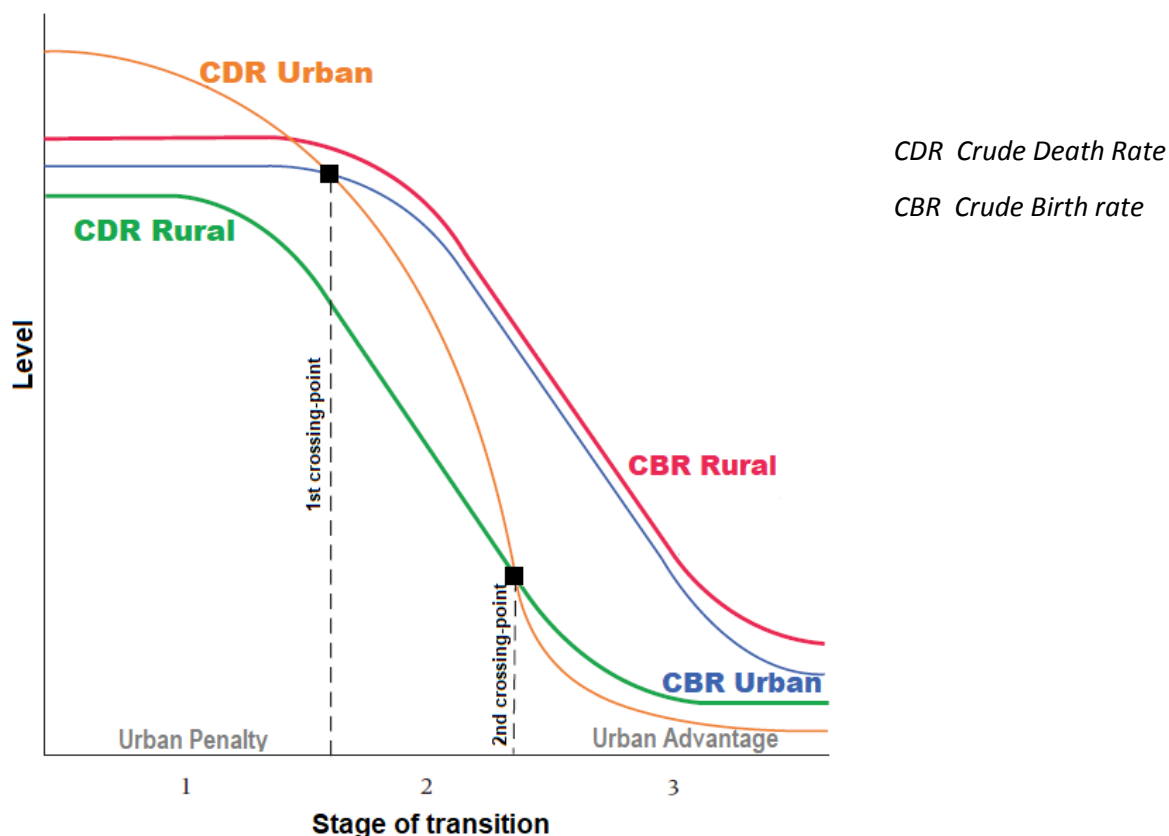
The *stylized version* of the urban transition identifies three phases in the urban growth rate: 1) an initial phase of increase; 2) exponential growth; followed by 3) slowing down to logistic growth. In each phase, there is a corresponding level of mortality, fertility and flow of urban-rural migration. The overall importance of each component varies according to the phases in this model. In general, this model could be applied to all urbanization processes around the world if it is assumed to be a linear continuous process.

Dyson (2011) expands on De Vries’s *stylized version* by placing more importance on the role played by mortality in the urbanization process (Figure 1). He identified a first stage of “urban penalty”: when deaths exceed births and urban growth depends entirely on rural-urban migration. This is observed in urban areas in the pre-transition stage. A second stage is driven by the crossing-point in which urban crude death rates become lower than urban crude birth rates. The crossing is due

mainly to a decline in infectious diseases, which allows urban natural growth and makes urban areas more attractive to migrants. A third stage is characterized by a high net migration in favor of urban areas, while urban mortality reaches lower levels than rural ones. This represents a second crossing-point of the rates in the whole process and the so-called “urban advantage”. Finally, after the decline in mortality in rural areas, the role of migration is further enhanced through population pressure (De Vries 1990; Dyson 2011).

Mortality declined faster in urban areas because urban populations switched from being the most vulnerable to being the chief beneficiaries of advances in medicine and improvements in public hygiene. By controlling infectious diseases, urban populations increase naturally. Once mortality starts to decline in rural areas, the increasing demographic pressure transforms rural migrants into an additional source of urban population growth (Fox 2012). To sum up, controlling infectious diseases is what made it possible to link the demographic transition with the urbanization process.

Figure 1.1 The stylized urban demographic transition



Source: De Vries, J. (1990), Problems in the measurement, description, and analysis of historical urbanization. In “Urbanization in History: A Process of Dynamic Interactions” (eds.) Van Der Woude, A; De Vries, J; Hayami, A; Clarendon Press, Oxford, Pp58. Dyson, T. (2011). The role of the demographic transition in the process of urbanization. Population and Development Review 37 (Supplement), p. 39.

As stated previously, the demographic transition and urbanization in this stylized model are causally related and always occur one after another through the role played by mortality (Dyson 2011). However, a recent analysis conducted by Bocquier and Costa (2015) on Swedish and Belgian demographic historical data differs from this view. These authors point out that urbanization is

more than an inevitable outcome of the vital transition, as affirmed by Dyson and others, but instead that the vital transition can be at different times beneficial or detrimental to urban transition. The link between vital and mobility transitions is interdependent and more likely to be established as a “general-systems approach”, caused not by a direct causal relationship but by a systemic one (Bocquier and Costa 2015).

#### **1.4 Urban bias vs. over-urbanization in mortality**

In European historical transitions, the process of convergence between urban and rural mortality levels (when urban areas caught up with rural ones) was observed up to the 1920s or 1930s at the latest. This period was followed by a long period of either lower levels of mortality in urban areas or at least insignificant differences between urban and rural areas. Nowadays, different relationships have been found between urbanization and mortality at the individual level, especially in developing countries. A 1952 study of 61 countries by the United Nations found a clear inverse association between levels of infant mortality and urbanization, irrespective of the degree of economic development (UN 1952). This relationship has in fact changed as of 2001, when many developing countries were found to show lower infant mortality rates in rural areas compared to urban ones, rather than the other way around (UN 2001).

The uncontrolled and rapid urbanization process has reinforced the incapacity of developing countries to provide public goods and services to all populations; and a bias in favor of or against urban areas has been identified as one of the main spatial inequalities. Whether or not the relationship is linear and causal between urbanization and mortality, two scenarios are possible when transversally linking both processes: an inverse relationship (or urban advantage) versus a direct relationship (or urban penalty). Because the levels of mortality are affected by the quality of the environment and the range of services provided to manage it (Gould 1999), the idea of an urban penalty versus an urban advantage has been present in most subnational mortality analyses (Champion and Hugo 2004). These two antagonistic scenarios are well known in economic, geographic and social theories, where they are referred to as urban bias (urban advantage) and over-urbanization (urban penalty). Both terms have been subject to long-standing discussions in macro-level development approaches to explaining socioeconomic inequalities and spatial gaps in living standards.

##### **1.1.6 Over-urbanization thesis**

The term “over-urbanization” was first introduced by Davis and Golden (1954) to describe countries in which the rate of industrialization grew more slowly than their rate of urbanization. From a clear developmental paradigm, it is meant to explain rapid urban growth in frameworks of continuous poverty and economic stagnation. Davis and Golden used a cross-sectional analysis of the male labor force rate engaged in non-agricultural activities and the percentage of population living in urban areas over 100,000 inhabitants. They set the threshold at half of the male labor force concentrated in agricultural activities in order to determine if countries were over-urbanized or not. Comparing the distribution of rates across countries, they suggest that countries in the early stages of industrialization suffer an imbalance in their population spatial distribution. A high concentration of population in cities was the result of the market’s failures to efficiently allocate labor between urban-rural areas. (Davis and Golden 1954). The glaring defect of developing economies is that they



focus on industrialization and are biased toward strategies for developing a modern urban sector. In this way, they neglect agriculture and promote a depletion of their resources, which in the end will produce either or both stagnation and insufficient economic growth in rural areas (Todaro and Stilkind 1981).

The concentration of the most specialized and better-paid jobs in urban areas stimulates rural-urban migration and, consequently, urban areas that are overcrowded with unskilled rural immigrant workers that are either unemployed or in marginal employment (Gugler 1982). These distortions have made countries unable to provide basic services while the job market fails to grow at the same rate as the urban population. Ultimately, the population's basic needs are unsatisfied in both cities and rural areas (Rogers and Williamson 1982).

This thesis was widely accepted during the 1950s and 1960s to explain why developing countries did not manage to achieve the same level of economic development through urbanization when compared to developed countries. The over-urbanization thesis posits the existence of more push than pull factors that promote rural-urban migration due to increased population, the diminished size of holdings, and absentee landlord exactions (Kamerschen 1969). A posterior revision by Harris and Todaro (1970) postulated that over-urbanization was a consequence of wage-distorting government interventions in the labor market, which thus inflated the wages of a few while raising the expectations of the masses (Harris and Todaro 1970). Rural inhabitants migrated to urban areas despite notable levels of urban unemployment and insufficient basic services, with hopes and expectations of higher future wages (Kelley and Williamson 1984). The lack of readjustments to the labor markets was not because the rate of urbanization was greater, but because of an inability to handle the absolute numbers of people migrating to urban areas looking for better jobs.

Sovani (1964) was one of the greatest critics of the over-urbanization thesis. He questioned not only Davis and Golden's intention to define a "normal" relationship between industrialization and urbanization, but also their efforts to calculate an expected level of equilibrium between the two. He claimed there was indeed no sufficient evidence for the hypothesis that rapid urbanization actually made urban areas worse off (Sovani 1964). Scholars who followed the over-urbanization thesis emphasized later on that "an over-urbanized space is neither tied to an optimal city-size nor can it be specified by a mathematical population limit; but, rather, the population readjusts its capacity according to its economic development goals" (Cohen 2006).

The role played by the cities in developing countries is somehow comparable to the early stages of historic urbanization in industrialized countries, when cities were closer to being graveyards than healthy spaces. The unparalleled industrialization processes inherent to recent urbanizations stagnate the capacity of societies to respond. For developing countries, "this stage is not simply a readjustment period or part of the birth pangs of industrialization that eventually will grow to provide adequately for almost all people (...) rather, it is an outgrowth of a philosophy and failed strategy of development" (Todaro and Stilkind 1981). Consequently, over-urbanization will represent an obstacle to their own development. The pattern of social inequality created by rural poverty, city-ward migration and urban marginality will continue in the countries with developing economies because — rather than representing a problem for the local elites in charge of the government — it allows them to optimize their own power, privilege and profits (Smith 1987).

The increasingly dominant role in the global economy of cities — as centers of both production and consumption — fosters rapid urban growth even more so. In addition, it will seriously outstrip the future capacity of most cities to provide adequate services for their citizens. High demand for

housing and social services leads to a distortion in the pattern of public expenditure:1) it reduces the total public expenditures on services related directly to production; and 2) it imposes a burden on the limited financial capacity of governments (Frankman 1971). It is not only a case of new industrialized countries failing to achieve high levels of aggregate economic growth rates, but also a matter of increasing levels of inequalities in cases where overall growth exists (Smith 1987).

When studying mortality, the over-urbanization thesis has been applied to explain excess mortality in urban areas in some developing countries. Scholars have found that even though developing countries all over the world have built, stocked and staffed their schools, health facilities and family planning clinics while providing housing and transportation services with varying degrees of success; some rural areas remain poorer than ever while various urban areas have become slum-centered poverty spaces filled with crime. The effect of over-urbanization in mortality has been compared to the urban penalty found during the Victorian era in Europe. The spatial proximity of urban residents and their dependence on public resources leave them more vulnerable to communicable diseases than rural inhabitants, who enjoy spatial dispersion as measure of protection.

The current urban population faces, on the one hand, exposure to unhealthy physical environments filled with communicable diseases, and, on the other, a growing problem of non-communicable diseases associated with social instability, specifically mental ill health, violence, accidents and chronic diseases. The co-existence of these two different epidemiological profiles poses a challenge to generalized ideas that the urban areas in some developing countries could be taking the lead in the mortality transition nowadays. Analyses of child and adult mortality by causes of death in Kenya, Nairobi and Burkina Faso provide enough illustrations of the urban penalty faced by many urban poor populations (Rossier, Bassiahi Soura et al. 2014). The same happens to Leon (2008) in a review of hypertension in sub-Saharan Africa, where he found that rates were consistently higher in urban versus rural areas (Leon 2008).

The emergence of cities without planning accumulates inhabitants in extreme poverty conditions and lays the groundwork for different forms of segregation (Dupont and Sidhu 2000; Menna-Barreto 2000). Cities become centers of wealth and poverty at the same time. Similarly, the socioeconomic diversity of the urban population makes it possible for many specialized markets and roles to develop. Urban health providers in the public sector operate alongside a great variety of private-sector providers. These arrangements call into question the ability and willingness of urban residents to pay for their health services; the urban poor who are unable to pay fees remain as dependent on subsidized public-sector services as their rural counterparts do, while the urban rich have access to high quality services (Harpham, Reed et al. 2003). Even, the cost of routine services and amenities are higher in urban than in rural areas, and this extra cost undercuts household savings. The scarcity of public water supplies, for example, forces many low-income urban residents to pay much more for low-price services (Cohen 2006).

Differences in health outcomes according to social strata within and between urban areas start to take on more importance than residential areas. One outcome of the ongoing structural transformation is the increasing recognition of an urban penalty wherein slum residents exhibit notable inequalities in health relative to non-slum residents in urban and even rural populations. The double burden of being affected by communicable and non-communicable diseases is not equally shared by all urban residents, and gaps between social classes establish the guidelines for

dealing with health inequalities, because the health-related characteristics of living conditions in cities and metropolitan areas have different effects on the health of different groups living in the same city (Freudenberg, Galea et al. 2005).

The greater dependence of urban dwellers on household income makes them more vulnerable to economic shocks — which are abundant in developing countries — and to failures in the public health system (Ruel, Haddad et al. 1999). What is more, the negative externalities that accompany life in slums and squatter settlements can magnify the effects of individual poverty (Harpham, Reed et al. 2003). It is expected that health outcomes in cities, especially the largest ones, end up being worse than those in rural areas.

### **1.1.7 The Urban Bias Thesis**

In 1977, Michael Lipton introduced for the first time the Urban Bias Thesis as a framework for understanding economic and social inequalities in countries with developing economies. This approach pertains to the political economic genre and entails a systemic view of development. He identified how most macro- and microeconomic policy initiatives have resulted in an over-development of urban areas and an under-development of rural areas as a product of capitalist economies (Lipton 1977). Meanwhile, distortions continue as a result of trade relationships and the exploitation of natural resources by colonial powers (Preston 1979). The central thesis of the urban bias, which was expanded on later by Robert Bates (1981), focused on how the development process in countries with developing economies is systematically biased against the countryside and deeply embedded in the political structure of the countries, which are dominated by urban groups. As a result, the countryside is economically poor because it is politically powerless (Bates 1981; Varshney 1993). The over-concentration of urban areas is the exact result of an urban bias in public policies that have led to excessive rates of urbanization. Countries with developing economies are unable to satisfy basic needs beyond the urban areas, due to a high concentration of goods and services in cities, especially in their capitals. Thus, the urban setting holds an advantage in terms of living standards and access to services (Cohen 2006).

From an urban research perspective, Castell (1977) also related dependency and urbanization and how urban growth in underdeveloped regions is closely associated with capitalist penetration and expansion (Castell 1977). Thus, ongoing urbanization must be understood as the expression of a colonial/neocolonial phase in which policies promoted hyperconcentration in the largest cities and considerable estrangement between urban areas and the rest of the country (Smith 1987). Along with the initial Urban Bias Thesis and from a society-centered analysis, the social conflict between foreign and national interests consumes developing countries. Beyond the class conflict, the new economic and social structure aims to produce and export basic industrialized goods and thus dominates the former agricultural social structures.

Revisiting his theory, Lipton (in “Urban bias revisited” published in 1984) claimed that urban bias emerges because the rural areas of developing countries suffer from too little expenditure on welfare and huge differences in taxes, salaries and food prices. The related policies have established an unfair gap that affects the population through inefficient distribution of resources (Varshney 1993). Rural workers are paid less than their urban peers and they have to pay twice as much for manufactured goods. What is more, the rise in urban-based middle-class elites in developing countries reinforced and accelerated the urban bias. Once in power, they determined policies leading to city growth and a languishing countryside (Keyfitz 1982). The concentration of

decision makers in the largest cities — especially the capital cities — induces producers and service providers to also locate their businesses in these cities (Todaro and Stilkind 1981). Consequently, price distortions are no longer the main expression of urban bias, but instead they are replaced by expenditure biases (Lipton 1984; Lipton and Ravallion 1993; Eastwood and Lipton 2000). Unlike the over-urbanization thesis, the urban bias theory assumes that wealthy elites, who benefit from the social infrastructure of urban workers more so than the rest of the population, control the governments (Smith 1987; National Research Council 2003). Urban bias therefore becomes evident not only in the provision of education and healthcare resources, but also in the public spending decisions that affect the broader geography of the country.

The spatial concentration of the population allows for economies of scale as well as a greater scope of exploitation in infrastructure investments (Becker and Morrison 1999). Nation states keep promoting scenarios of high population density because it typically implies a lower per capita cost of providing infrastructure and basic services. In the end, despite the high rates of urban poverty found in many cities, urban residents in comparison to people in rural areas enjoy on average better access to education and health care in addition to other basic public services such as electricity, water, and sanitation (Cohen, 2006). Given higher rates of poverty in the countryside than in the city, urban biased policies are constantly transferring resources from the poorest to the less poor.

Since its first iteration, different reviews and criticisms have been made about the Urban Bias Thesis. Furthermore, various stages have been identified in the way that rural-urban economics manifest into livelihood strategies (Jones and Corbridge, 2010). From a demographic perspective, Keyfitz (1996) insisted on the importance of considering urban bias to understand the causes of rural migrations, specifically in the form of cities having more favorable conditions, individuals improving their living standards through migration, and rural areas remaining underdeveloped (Keyfitz 1996).

Undoubtedly, the concentration of goods and services in urban areas is indeed an indication of bias. New economic geography suggests that instead of talking about intentional bias in the reallocations of resources, most cities grow by exploiting the efficiency gains associated with clustering activity. Cities could apply economies of scale and market access through the proximity and dense networks of association. Then, the concentration of goods and services in urban areas is not necessarily a result of an intentional urban bias but rather an efficient allocation of resources. In this sense, “what should matter is not the location for goods and services but that they are available to people living elsewhere” (Jones and Carbridge 2010).

An urban advantage in health for some developing countries is also traceable back to the nineteenth century, when cities started providing social services to the immigrant colonial settlers (Gould 1998). This has remained constant in many countries where the concentration of amenities, preventive programs and medical facilities are focused on urban areas (Oris and Fariñas 2016). The advantages result from a combination of factors. First, absolute poverty and lack of services tend to be mainly rural phenomena. Secondly, urban populations have higher public health coverage rates than their rural counterparts. Thirdly, due to proximity, dissemination and uptake of public health interventions, they are likely to be more effective in an urban setting (Leon 2008). Many conditions that influence health at the ecological level, including community amenities such as good housing is more common in urban than in rural areas. Housing conditions and access to utilities play a particularly important role in explaining most of the rural-urban differences, even more so than

community characteristics. Rural households do not behave so differently from their urban counterparts, but they exist in conditions that are far more detrimental to their health outcomes (Van De Poel, O'donnell et al. 2009). Furthermore, individuals with higher incomes and higher education (factors considered to be robust predictors of health and determinants of lifestyle) are more likely to gather in the cities (Sastry 1997). Recent studies in developing countries carried out by Harpham et al. (2003) showed a clear advantage in urban children's height and weight; through analyzing the consecutive demographic and health surveys of 18 countries, they found strong evidence to indicate that even urban poor children enjoy better height and weight compared to rural children, at least on average (Harpham, Reed et al. 2003).

The underlying differences in socioeconomic and behavioral characteristics between urban and rural settings at the individual and household levels are not indeed driving particular health outcomes, but the concentration of factors results in better outcomes in the cities (Phillimore and Reading 1992; Sastry 1997; Haines 2001; Reher 2001; Zimmer, Kaneda et al. 2007). What is more, urban institutions are better organized and have greater power than rural areas do for getting the support they need from central governments. Cities are in general richer than rural areas, and urban residents can rely on care through insurance programs, have access to qualified medical personnel, and can draw on an array of private health resources.

Even in countries like China and India, where there was some evidence of excessive mortality rates in urban areas compared to rural ones in the 1980s, evidence of convergence is now observed. The prevalence of hypertension, obesity and smoking that was previously associated with urban life styles has been rising rapidly in rural areas. Smoking is even higher now in rural than in urban populations in both countries (Gu, Reynolds et al. 2002; Srinath Reddy, Shah et al. 2005; Wang, Mi et al. 2007).

Nowadays, a complex system of cities challenges the simplified dichotomy of urban-rural settings; cities are normally attached to smaller towns, peri-urban areas and so on, thus expanding their sphere of influence.

## **1.5 Conclusions**

The occurrence of the urbanization process itself is undeniable all over the world, whether in historic or recent times. Differences between historic and recent urbanization are due to the exceptionally rapid overall population growth in recent times because of technologies, expanded welfare systems and the spread of secular ideas, along with the recently decoupled relationship with economic development. The onset of an urban transition should therefore be understood as part of a global historical process linked to the changes and diffusion of technology and institutions, not simply as a product of endogenous economic and demographic forces (Fox 2012).

Mortality decline has occurred in different societies in diverse ways as well. The conditions that influenced the decline were variable in terms of diseases, improvements in nutritional status, public health measures, and the deployment of public utilities infrastructures, among others. In order to construct a broader causal explanation, population theories have established inverse and direct links between the urbanization process and urban-rural differential in mortality. It depends on how the urbanization process advances and how the economic development convey with the urbanization process. In a scenario of decoupling urbanization from development, two outcomes

could be found regarding urban-rural differential in mortality: an effect of over-urbanization (urban penalty) or urban bias (urban advantage).

Both urban advantages and penalties are found in recent years when analyzing mortality in developing countries. In South Asian countries, for example, a rural mortality disadvantage is recorded during infancy and early childhood (Saikia, Singh et al. 2013); while at the same time Burkina Faso shows an urban disadvantage in adult mortality (Rossier, Soura et al. 2016).

In this sense, urban (dis)advantages in mortality may indeed not be different stages of a linear process, as suggested by the urban transition. Once economic and development strategies are considered, urban (dis)advantages may be the outcome of resource re-allocation and livelihood strategies applied by developing countries as a reaction to their rapid population growth and urban concentration. A key element for understanding the urban-rural differential in health outcomes relies on the importance given to cities in the macro-level development strategies that countries implement. The following chapter is dedicated to describing the urbanization process in Latin America, its historical approaches to development and its demographic outcomes.

## 2. URBANIZATION IN LATIN AMERICA

Since the beginning of the twentieth century, the population of Latin America and the Caribbean has increased tenfold: first, from 60 million to 161 million in 1950, then up to 622 million in 2018, while the annual growth rate decreased from more than 5 percent in 1950 to less than 2 percent after 2010. The region nowadays represents 8.5 percent of the world's total population (ECLAC 2011; UN-Habitat 2012). The growth was mostly concentrated in the urban areas; and in a period of about 50 years, Latin America went from predominantly rural to predominantly urban.

The urbanization process in most Latin American countries has been awash with incipient industrialization. At the same time, two demographic phenomena occurred: 1) a faster decline in mortality rates compared to fertility rates, which have led to a natural growth of the population; and 2) a strong rural-urban migration that has concentrated the populations into the cities. This chapter aims to summarize the elements that characterize Latin America's urbanization process. It begins by describing the development approaches historically applied in the region and their consequences for the current city system, as well as the effect of urban bias on the overall resources allocation. In order to do so, this chapter is divided into seven sections. The first section summarizes the path of the urbanization process in Latin America, while the second one looks over the heterogeneity found in the region.

The third section reviews the different development approaches adopted since the second half of the twentieth century in the region, and their implications in the configuration of the urban-space. The fourth section explains the current city systems and the prominence of the metropolization process. The fifth section aims to summarize the evidence of urban bias in Latin America, how it is observed, how it could be measured in the region, and if there is evidence of it in mortality patterns. Finally, a brief conclusion is provided.

### 2.1 The urbanization process in Latin America

Throughout the nineteenth century, the levels of urbanization in Latin America and the Caribbean were lower than in North America, Europe and Oceania. The minority of the population living in cities was concentrated in single cities, usually the country capitals (Merrick 1995). Later on, a fivefold increase is estimated to have occurred between 1920 and 1960 in the Latin American urban population. During this period, while rural and small town populations (less than 20,000 inhabitants) increased by just two and a half times (Rowley 1976), the population living in cities exceeding 500,000 inhabitants increased from an estimated 12 million to 35 million.

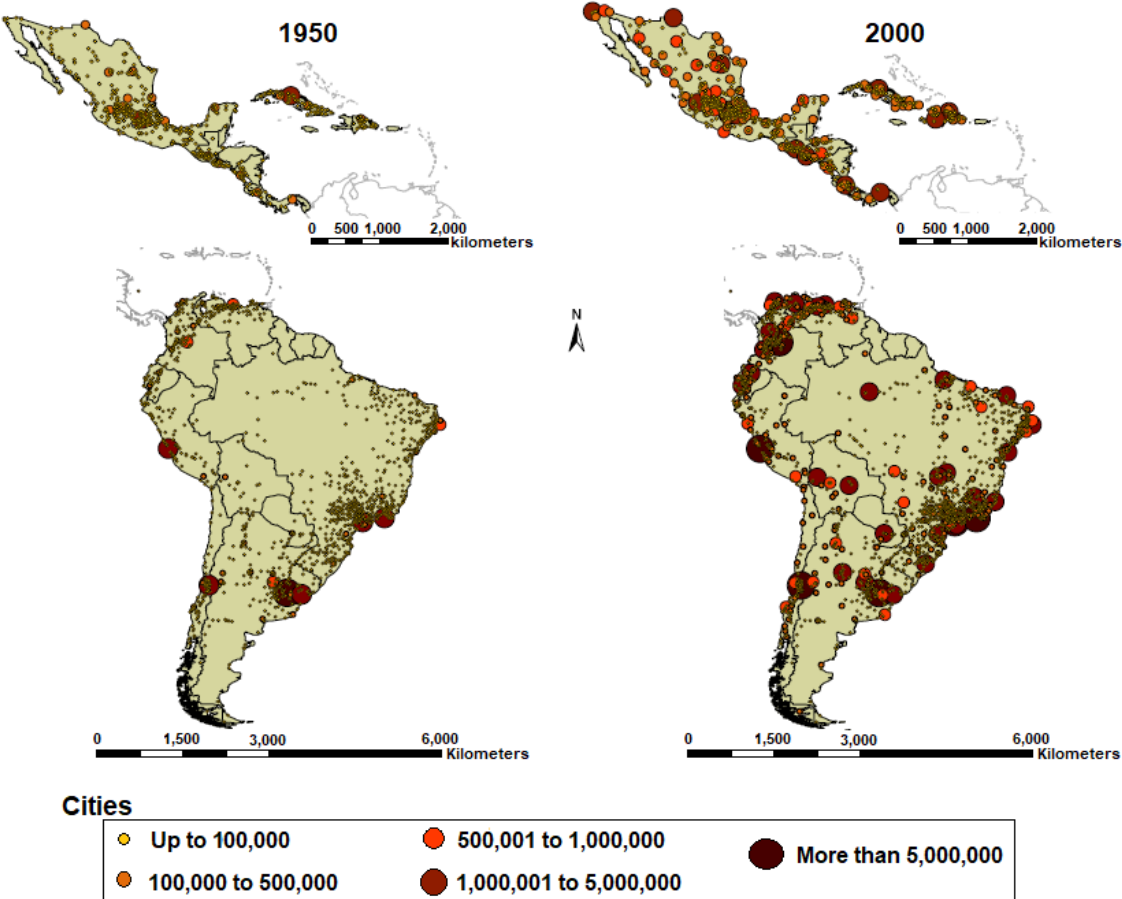
In Brazil, Mexico, Colombia and Venezuela alone, the number of cities with over 500,000 inhabitants increased from 3 in 1940 to an estimated 18 in 1970 (Frankman 1971). The massive growth of these big cities increased the proportion of the continent's urban population from 42 percent to 58 percent (Rowley 1976). This rapid urban population growth was due to a real migration revolution, a rural exodus that generated explosive urban growth (Da Cunha and Rodríguez 2009). Most of the rural migrants bypassed the small cities and migrated directly not to just any big city but to the capitals (De Oliveira and Roberts 1996). Caracas, for example, increased its population by nearly 200 percent between 1950 and 1961, while Lima showed an increase of 286 percent between 1940 and 1961 (Dufour and Piperata 2004).

The factors driving this rural-to-capital-city migration were the large-scale commercialization and mechanization of agriculture, the development of more export-driven economies, and industrialization. Transformations in both society and economy were the result of an “import substitution” strategy that most Latin American country governments promoted to encourage urban activities and favor the “modernization” of countryside investments (Da Cunha and Rodríguez 2009). All together, these processes reduced the demand for farm labor and created greater demand for labor in urban centers during a period of natural population growth in rural areas (Greenfield 1994). Movements from the countryside to the cities continued from the 1970s to the 1990s, and rural populations started to shrink in absolute terms. Migration, however, diversified from this period on; it was more concentrated among small- and intermediate-sized cities, which tended to grow more rapidly than the very large metropolises (Dufour and Piperata 2004).

By the year 2000, most Latin American countries had already achieved urbanization levels (urban populations of around 77 percent) that were closer to Europe than to Africa or Asia (40 percent urban populations, on average). During the first decade of the twenty-first century, urbanization levels finally caught up to North American levels as well as those of many European countries. In this point, the rate of urbanization started to slow down to less than 2 percent, a figure that corresponds to natural population growth (Cohen 2006). Between 1950 and 2000, the region grew from 314 to 1,851 cities with more than twenty thousand inhabitants (see Figure 2.1), with these cities being concentrated mostly in the coastal areas and following pre-Hispanic settlement patterns.



Figure 2.1 Latin American and Caribbean cities with over 20,000 inhabitants, 1950 and 2000



Source: Compiled from data provided by the Latin American Demographic Center for the United Nations Economic Commission for Latin America and the Caribbean CELADE-ECLAC, UNDESA and national censuses.

The slowing down in the growth rate for most countries occurred because of the ongoing demographic transition and the reduction in emigration from the countryside (Da Cunha and Rodríguez 2009). Average fertility rates in the region declined from 5.8 children per woman in 1950 to 2.09 in 2010; and life expectancy over the same period rose from 51.4 to 74.5 years. Urbanization and the demographic transition are closely related in most Latin America countries; the most urbanized countries in the region are the most advanced in the demographic transition (Villa and Rodríguez 1994).

The region’s urbanization is virtually consolidated, and 80 percent of the population is living in urban areas around the year 2010. After the first decade of the twenty-first century, the evolution of the urban population tends to be limited to natural growth and is incremented only by the migration between cities, the growth of secondary cities, and the emergence of mega-regions and urban corridors. The patterns of capital city primacy remain important in just a few countries such as Argentina, Chile, Panama and Uruguay, where over 40 percent of the populations live in the capital city metropolitan areas; while in other countries of the region, much more complex city networks cover their national territories.

Nowadays, 14 percent of the region’s urban population lives in megacities with more than five-million inhabitants. Around 25 percent lives in cities whose populations are within a range of five hundred thousand to less than five million inhabitants, and more than half of the urban population lives in cities with less than 500,000 people. All of this translates into a renewed urban dynamism in which more than two-thirds of the region’s wealth comes from cities. What

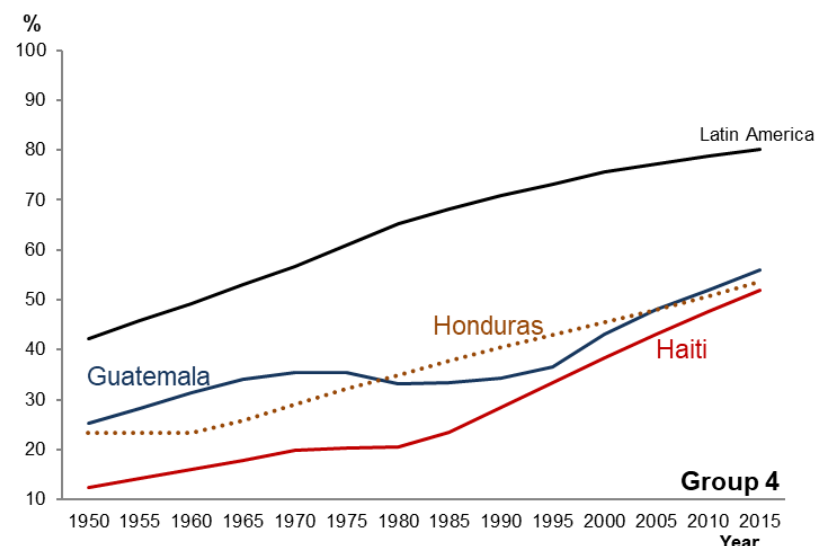
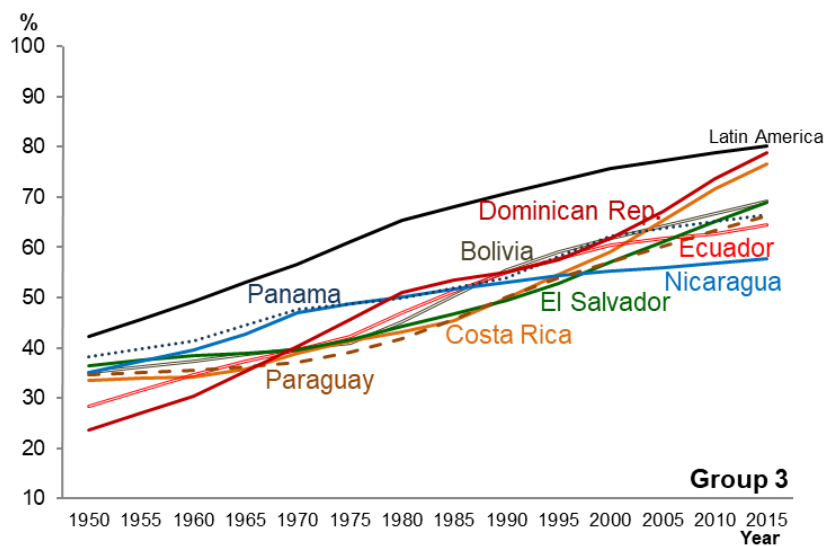
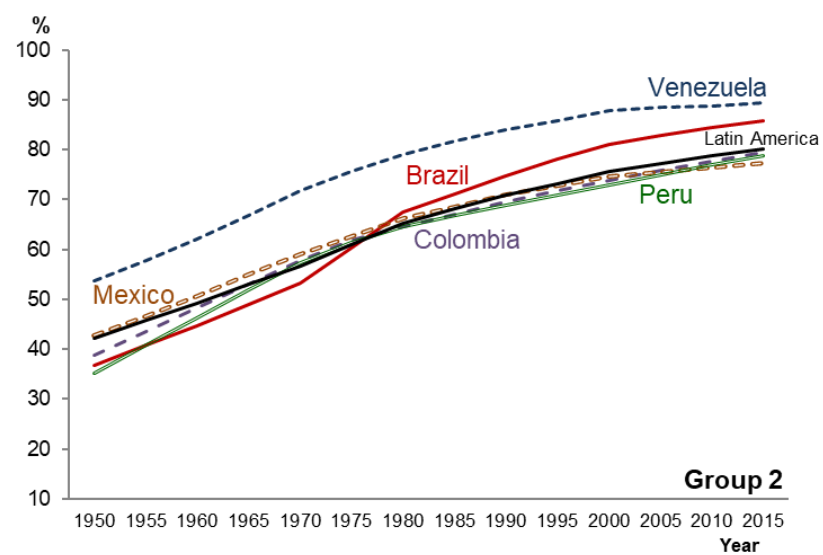
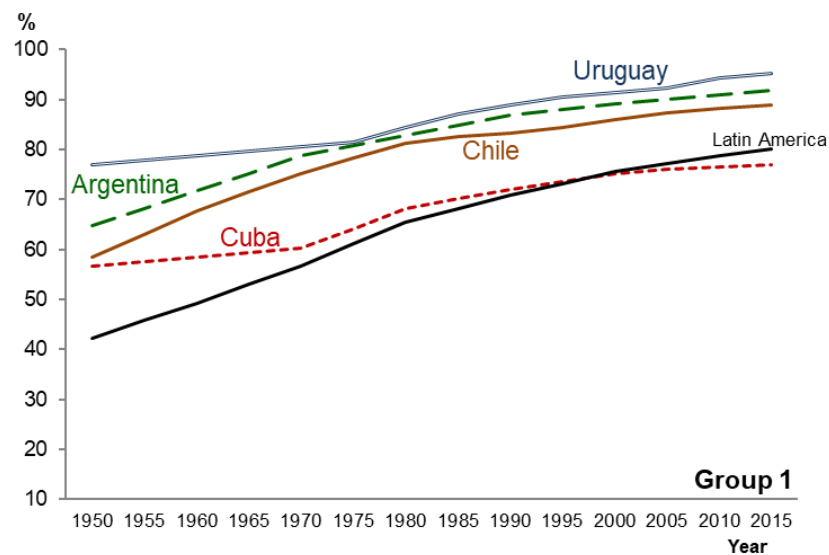
is more, although most of the added value is still concentrated in a handful of large metropolitan areas, the range of cities that contribute to that wealth has been extended (UN-Habitat 2012). The decreasing importance of Latin American capital cities has not been a process of de-metropolization or demographic de-concentration, but rather a diversification of several metropolises.

## **2.2 Regional heterogeneity**

The high level of urbanization is an unquestionable fact all over the region. However, the process did not proceed homogeneously through time and space across the Latin American region. If countries are considered separately, one can perceive great heterogeneity in the stages of the urbanization process. Four different groups of countries can be identified according to: 1) their process of urbanization; 2) the final urban population proportion achieved in 2015; and 3) their settlement patterns (see Figure 2.2).

The first group is Argentina, Uruguay, Chile, and Cuba, which are countries with early urbanization and where during the first half of the twentieth century their urban populations had already reached around 50 percent or more. The rate of urban growth started to slow down after the seventies; and by the year 2015, more than 85 percent of their population was urban. Cuba presents some differences from the group, despite starting with high levels of urbanization at the beginning of the period. Only 78 percent of Cuban population in 2015 lived in urban areas. Even before the 1980s in these countries, more than half of their populations lived in cities larger than one hundred thousand inhabitants. Still more, a great concentration of their populations remained in the capital city metropolitan areas during the entire urbanization process. It means that the urban growth exhibited was mostly due to the growth of the capital city.

Figure 2.2 Percentage of urban population



Source: CEPALSTAT. Compiled with data from the Latin American Demographic Center for the United Nations Economic Commission for Latin America and the Caribbean

The second group comprises Brazil, Colombia, Mexico, Peru and Venezuela, where urbanization occurred later but a more accelerated rate. In the 1950s, at least 35 percent of their populations were considered urban; and in 2015, between 70 percent and 80 percent of their total populations lived in urban centers. Venezuela was something of an exception, as their accelerated rate of urban growth ultimately led to an urban population with levels similar to the first group (an urban population of 87 percent). For these countries, the slowing down of their urban growth rates occurred after the 2000s. A predominant characteristic of this group is the demographic deconcentration process of their capital cities, especially in Brazil, Venezuela and Mexico. These countries more clearly diversified their metropolises during their urbanization process, and a network of big cities was created across their territories.

Bolivia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Nicaragua, Panama and Paraguay, form the third group. These countries had around 30 percent of their populations living in urban areas in the 1950s. Their urbanization rates are the highest in the region, without any periods of slowing down until 2015. Two main paradoxes may be seen in this group. First, Bolivia exhibits a degree of urbanization superior to other countries, without indicators of greater economic prosperity. Second, the estimated urban percentage of Costa Rica is lower than what can be expected from their degree of socioeconomic development (Rodríguez 2002). Most of the countries in this group have less than 50 percent of the urban population living in settlements of over one hundred thousand inhabitants in 2015.

Finally, a fourth group is comprised of Guatemala, Honduras, and Haiti, the least urbanized countries and the ones showing the most rapid increases in urbanization, with growth rates of over 2.5 percent throughout the period. These countries still maintain urban population levels of around 50 percent in 2015, with less than 30 percent of their populations living in urban centers of over one hundred thousand inhabitants.

When one look at the variety of stages in the demographic transitions among these countries, it is possible to find that they are somehow related to the levels of urbanization achieved by the countries. Generally, the countries that experienced early urbanization (first group) also experienced an earlier demographic transition decades before. In contrast, countries with a temporary lag in urbanization are still in the early stages of the demographic transition. One exception is Venezuela, which at the end of the twentieth century is among the most urbanized countries in the region; but its demographic transition is less evolved than that of the other advanced urban transition countries.

### **2.3 Urbanization and development in Latin America**

Before the twentieth century, the spatial population distribution in Latin America was due largely to the development of pre-Hispanic settlements. A high concentration in the capital cities and seaboard areas are historically recorded in most of the countries, and these were a response to economic development oriented toward the external markets that were established by the colonial system of administration. The Latin American countries exported primary goods in exchange for manufactured products. The state functioned in a classical liberal style, so its functions were reduced to external security, maintenance of internal order, and ensuring the conditions for fulfilling contracts (ECLAC 1996). It is only in the twentieth century that a real process of urbanization began. The initial phase of this process was not

concomitant and synergetic with industrialization and economic development, as its evolution was partially detached from economic, social and institutional progress (Davis and Casis 1946; Hoselitz 1957).

Different economic and social paradigms have mediated the relationship between urbanization and development throughout the direct public policy and social changes that occurred during the twentieth century. In a context where the processes of industrialization, urbanization, modernization and development have become intertwined, the literature highlights at least three broad stages of socio-economic policies shaping the role of the Latin American city: 1) the period that imposed import substitution policies in the mid-twentieth century; 2) the neoliberal economic policies during the eighties; and 3) the rise of populist nationalism at the beginning of the twenty-first century.

### **2.3.1 The import substitution policies**

*The imposition of import substitution policies* and the development of incipient industrial sectors among the region's largest economies characterized the two decades that followed the end of World War II in Latin America (Frankman 1971). Economic theories formulated during the 1950s and the 1960s were meant to modernize the countries, placing industrialization at the center, regardless of ideological orientation or political regimen. Rapid industrialization was considered the only model for economic development, and an inevitable part of this industrialization process was urbanization.

The direction of import substitution policies into producing manufactured goods rather than raw material tended to be situated in consumer centers, i.e., large urban centers. The intentions were to replace economies driven by the extraction and exportation of raw materials with economies driven by industrial production. The final goal was to increase industrial production enough to supply the internal market without needing to import manufactured goods. Rechanneling economic development called for even greater state intervention, which was extended to: 1) supply social security services to alleviate social inequalities; 2) ration the very limited supply of foreign exchange; and 3) create state sources of credit (Council 1959). All these interventions underscore the concentration of power in the cities.

Similarly, urbanization was believed to be a necessary and desirable by-product of modernization, and most governments directly or indirectly encouraged the growth of cities (Todaro and Stilkind 1981). The urban explosion in most Latin American countries was due to new industrial development, expansion of the secondary sector, and the feebleness of the agricultural sector. These changes were at the beginning driven mostly by national governments. In fact, 40 percent of total fixed capital investment in the whole region during the fifties was made by the public sector.

The fast urbanization process during the period of import substitution policies led to the depopulation of rural areas and an even stronger concentration of populations in the largest of the large cities, usually the capital. The transformation of the urban landscapes of Mexico City, Buenos Aires, Bogotá, Havana, and Caracas raised awareness of not only urban planning, but also of regional planning in Latin America (Baeninger 2002). In an attempt to balance the incipient industrialization, agrarian reforms were made in most of the countries during the 1960s and 1970s. The consistent outcome of these reforms was an increased influence of the state on economic and political conditions in the rural areas (Grindle 1986). It also facilitated

capital penetration into the rural sector, which increased social differentiation and manifested into rapid rural proletarianization (Redclift 1984).

In a second stage, while the urbanization process led to populations concentrating around the main cities in almost all countries of the region, some countries engaged in moving rapidly toward development and other dimensions of modernization by creating new industrial cities, such as Manaus in Brazil and Ciudad Guayana in Venezuela (Smith and London 1990). Along the same lines, a deconcentration of the larger cities was also implemented; the industrial areas were moved and enlarged to the peripheries of the cities, thus expanding their areas of influence.

The adverse effects on development attributed to rapid urban growth during the time of import substitution policies was seen in the form of outpacing increases in agriculture production, which degenerated into an increase in food imports — the exact opposite outcome of what was expected. The slow modernization of the agriculture sector due to lack of private and public investment and subsidies, together with land tenure systems based on large latifundia, devolved into the relative stagnation of food production (Council 1959; Gugler 1982). The growth of agricultural production in Latin America failed to keep pace with that of the population, even though this was necessary for the countries to make heavy inroads into achieving exportable surpluses.

Labor became redundant in the rural areas and failures in the agrarian reforms left most of the rural population without access to land, either because of institutional barriers or a lack of resources for opening up virgin land (Gugler 1982). In the process of rural modernization, some countries switched from patronage to business systems. The social category that expanded during this period was a rural proletariat dependent on salaried seasonal work. The lack of stability created by the temporal discontinuity of their work made it difficult to create laws for labor relations when hired by latifundia. In the same way as when working on a small family farm, the possibilities for articulating workers' interests and their possibilities for social representation were minimal (Chackie and Villa 1993).

Bad conditions in countryside living standards kept promoting high rural-urban migration flows, which outpaced the ability of industry to absorb the growing work force. The magnitude of the disparities between the earnings of the rural and urban population (which on average was triple) led to a huge mass of unqualified workers moving to the industrialized cities in flows that were faster than the rate at which the developing industrial sector was increasing. In the end, rural agricultural unemployment came to be transferred to urban unemployment (Frankman 1971).

In terms of socio-economic development, this period was characterized by “chronic insufficiencies and imbalances in public services, the employment market, transportation and housing, in particular for the most vulnerable strata of the population” (Atria 1975). The import substitution model's limitations in fully developing the region's industrial sector led to the growth of shantytowns and a culture of marginality that accompanied the rural to urban migration. The mushrooming growth of shantytowns is regarded as a response to urban growth under historically unprecedented conditions, whereas “shantytowns were previously somewhat similar to the extra-mural housing developments of early pre-industrial European towns, which were settlements for the poor outsiders as opposed to the intra-mural settlements of the political and cultural elites” (Rowley 1976).

The initial overgrowth of the cities on mainly self-built housing began to be a public concern, and nation states started to develop strategies to improve housing quality and to expand public facilities into existing shantytowns. Either by funding new constructions or replacing precarious housing, impoverished neighborhoods became formalized. The governments' major role in such housing schemes was to create a favorable environment for the full development of self-built initiatives for the urban poor, which became characteristic of the 1970s and much of the 1980s. This implied a major break from the earlier period, when state intervention meant evicting the inhabitants from their spontaneous settlements and clearing away their provisional shacks (van Lindert 2018).

In the end, there was a gradual transition from an agrarian economy to — not exactly a fully industrial society — but to a service and informal economy, which impeded economic expansion (Bradshaw 1987). The urbanized Latin American labor force was not quite engaged in manufacturing but in an impromptu urban tertiary sector (Todaro and Stilkind 1981). The income distribution turned out to be more unequal in cities than in rural areas, and the marginal areas of the cities were far from being a homogeneous group but were instead marked by a wide variety of occupational statuses and living standards.

In the regional economic narrative, the failure of the import substitution policies was systematically attached to the inefficient state interventions in economic life. Regional states became the greatest redistributors of income during the period of faster urbanization in the region. Latin American economies were funded by policies that led to large macroeconomic imbalances and hyperinflationary phenomena. Public investments mounted excessive external debts and later led to the well-known debt crisis (ECLAC 1996).

### **2.3.2 The neoliberal economic policies**

The *neoliberal economic policies* emerged as a prescription not only for the region's economic stagnation during the "lost decade" of the 1980s but also for the failure of the import substitution policies period. In response to the regional economic narrative, in which inefficient state interventions in economic life drove the economic stagnation, nation states were forced to reduce public investment, start a sweeping wave of privatization, eliminate taxes, and reduce inflation rates. In some countries the policies worked, while in others they increased poverty levels.

The neoliberal economic policies had a particularly hard effect on the largest cities in the region. Cuts in social investments and public services employed to alleviate socio-economic inequalities, particularly in the cities, were carried out during this period in response to the "debt crisis". The impact was such that, by the end of the 1980s and the beginning of the 1990s, the levels of urban poverty had increased considerably and a number of cities faced critical conditions (Da Cunha 2002; Rodríguez 2002). Several countries in the region proceeded with reforms that transferred the execution of certain stages of the implementation of social policies to the private sphere. Social security was one of them, for example. Chile, Argentina and Peru changed their legislation and made private companies become providers of health services and administrators of pension funds (ECLAC 1996).

In parallel, and under the influence of the postulates proposed by the dependency theory, the center-periphery relationships at both the global and intra-national scale came to serve as explanations for the previous urban macrocephaly (Cuervo Gonzalez 2017). The resurgence of strategic planning and widespread administrative reforms aimed to decentralize both power

and decision-making; and the entire region experienced increased access to public resources as well as the continued growth of urban centers, especially of secondary cities (Baeninger 2002). Some small- and medium-sized cities underwent accelerated growth due to large-scale industrial investment, but the “decentralization of competencies was not always accompanied by the transfer of governance resources and capabilities. Few local governments succeeded in financing themselves and most of them continued to depend heavily on the central government. Sufficient capacities were not created at the local level, nor did the regulatory mechanisms make it possible for local authorities to increase their budgetary, financing or investment capacities” (UN-Habitat 2012).

The largest cities continued to be better positioned on average, but were under threat of facing deeper social and income disparities. The trend toward a decreasing importance of the capital city — defined by their proportional contribution to the national GDP originated during the import substitution policies period, but this was either stopped or reversed in most of the countries (Cuervo Gonzalez 2017). The peripheries of the largest cities began to lose any advantages at the expense of the recent consolidation of secondary industrial metropolises and agro-industrial regions; but most of these areas eventually suffered their own severe setbacks because of the accelerated deindustrialization and the privatization waves of the 1980s and 1990s (Piña 2014).

### **2.3.3 The populist nationalism**

Discontentment with the neoliberal model of economic development and globalization promoted the rise of populist nationalism in many countries during the first decade of the twenty-first century (Baeninger 2002). During this stage, important structural changes occurred in Latin America. Namely, domestic economies became integrated into the world’s economy and public programs were implemented in order to reduce poverty levels and to improve infrastructures and economic recovery, all measures that were especially notable in comparison with the previous decade.

An economic bonanza resulted in rising oil and gas prices, as well as in new commercial partnerships at international levels. The governments of several countries increased their incomes through taxes and/or royalties, and these in turn contributed not only to financing public social spending and reducing the poverty levels of the countries in the region, but also to lowering levels of external public debt. In general, the policies implemented were less severe in the cities and thus invalidated the catastrophic projections made at the beginning of the 1990s. The economic content and functions of the primate city were profoundly transformed. The predominant trend was to reduce industrial economic activities and consolidate the tertiary functions of the big city (Da Cunha and Rodríguez 2009; Cuervo Gonzalez 2017). The transition of the productive base from an industrial base to a mixed base led to a labor market that was clearly distinguished by a large service sector in the cities. In 2000, the industrial sector contributed less than 16 percent to urban employment while service workers were more than 33 percent. In this context, the informality of employment continued to be one of the main challenges to the economies of the region (Montero and Garcia 2017).

The decline in inequality became quite widespread after 2000. In general terms, the previous period of increasing inequality (1990 and 2002) was reversed during 2002 to 2010 (ECLAC 2014). This reduction was strongly influenced by large-scale public programs of direct cash transfers to households and a reduction in labor income inequality, the latter of which is



associated with more equal access to schooling. A general change in the distribution of resources was seen, and public spending began to target the poorest populations (Lopez-Calva and Lustig 2010).

Although recuperation has presented oscillations and has not yet reduced the great inequality, it has allowed for increasing investment levels, thus promoting a physical expansion of cities that outpaces their demographic growth. Most of the growth observed in urban populations over the past few decades (as well as that which is projected to occur up to 2030) has been in small- and medium-sized towns and cities of fewer than 1 million inhabitants. The largest cities in the region remain dual, divided, and segregated in both spatial and social senses because the initiatives to combat poverty have not eliminated inequality. High urban income inequality coefficients and informal settlements persist, but the proportion of the population living in slums has fallen over the past decades (UN-Habitat 2012). The image therefore of contemporary urbanization being one of ever expanding megacities and dystopias with sprawling slums is nowadays misleading and incorrect (Leon 2008).

In summary, the urbanization in Latin America that was initiated as a concentration and centralization process around capital cities has without a doubt worsened the unequal geographical development and exacerbated the social economic and spatial inequalities. Large industrialized cities that have either emerged or been expanded were delineated to maintain the exploitive relationships with the rural areas, and the process of economic growth from urban to rural areas was presumed to trickle down to the countryside by intentional and unintentional governmental policies.

Urbanization took place in the sense of both spatial concentration and the "diffusion" or penetration of urban life modes beyond the geographic space of cities. Social stratification, the distribution of income, employment and the prevailing modalities of political participation have manifested themselves in rigid responses to the demands of the new urban groups and layers. The pressures generated by the rapid centralization of power into the hands of the urban elites have reinforced the demands of most organized urban groups that state policies distribute public services in their favor (Atria 1975). Once the supremacy of the cities was established, problems derived from uncontrolled urbanization set the framework for social inequalities within the same urban space. The demographic growth of peripheral areas, with less accessibility and infrastructure, aggravated the impacts of urban poverty in Latin American.

At the end of the process, urban concentration, agglomeration economies, and the expansion of built-up areas related to urbanization have helped stimulate economic growth and development in the regions (Chen, Zhang et al. 2014). The cumulative deficit in infrastructure, resources and regulations have led to the urbanization and functionality of Latin American cities becoming distinguished by poverty, precariousness, informality and anomy; yet, it is also undeniable that, on average, the most urbanized Latin American countries tend to have the highest levels of development (Da Cunha and Rodríguez 2009). What is more, among the most urbanized cities, those with the highest levels of primacy for their capital cities have the highest levels of human development in the region.

Since the mid-twentieth century, a clear relationship has been observed between the level of urbanization and social economic development that is achieved — regardless of the size, population density, or territorial extent of each country, and not even of the ideological tendency or political regime adopted. There are only two specific countries where there is a

clear separation between urbanization and socio-economic development: Costa Rica, with a very low degree of urbanization for its human development index; and Venezuela, with a very advanced urbanization for its human development index. These are suggestive of the partial autonomy for both processes (ECLAC 2012). Even though throughout the entire urbanization process Latin American economies have been primarily exporters of raw materials and basic manufactured products, urban activities have not necessarily generated more resources than rural alternatives, especially when considering the abundance of natural resources (Mc Milan and Rodrik 2011). The over-importance of the urban space is related more to the development of tertiary sector activities and to resource re-allocation in public policies than it is to real production.

Urbanization has caused huge transformations not only in the spatial relocation of the population between rural and urban areas, but also between cities and regions. Nowadays, one out of three Latin Americans lives in a city of a million or more inhabitants (Da Cunha and Rodríguez 2009). In this sense, it turns out to be more convenient to focus not just on the direct association between urbanization and development in the region, but on how the urban functions that have spread over larger geographic areas have also changed the traditional distinction between urban and rural areas by creating a more complex city system (Cohen 2006) — in particular, with the diversification of the metropolization process initiated during the second half of the twentieth century.

## **2.4 Current city systems and metropolization**

Fundamental demographic variables play positive roles in the process of modernization in Latin America. To identify these roles, the demographically defined modernization process must be considered together with the implications of some aspects of the urban hierarchy (Browning 1967). In this sense, it is necessary to review the importance of the metropolization process for the Latin American urban hierarchy. The word metropolization has been used to denote several processes: on the one hand, it refers to the multiplication of urban areas (Ascher 1995); and on the other, to the increasing size and densification of the existing cities (Veron 2006). Latin America's urbanization process has always been characterized by a concentration of population in just one or two major cities dominating the rest, which also usually monopolize the wealth as well as not just the socio-economic and administrative functions but also even the political capital (Herrera and Pecht 1976; Rowley 1976).

Internationally, only Oceania surpasses Latin America in the average percentage of people living in the main cities. However, the metropolization process in Latin America has turned out to be compatible with a system of human settlements in which there are abundant urban poles. The two most populous countries in the region, Brazil and Mexico, contain the two largest cities in the region: São Paulo and Mexico City, respectively. These clearly illustrate the existence of urban systems that combine gigantic cities with urban networks (Villa and Rodríguez 1998). In recent decades, small- and intermediate-sized cities, where most of the urban populations live, have grown at higher rates than the largest cities, thus rebalancing the hierarchy of cities in the region and leading to greater diversification (UN-Habitat 2012).

The new importance of migration between cities is undoubtedly a strategy for population redistribution. This has meant that many cities have spilled over into their municipal administrative boundaries and absorbed other urban centers in a conurbation process. The growth of intermediate-sized cities has enhanced their competitiveness and attractiveness as

places to live, which has generated other processes of hidden urbanization (Piña 2014). The result has been “the emergence of urban areas that have a large territorial size that is sometimes formalized in a metropolitan region and comprises many municipalities, with intense activity occurring across all fields” (UN-Habitat 2012).

Nowadays, three major configurations of population distribution must be distinguished in the Latin American region, particularly in regard to the demographic importance of the largest cities: 1) monocentric, which means a high degree of demographic concentration in the main cities (such as Peru, Chile, Argentina, Uruguay, Paraguay and most of Central America); 2) bicephalic, in which populations are concentrated in two large cities (as in Bolivia and Ecuador); and 3) polycentric, which is an urban system with numerous articulating nodes that counterbalance the main city (such as Brazil, Venezuela, Colombia and Mexico). These groups have not evolved in the same direction. Brazil’s and Mexico’s great metropolises stopped growing, with the first case being because Sao Paulo’s periphery deconcentrated and its general urban network differed from the urban primacy experienced by other Latin American countries (Villa and Rodríguez 1994; Baeninger 2002). In the Mexican case, metropolitan expansion occurred as a result of basic manufacturing industries deploying along the USA border, thus deconcentrating the capital city. At the same time, Colombia and Chile accelerated the expansion of their larger cities, thus enlarging the demographic and economic weight of the major metropolises (Cuervo Gonzalez 2017).

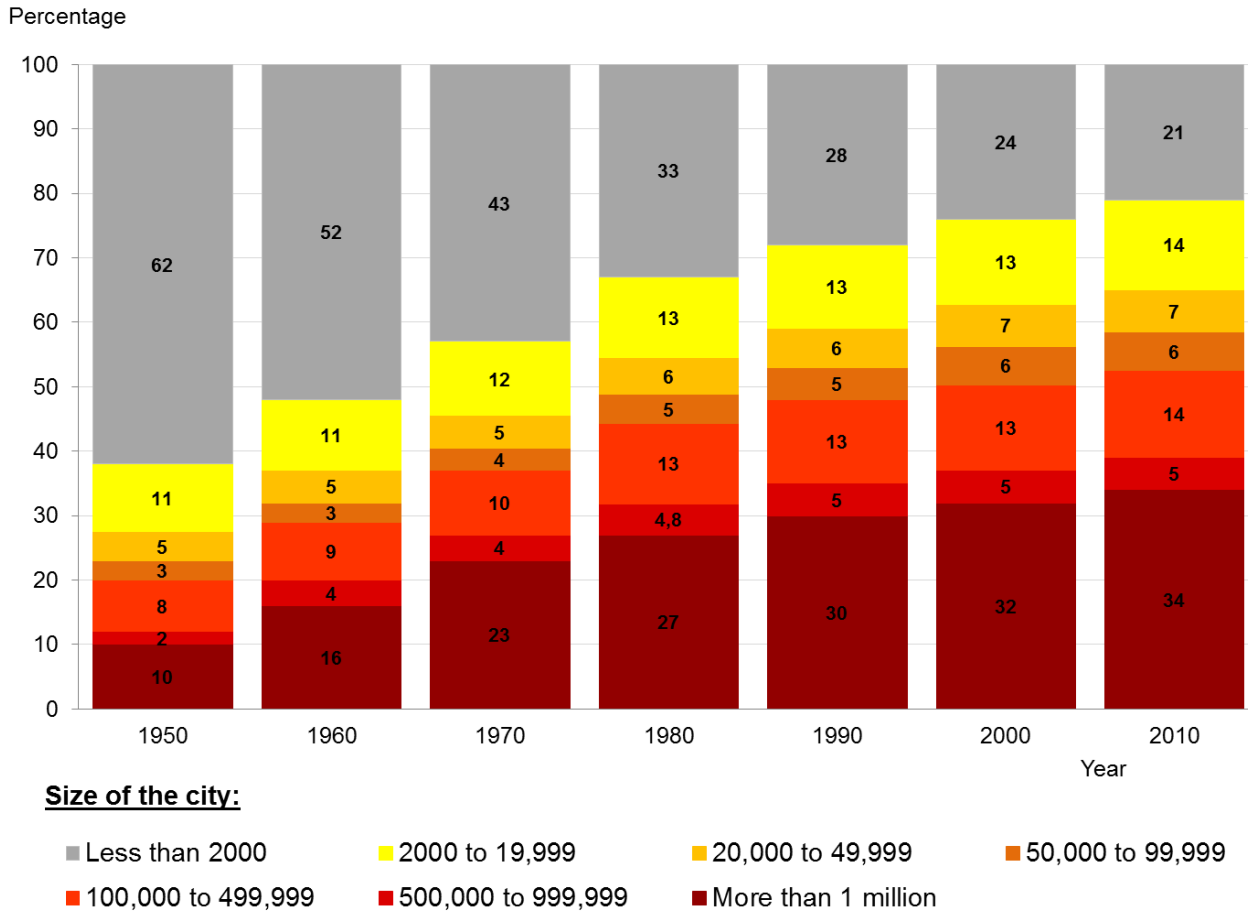
Metropolitan peripheral areas generally grew more rapidly than the central areas, thereby rejuvenating their age structures and generating the need to relocate services. This process, encouraged by certain speculative use of land, rose to serious pressures on public resources and had important environmental repercussions (Chackie and Villa 1993). First, the main figures generating the peripheral expansion were the poor population, especially poor migrants who gradually expanded the urban ratio of the cities either informally by invasions in which they took over empty land or formally through social housing programs governed by the principle of building where land is cheaper (Rodríguez 2002). Similarly, the living conditions in the metropolis peripheries have been associated with: insufficient expansion of urban infrastructure and equipment; critical situations of a socioeconomic nature, such as unemployment, overcrowding, poverty, and the spatial distribution of inequalities; deviant behaviors such as delinquency and drug addiction; and environmental collapse, such as air and water pollution, soil degradation, and perilous exposure to natural disasters.

After rapid growth during the second half of the twentieth century, populations living in metropolises of over-one-million inhabitants represent less than 35 percent of the total population in the region for the last two decades (see Figure 2.3). At the same time, intermediate-sized cities (ranging between 50,000 and less than one million inhabitants) have been highlighted as the most populous spaces in the urban system of the region, where the largest proportion (around 60 percent) of Latin Americans live (ECLAC 2014). Any definition of intermediate-sized cities is imprecise, not only because of the conceptual complexity, but also because the notion of intermediate-sized city also involves a relative definition of what is “large” and “small”. Cities with more than 500,000 inhabitants can be intermediate-sized in Brazil and Mexico, but these constitute the largest cities in Central America (Rodríguez 2002). Likewise, Latin American intermediate-sized cities could be divided according to their growth patterns into two categories: those with less than 500,000 inhabitants and those with between 500,000 and 1 million inhabitants. The cities between 50,000 and 499,999 inhabitants have tended to grow more rapidly than those between 500,000 and 1 million inhabitants. The

differences in terms of growth patterns between these two groups are notable in Argentina, Chile and Venezuela; they are moderate in Mexico and Peru; and nonexistent in Colombia. The only exception to this trend is Bolivia, where the only city of 500,000 to 1 million inhabitants has expanded at a dizzying rate (Jordan and Simioni 1998).

The growth of the intermediate-sized cities is associated not only with natural increase but also with migration from both small and large cities. During the first decade of the twenty-first century, three out of four migration movements occurred from an urban origin to an urban destination (Rodríguez 2017). During the last decade, Latin American intermediate-sized cities have been considered to be emerging cities due to their strong contribution to national economic dynamism, which has been caused by their dual condition of populations and economies that are growing at rates greater than the national growth levels (Montero and Garcia 2017). Unfortunately, these cities have suffered the same effects of rapid urbanization as the metropolises. Even at a minor scale, some intermediate-sized cities are starting to face problems from the accelerated growth of peripheries without services, insufficient transport systems and pollution (ECLAC 2002).

Figure 2.3 Percentage of population by size of the city in Latin America, 1950-2010.



Source: Cepal (2012). Población, territorio y desarrollo sostenible. CEPAL-CELADE, Quito LC/L.3474(CEP.2/3). P.. 154.

For their part, small cities (20,000 to 50,000 inhabitants) have demographic and living standard patterns that are quite close to those of intermediate-sized cities (50,000 to 499,000 inhabitants), but they differ from rural and semirural areas (under 20,000 inhabitants) as well as the largest cities (500,000 and more inhabitants). These differences are even more accentuated in the most populous countries. There is no doubt that changes in economic policies conceived for the deconcentration of the largest cities have acted in favor of intermediate-sized and small cities in general, making them economically competitive and appealing to other urban migrants. These two groups (intermediate-sized and small cities) tend to have infrastructures, equipment and services that are similar to those of the large cities, while at the same time they have advantages in matters of governance and quality of life as a result of their smaller population size. However, compared to larger cities nowadays, they are still lagging behind in several dimensions such as education, culture, recreation, technological diversification and others (Rodríguez 2017)

The rural population in Latin America accounts for only 12 percent of the total demographic increase in the region over the last 40 years. By “rural”, it means the word in terms of the formal non-urban definition adopted by each country. As Figure 2.3 shows, the relative importance of the rural population has diminished rapidly since the fifties. After 1990, the annual rural population growth rate is less than 0.4 percent; and by 2010, it represents only 20 percent of the population in the region.

Compared to urban areas, the lower living conditions in the rural areas is one of the factors that explains the rural demographic stagnation and the persistence of migration from the countryside to the city, even at the currently low levels (Villa and Rodriguez 1998). This demographic stagnation does not imply that the rural population has become insignificant, since currently one in every five inhabitants of the region lives in rural areas; but they have not consolidated as developed areas in order to attract or maintain their population. Previous policies designed for population distribution attempted for the countries to populate historically empty land, such as The Amazon; has a limited impact. In this sense, the contribution of rural-urban migration to city population growth in absolute numbers has been reduced not because of a decreasing migration flow but due to the very high relative importance of cities, which means that the number of potential rural migrants is already very low (Montero and Garcia 2017).

## **2.5 Urban bias in Latin America**

The historical advantage of the urban areas — especially the capital cities — has been well established in Latin America. There has been a long tradition of highly-developed urbanism, with the urban sectors dominating the rural areas. Until almost the mid-twentieth century, the regional economic and social structures were essentially organized to provide commodities to the international market, especially precious metals and food. Similarly, “large cities had a centrifugal development, exerting their dominion over the surrounding rural areas” (Redclift 1984). The importance of the cities, especially the capitals, increased during the incipient industrialization process when central governments came to have more control over provincial centers.

Focusing on demographic terms, some authors have already pointed out not only the historical advantages of the largest Latin America cities in terms of living standards and development, but also how these advantages have reached their limit and are affecting the populations

negatively. The change came as an effect of the decentralization process carried out by most of the countries through neoliberal economic policies, and this has not led to the repopulation of the rural areas but instead to the increasing importance of medium-sized and small cities (Baeninger 2002). From an economic perspective, they have failed to reduce urban bias as they were expected to do, despite the structural adjustments and pro-decentralization policies that took place during the neoliberal policies phase. At the end, these policies have been successful only “reducing the price twists against rural goods, while instead the distributional urban bias on public spending on goods and services has continued to increase significantly” (Eastwood and Lipton 2000).

As a result of “the expansion of social-welfare programs during the second half of the twentieth century, it was possible to find in the larger cities the full complement of modern medical care in terms of specialists, hospitals, clinics and special equipment; while in most rural areas in Latin America there was a severe shortage of doctors, services and supplies” (Browning 1967). At the same time, urban areas experienced substantially better quality of the environment in terms of access to piped water and toilet facilities in the house, which is important for explaining the prevalence of infectious diseases such as diarrhea, which is responsible for a large proportion of infant mortality (Tim, xe et al. 1995). Even studies on the development of welfare state regimes in the developing world have similarly argued that in the case of Latin America, “the formation of relatively generous but narrowly targeted welfare programs for urban groups was due to a coalition of capital and labor working against rural interests” (Varshney 1993).

Revisiting his theory, Michael Lipton (1984) concluded that despite the de-concentration and decentralization policies deployed by developing countries, the existence of an urban bias remains in the distribution of public expenditure. However, in order to prove this phenomenon when evaluating public spending on goods and services in Latin America, a problem of definition is compounded by problems of measurement. Official data in Latin America are not always of the highest quality; and, given the political sensitivity of social spending, data are open to manipulation (ECLAC 1994). In recent years, data collection at the central government level has considerably improved for most Latin American countries. Simultaneously, the wave of decentralization and privatization of public services have achieved different levels among the countries in the region. Then, any long-term spatial detailed analysis of public social spending ends up being hard to come by.

Broadly speaking, some analyses have proven how the allocation of public resources in Latin America has failed to respond to socio-economic needs. Even though their overall spending strongly resembles that of countries with developed economies, their allocation seems to be far from responding to their populations’ needs. Only by looking at the education and health systems, urban areas hold more advantages regarding the allocation of resources. In education, the ratio of enrolment in primary schools compared to tertiary level facilities was almost exactly ten to one in 1995, which means that for every ten students enrolled in primary school, only one continued on to attend tertiary facilities, whereas the public spending ratio was typically around two or three to one (Ramirez, Silva et al. 2009).

Another example is found in public healthcare system expenditures. Across Latin America, there is a dramatic bias towards expensive curative interventions instead of the cheaper and more effective services of promotion and prevention. In this way, richer groups benefit disproportionately from (often subsidized) high-cost services such as surgery, while the same money would have a far greater impact on the overall health status of the population if allocated to prevention. This inadequate allocation of public expenditure should be interpreted

as a failure in the implementation of Western policies that are wholly inappropriate to a context filled with basic inequalities (Lloyd-Sherlock 2000). Similarly, government expenditures on the armed forces, bureaucracies and the like are constantly created as an expensive form of subsidizing the urban middle class (Colburn 1993), while rural peasants suffer from price-regulation, direct taxes on their labor, and non-participation in subsidies (Grindle, Comisso et al. 1996).

Through a more state-centric analysis, urban bias is seen on the part of some Latin American states that consciously emulate successful models of economic development without any consideration of existing social inequalities. Even inside the cities, the most important problems are not directly related to their size but to their distribution of urbanization costs and benefits. As Chackiel and Villa (1993) describe the matter, “Inefficient economic management, atmospheric contamination, transportation problems and those related to the poverty of the city are more directly related to urban management and the contradiction between the privatization of benefits and the socialization of costs than to the demographic size of the metropolis” (Chackie and Villa 1993).

Beyond the real allocation of resources, some debates have emerged concerning various issues, such as: the relative growth of urban poverty; the increasing spatial interdependencies and complex livelihood strategies that the urban hierarchy has developed in the region; and being able to identify the dividing line between public and private social expenditures. Mostly because “just focusing on the concentration of some goods and services in urban areas is not necessarily an indication of “bias” but of convenience and an efficient use of resources, which makes economies of scale and mobility patterns more pertinent for studying inequalities. What is more, not all biases are the result of ‘distortions’, and neither poverty nor development present themselves along strictly urban/rural lines” (Jones and Carbridge 2010). However, when one examines the average outcomes in living standards, education, health and the general welfare of the population, the historic advantages of the urban space and capital cities seem to remain constant in Latin America. Rural areas still lag behind urban areas socioeconomically, in their lack of infrastructure and connectivity, and they experience an unequal distribution of resources, especially land. In addition, inequalities are found in the cities when relating the size of a city’s population and certain living conditions. Inhabitants of larger cities tend to have higher education levels and lower illiteracy rates, as well as greater access to modern equipment associated with information and communication technologies (ECLAC 2012)

During the first decade of the twenty-first century, studies on poverty show that around 53 percent of the rural population lives in poverty (ECLAC 2012), and the difference between the percentage of the population below the poverty line in urban and rural areas is notorious, with rural poverty being around 25 percentage points higher than urban poverty (Montero and Garcia 2017). Two separate types of poverty then must be considered in Latin America nowadays. First, there is the rural poverty that is associated with peasant family agriculture and settlement of native, which one could call *persistent poverty*. This condition of poverty is stable, that is, it has perpetuated over the years in the absence of upward mobility processes (Ramirez, Silva et al. 2009; Cuervo Gonzalez 2017) and is related to the relative absence of the state in remote areas (Jones and Carbridge 2010). Second, the undeniable form of urban poverty in which there is an immense grey economy of working poor in the cities in all Latin American countries. They suffer from precarious work conditions and self-built housing, but at the same time, they may benefit from better investment in schooling and health care. This urban poverty

is the one that is more susceptible to public policies and economic crisis (Ramirez, Silva et al. 2009).

In contrast to poverty, inequality has been traditionally characteristic of urban spaces in Latin America, although over recent decades in the largest cities it has not been far from national levels. With the exception of Santiago (Chile), La Paz (Bolivia) and Brasilia (Brazil), all capital cities show lower levels of inequality than their respective countries. On the other hand, living standards and access to services vary significantly, depending on the size of the cities. The bigger the city, the greater the access to services and new technologies such as telephones, computers, and internet (Montero and Garcia 2017). The economic activity of the region remains highly concentrated in a small number of urban centers: only 40 major cities in Latin America generate approximately 30 percent of regional Gross Domestic Product (GDP)(UN-Habitat 2012).

## 2.6 Conclusion

While Latin America is presented as one of the most urbanized regions in the world, it is worth mentioning that it is also one of the least populated. The average population density per square kilometer is below the world average, mainly due to the very low occupancy rates in larger protected areas and the persistent concentration of land ownership. The amount and pace of urbanization are *Sui generis*, as well as its concentrated character, the constant metropolization of its cities, the primacy of the capital cities, and the apparent independence of the relatively slow industrialization process. Overall, urbanization has been a continuous and rapid process during the last half-century, regardless of periods in which macroeconomic, political and institutional instability were full-blown. Therefore, most of the countries in the region have already gone through their full urbanization process, with more than 70% of their population living in urban areas.

Although it cannot be questioned that the region is quite below the developed regions in terms of per capita income, productivity and reduction of poverty, the over-urbanization hypothesis can lead to an erroneously negative evaluation of Latin American urbanization (Rodríguez and Martine 2008). 'Over-urbanization' problems found in the region may be more related to the allocation of resources and to the contradiction between the privatization of benefits and the socialization of costs, than to the demographic size of the metropolis or its available public resources to invest.

Urbanization and development have undeniably had a positive relationship in Latin America. In the same sense, without refuting that Latin American cities are marked by poverty, precariousness, great inequality, insecurity and informality, it is the largest cities that have benefited the most from the development and modernization process that accompanies urbanization. The largest cities have provided their populations with better living conditions on average than any other city or area in their countries. This advantage has continued to be the constant and real contribution of the capital cities to the national economies. Thus, an urban bias is still seen through the relationship between development policies and the urbanization process.



The favoritism towards the cities in the distribution of public spending on goods and services can be tracked when analyzing the expansion of social-welfare programs during the second half of the twentieth century. Even though the overall spending strongly resembles that of developed countries, its allocation seems to be far from a response to the needs of the populations. Richer urban groups benefit disproportionately from (often subsidized) high-cost public services while still most of the populations in these countries lack basic services and goods. The inadequate allocation of public expenditures has historically had a clear effect on the living standard outcomes of countries and other inequalities found among territories and social groups.

When analyzing socio-economic differentials, a gradient has been directly attached to the size of the cities. The biggest cities maintain on average the most advantageous outcomes in living standards while the most isolated areas are associated with the least favorable ones. This gradient is particularly clear after the 1980s, when the largest cities — especially the metropolises — were affected by a period of prolonged economic crises and a new pattern of consolidated population distribution while increasing importance was given to intermediate-sized cities. By the end of the twentieth century, a complex system of cities with difference sizes and relevance became visible in all countries.

As expected, mortality differentials may also be affected by this urban bias, although few advances have been made in analyzing this aspect. The main challenge is that an inter-country and inter-city comparison is needed in order to be able to generalize. In further chapters, the link between the urban bias and urban-rural differential in Latin American mortality and cause-of-death patterns is addressed.

### 3. MORTALITY IN LATIN AMERICA

Average life expectancy in Latin America and the Caribbean rose from 29 years in 1900 to 74 years in 2010. That same year, 98 percent of children lived to see their first birthday, while only 75 percent did so 100 years earlier. To put this in perspective, North American life expectancy at birth in 1900 was 48 years, almost 20 years more than the Latin American region as a whole; and by 2010 the difference was just 4 years, with a North American life expectancy of 78 years at birth (PAHO 2012). This advance was influenced mostly by the demographic changes that occurred during the 1950s and 1960s, a period of explosive growth that pushed Latin America's population well above others low-income regions (Schultz 1993). Latin America was the healthiest low-income region in the world, and life expectancy continued to rise until it increased by more than 20 years over the next 50 calendar years in most countries of the region, the constant decline in infant mortality is the primary driver behind this initial increase in life expectancy.

Improvements in mortality have occurred continuously, even during volatile and slow periods of economic growth and despite the fact that poverty levels during the first decade of the twenty-first century were as high as those at the beginning of the 1980s (Butterworth and Chance 1981). Although modern developed countries have reduced both mortality and fertility through the process of industrialization, this process has evolved quite differently in developing countries such as those in Latin America. Declines in mortality do not appear to be closely related to economic and technological development; in fact, the mortality rates have declined much more rapidly than the economies have developed (Arriaga 1970)

Nowadays, low to middle levels of mortality are seen at the national level in most Latin American countries. Still, advances made in overall living standards have not reduced the major disparities in access to health care services among countries, geographic regions, and population sub-groups. Furthermore, there are persistent unequal provisions of services such as piped drinking water, waste disposal, and electricity, among others. As a consequence, high infant mortality continues to be the most characteristic demographic dimension of poverty for some subpopulations (Chackie and Villa 1993).

This chapter is divided into six sections, all dedicated to summarizing the mortality patterns and health transition in Latin America with a focus on the gaps found among countries, geographical areas, and sub-populations – especially those gaps that were introduced by the urbanization process. This is because the Latin America health transition generally emerged first in urban locations (Tanner and Harpham 2014) and tended to proceed more rapidly in those countries with higher levels of urbanization (Da Cunha and Rodríguez 2009).

The first section examines the determinants of the mortality decline, followed by a presentation on the evolution of causes of death in the region. The third section reviews the broader analytical framework of the Latin American health transition, while the fourth section analyzes the heterogeneity found among the countries in this region. The fifth section is dedicated to exploring the main gaps that the literature finds in mortality patterns: the sex differential and the urban-rural gap in mortality. Certainly, other differentials in mortality are found in Latin America, such as those by social class, educational level, and ethnicity; but these differentials are only possible to analyze in a small sample of countries or by studies that focus mostly on infant mortality due to the lack of quality data has made regional comparisons hard to come by. Additionally, those studies have highlighted that advantaged subpopulations in the

region, e.g., upper social class, the highest educational levels, and non-discriminated ethnic groups tend to live in urban settings while the less advantaged populations are more likely to live in rural areas. A brief conclusion is presented in this chapter's sixth section.

### **3.1 Mortality determinants in Latin America**

There are diverse opinions about the factors that determine recent decreases in mortality rates. The first studies conducted in this regard focus on nineteenth-century Western Europe. In their search for answers, scholars have provided explanatory models of the causes and stages of the phenomenon. Broadly speaking, a notable portion of the specialized literature considers economic growth to be one of the main determinants of mortality decline. Economic growth has been measured as: improvements in nutrition (McKeown and Brown 1955; McKeown and Record 1962; McKeown 1964; Frederiksen 1966; McKeown, Brown et al. 1972; McKeown 1978; Waaler 1984; Fogel and Costa 1997); income (Roges and Wofford 1989); the impact of structural factors such as medical-health advances (Coale and Hoover 1958; Arriaga and Davis 1969; Preston 1976; Preston 1979; Davanzo and Habicht 1986; Deaton 2004; Cutler, Deaton et al. 2006); and the strengthening of public health systems (Caldwell 1993; Soares 2007). Attempts for a more global understanding of the phenomenon has created multi-causal explanatory frameworks that consider (among others): cultural and behavioral factors; population health behaviors (Szreter 1988; Preston and Ewbank 1991; Caldwell 1993); the role played by social assets in health (Murray and Chen 1993); household social status (Behrman and Deolalikar 1988; Birdsall 1990); the community (Pebley, Goldman et al. 1996; Sastry 1997; Mc Question 2000).

Contrary to Europe, no long-term studies on mortality trends exist for pre-twentieth century Latin America. The lack of data has driven studies to concentrate primarily on analyzing the determinants behind the region's decreasing mortality trends of the twentieth century. This decrease is characterized by being reversible and discontinuous while adhering to patterns that are dissimilar to those of developed countries (Palloni 1981). Several stages in the process of decreasing mortality have been identified according to the speed of the decline and certain factors that may be associated with it. With the exception of Argentina and Uruguay, the greatest improvement in life expectancy began in Latin America after the Second World War. The impact of economic development on the decline in mortality in Latin America was relevant only in the early twentieth century, when decreases were incipient in the region. For the period 1900 to 1930, mortality decline was very slow and the whole region added only an average of 0.21 years per calendar year to life expectancy at birth (Arriaga 1970).

From the thirties to the sixties, when the decline began to accelerate in most of the countries, the main determinants in mortality decline that have been identified are, on the one hand, sanitary controls applied on the basis of elementary notions of personal hygiene and, on the other, incorporating medical advances into standard health practices (Arriaga and Davis 1969; Preston 1976). Most Latin American countries enacted effective health policies, such as the large-scale immunization of populations, eliminating disease vectors, distributing antibiotics, and the large-scale construction of systems for drinking water supply and sewage disposal (Palloni and Pinto-Aguirre 2011). The decline in mortality achieved its steepest decrease during these decades in most of the countries. While improvements in the quality of life and the nutritional status of people are related to economic development, they explain only to a lesser

extent the total decrease in mortality (Palloni 1981). Despite general improvements, the impact of health policies was not the same for all population sub-groups.

During the 1980s, the levels of infant mortality recorded in the region were still high, as well as the notable numbers of deaths due to infectious and parasitic diseases in some countries. As economic development strategies based on import substitution were gradually exhausting themselves in all countries, the 1982 debt crisis led to the enforcement of drastic austerity measures and budget cuts. “Neo-liberal” politics and monetarist economic policies became more and more widespread (Imbusch, Misse et al. 2011). Most of the countries in the region reduced expenditures on their health care systems, stopped ongoing expansions of public health infrastructures, and reduced immunization campaigns. It became common across the region to see waves of privatization across the health care systems as services were outsourced.

After the 1990s, the mortality decline began to slow down and a sort of stagnation in life expectancy is seen in most of the countries (Di Cessare 2011). The slower rate of mortality decline in Latin America may be attributable to well-known historic causes such as poverty and inequality, while some new causes may also have impacts such as rapid lifestyle changes that include but are not limited to poorer and more industrialized diets, increased smoking, increased obesity, and the so called “epidemic of violence”. In this scenario, the most important determinants in reducing mortality have been identified as improvements in private living standards, housing, clothing, nutrition, transportation and access to medical care (Palloni and Pinto-Aguirre 2011). All of these are correlated with individual access to commodities and are enhanced by inequalities. A more limited access to effective health care and medications remained, mostly due to the stagnation in public health expenditures even during the national populism phase. Total average spending on health in the region increased only marginally, from 6.4 percent of gross domestic product (GDP) in 2000 to 6.5 percent in 2007 (Glassman, Gaziano et al. 2010).

### **3.2 Evolution of causes of death in Latin America**

Continuous problems with the availability and quality of the base data are the reasons why cause-of-death analysis of Latin America is a relatively new field when compared with studies on developed countries. In the mid-seventies, death registration was over 90 percent in only seven countries (Chile, Cuba, Uruguay, Argentina, Venezuela, Mexico, and Guatemala); whereas less than 70 percent were registered in other countries (such as the Dominican Republic, Paraguay, El Salvador, Honduras, Peru, and Nicaragua) (Chackiel 1999). Thus, the fact of the matter is that comparative studies and their conclusions for periods before the seventies rely on samples of countries whose vital statistics and defined causes of death are considered to be good enough for proper statistical analysis.

The most outstanding characteristic of the region up to the Second World War – when reductions in malaria and tuberculosis began – was an epidemiological profile dominated by infectious diseases and high infant mortality. This change in the epidemiological profile led to a predominance of non-communicable disease. At the beginning, cardiovascular diseases preponderated, followed later by a rise in man-made diseases such as diabetes, neoplasms, and external causes of death.

### 3.2.1 The reduction in infectious diseases

Malaria was the leading cause of death in almost all countries in the region, followed by typhoid fever, dysentery and tuberculosis. The high prevalence of enteric infections reflect the high environmental risk to which the population was exposed (Gabaldon 1965). The initial reduction in these infectious diseases was a consequence of two influences: first, some pioneer countries initiated interventions to eradicate vector-borne diseases (Panama and Cuba); and, second, most of the laggard countries incorporated into their health systems medical technology, antibiotics, and vaccinations (Palloni and Pinto-Aguirre 2011).

During the 1930's, mortality decline in the region was driven specifically by the reduction in malaria, mostly due to the massive application of dichlorodiphenyltrichloroethane (DDT), especially in those countries where the levels were highest (Palloni 1981). Eliminating malaria may also have led to reductions in other infectious diseases in the region by boosting the population's average immune resistance (Palloni and Pinto-Aguirre 2011).

Between 1930 and 1960, the reduction in mortality occurred extremely rapidly and progressed at almost the same rate in all countries, with Venezuela experiencing the fastest mortality decline in the region during this period (Arriaga 1970). Attributable gains to malaria reduction from using DDT drove Venezuela's life expectancy at birth to increase by one year per calendar year, going from 41 (female) and 38.8 (male) in 1936 to 54.8 (female) and 52.8 (male) in 1950. In parallel with malaria reduction, a second increase in life expectancy resulted from a reduction in deaths caused by tuberculosis. Mortality rates due to tuberculosis dropped from 215 to 45 deaths per one hundred thousand inhabitants between 1946–1956 (Gabaldon 1965). Later, these numbers of deaths continued falling until dropping by an extra 30 percent within the following 10 years (Bidegain 1989). By 1960, the tuberculosis death rate in Venezuela (19.2 per one hundred thousand inhabitants) was around the level of Uruguay (18.2), and lower than countries such as Colombia (27.8), Ecuador (35.9), Mexico (27.8), Peru (89.4) and Panama (27.3) (Gabaldon 1965).

Chile's experience between 1955 and 1975 was very much the same. As the country with the greatest gains in life expectancy for the period, Chile halved its registered deaths, not only by reducing infectious and digestive causes of death in their under-five-year-old population, but particularly by considerably reducing deaths due to tuberculosis in all age groups (Taucher 1978).

By the 1980s, poliomyelitis was eradicated, measles was under control, and progress was made toward impeding the spread of Chagas disease. Most of the countries halved their mortality rates from communicable diseases among children under 1 year old (PAHO 1998), and child deaths resulted mainly from conditions during the perinatal period (Chackiel 1999). Reductions occurred among youngsters up to age 15 who were strongly affected by infectious diseases, respiratory tuberculosis, and diarrhea, which increased regional life expectancy mostly as a result of this age group's gains.

Infectious and parasitic diseases currently continue to decrease in Latin America, although at differing levels and reduction rates among the various countries and subpopulations. However, previously defeated diseases occasionally break out and return to the region. The largest epidemic of cholera during the last decade of the twentieth century occurred unexpectedly in Latin America in 1991, after an absence of almost 100 years. Roughly, 1.2 million cases were reported from 1991 to 1997 in fourteen countries. The most affected was Peru, with around 540,000 cases, of which 322,562 occurred between 1991–1992 (Brandling-Bennett, Libel et al.

1996). Cholera's impact on mortality was, however, not as prominent as in previous centuries because public health interventions in the 1990s kept the case-fatality rate low at 0.92 percent (Guthmann 1995).

For their part, dengue, dengue hemorrhagic fever, and other vector-borne diseases still occurred at epidemic rates in many of the hemisphere's countries (PAHO 2012). In the case of malaria, the number of cases reported by the end of the 1980s was nine times higher than the number reported in the period 1955–1960 (Frenk, Bobadilla et al. 1996). The fact that the poor sector of the population continued to live without adequate sanitary conditions may be the main reason for the outbreaks (Taucher, Albala et al. 1996), although another important factor is the deterioration of public services as a consequence of the economic crisis throughout the eighties. Argentina and Brazil are two countries that experienced massive economic contractions and increasing poverty after the mid-1990s, and they also experienced short-term increases in infectious diseases (Palloni and Pinto-Aguirre 2011).

Despite lower incidences of communicable diseases such as tuberculosis, malaria, and HIV/AIDS, they still account for 10 percent of the region's deaths in 2004 (Glassman, Gaziano et al. 2010), and the annual rate of decline in the incidence of tuberculosis have slowed down. By 2015, tuberculosis remains a public health problem in the region, with a reported incidence of 32.8 cases per one hundred thousand inhabitants and an estimated incidence of 40.5 (Torres-Duque, Fuentes Alcalá et al. 2018).

### **3.2.2 Non-communicable diseases**

After the reduction in communicable diseases, a new wave of increase and reduction in deaths due to circulatory diseases flowed across the region. Already in the 1960s, circulatory diseases were competing with infectious diseases to become the leading cause of death in population aged 45 and over. This was particularly spot-on for arteriosclerotic and degenerative heart diseases and vascular lesions affecting the central nervous system. A large proportion of cardiac causes of death could be attributable to the high incidence of Chagas disease or *Trypanosoma cruzi* in rural areas, as Chagas disease results in affecting on the myocardium (Gabaldon 1965).

Between the 1970s and 1980s, decreasing circulatory diseases in the pioneer countries largely account for the decline in adult mortality. In Chile, for example, most of the gains in life expectancy during the seventies were driven by reductions in deaths due to cardiovascular diseases, stomach cancer, and cirrhosis of the liver (Taucher, Albala et al. 1996). A similar profile was registered in Costa Rica.

From the eighties on, the adult age-specific mortality showed different cause-of-death patterns; chronic non-communicable diseases already dominated ages 15 onward. First, the diseases of the circulatory system, which had been the most predominant cause of death, came to be replaced by neoplasm. The greatest reduction in mortality for the age group 15–44 was seen during this period for most of the countries, with the exceptions being Cuba, Venezuela, and Guatemala. Other causes for male young mortality are outweighed by external causes of death such as injuries, accidents, and violence. Female young mortality continues to be characterized in most of the countries by notable proportions of death caused by complications from pregnancy, childbirth, and puerperium. Maternal mortality rates in the low-mortality Latin American countries was around 4.5 per ten thousand births at the end of the eighties; whereas it was already 0.4 per ten thousand in Canada, the country with the lowest maternal mortality rates in the Americas (Chackiel 1999).

For the age group 45–64 years old, the average ratio between mortality from non-communicable causes to communicable causes during the period 1975–1995 went from 9:1 to 15:1 in Argentina and Uruguay; from 3:1 to 9:1 in Brazil, Chile, Costa Rica, Mexico, Venezuela, Colombia, Cuba, El Salvador, and Peru; and from 5:1 to 7:1 in Nicaragua, Guatemala and Haiti. Non-communicable causes during this period were mostly cardiovascular diseases.

The rise of neoplasms and diminishing cardiovascular diseases began to occur unevenly among countries, and more smoothly in time than the change from communicable to non-communicable diseases (Glassman, Gaziano et al. 2010). In Chile, for instance, a circulatory disease to neoplasm ratio for the age group 45–64 years in 1990 was 1:1, while the ratio ten years earlier was 1.2:1. At the same time, Brazilian females rose from a 40 percent to a 50 percent greater risk of death from diseases of the circulatory system than neoplasms (PAHO 1998).

Large heterogeneity exists in the region in terms of circulatory diseases. Among the countries that are forerunners in mortality decline (such as Argentina, Uruguay, Chile, Cuba, and Costa Rica), this group of causes was the single-most important contributor to gains in life expectancy for the period 1950–2000 (Palloni and Pinto-Aguirre 2011). In laggard countries, the patterns were completely different: they still experienced increases in mortality rates related to circulatory diseases during the same period. Contrary to what should have been expected even during the 1990s, age-adjusted cardiovascular disease mortality trended upward in Mexico, Brazil, and Venezuela. Two explanations for this may be posited: “either these countries were in an earlier stage of health transition and began to catch up with the rest of the region during this decade” (Stevens, Dias et al. 2008); or they failed to advance in the cardiovascular revolution. Despite their lethality being reduced, cardiovascular diseases continue to play an important role in the Latin American epidemiological profile during the twenty-first century. Studies on Argentina in 2010 found that it would still be possible to prevent a significant annual loss of healthy life-years to cardiovascular disease and stroke (Rubinstein, Colantonio et al. 2010).

At the end of the twentieth century, diabetes began to be an emerging epidemic for most Latin American countries, in particular for Mexico. Diabetes-related mortality increased 23 percent from 1998 to 2002 in Mexico, reaching 53 deaths per one hundred thousand and making it the leading cause of mortality in women and the second cause in men (Glassman, Gaziano et al. 2010). Cuba, Costa Rica, and Uruguay are the only countries where the impact of diabetes remains steady or declines slightly (Palloni and Pinto-Aguirre 2011). Studies on seven major Latin American urban areas estimated the prevalence of obesity (one of the main drivers of diabetes) to be 23 percent and that of smoking to be 30 percent of the population over age twenty-five (Schargrofsky, Hernandez-Hernandez et al. 2008).

### **3.2.3 Violence-related causes of death**

Special attention must be given to violence-related causes of death in Latin American. An incipient problem during the 1950s, it became epidemic in several Latin American countries as it affected young males to a disproportionate extent. A historically high incidence of crime is found for the region: the proliferation of violent youth gangs and the prevalence of domestic violence emerge at the top of more historical forms of violence, such as persistent civil wars, guerilla movements, death squads, state terrorism, dictatorships, social uprisings, and violent revolutions (Imbusch, Misse et al. 2011). The increasing homicide is the most alarming

dimension of the violence, for which the primary drivers are possibly the spread of firearms, alcohol consumption, drug trafficking, money laundering, and civil wars.

Gains in life expectancy due to the reduction in other causes of death have been offset by an increase in violent mortality in some countries of the region. Even more, homicide mortality – particularly among young men – is one of the major explanatory factors of the gap in life expectancy among several Latin American countries in comparison to high-income countries (Alvarez, Aburto et al. 2019). In general, males in Latin America are not just dying earlier on average; they are facing greater uncertainty about their eventual time of death due to the threat of premature mortality by violence. Violence has often been named as the main reason behind the gender differential in Latin America (Anzola-Perez and Bangdiwala 1996).

In the mid-1980s, El Salvador was in the midst of a full-blown civil war and had the highest mortality rate due to external causes (around 80 per one hundred thousand inhabitants), followed closely by Colombia and Mexico (Ruiz and Rincon 1996). The fully-fledged civil war in El Salvador lasted for 12 years, and killed more than 75,000 people between 1980 and 1992 (UN 1993). Since then, the homicide rate in Latin America has rapidly increased, with most of the victims of violence being young people between the ages of 15 and 25 (World Bank 2010). At the beginning of the 1990s, an ‘epidemic’ of violence had already been identified in El Salvador, Guatemala, Colombia, Venezuela, and Brazil; and by the 2000s, these countries topped the list of the most dangerous countries in the world (Waiselfisz 2008).

Even during periods of peace, extreme forms of brutality persist in countries with histories of long-term internal armed conflict, such as Guatemala, El Salvador, Nicaragua, and Colombia. Armed conflict has deteriorated the rule of law in these countries and led to escalations in state repression; gender-based violence targeting women; ‘extrajudicial executions’ by criminal organizations; and the proliferation of violent youth gangs. Due to the institutional weakness that characterizes these Latin American countries, public policies aiming to reduce violence and criminality have generally been inefficient. Anti-gang laws aimed at reducing these types of social violence and reinstating public safety by means of force have failed significantly (Rivera and Gutierrez Rivera 2010). In contrast, violence and homicides have decreased as a result of public policies that have reinforced the credibility of institutional mechanisms for pursuing justice and peace treaties, as in the case of Colombia (Kaufmann, Kraay et al. 2012; Briceño Leon 2017). Between 2000 to 2012, Colombia decreased its homicide rate from 66.5 to 30.8 per one hundred thousand inhabitants (UNODC 2014).

Two countries stand out for their rapidly increasing violence in recent years: Mexico and Venezuela. Increasing violent mortality is a recent phenomenon in Venezuela. Throughout the 1980s, its homicide rate was close to the levels of Costa Rica, at around eight per one hundred thousand inhabitants (Buvinic, A et al. 2005). Then, between 1995 and 2009, homicides in Venezuela increased steadily and more than doubled from 20.3 to 49.0 homicides per one hundred thousand inhabitants (UNODC 2014). From 1996 to 2013, homicides were the third cause of death in this country but had the largest negative impact on Venezuelan life expectancy, at –1.55 years for males and –0.07 years for females (Garcia and Aburto 2019).

In Mexico, homicide rates declined from 1995 to 2006, but they more than doubled between 2007 and 2012. This decline in homicides accounted for about 0.45 years of the overall gain in life expectancy while the subsequent increase accounted for -0.3 (Aburto and Beltrán-Sánchez 2019). The increase in violent deaths has been associated with the so-called ‘War on Drugs’, a military campaign that has resulted in: a greater number of enforcement operations for mitigating drug cartel activities; increased territorial competition among cartels; the



reappearance of mass graves; and a cycle of violence that has spilled over into the civilian population (Ríos 2013)

Brazil also shows a high proportion of violent deaths: around 550 thousand people died as a result of firearms during the period 1979 to 2003. The Brazilian firearm death rate rose to 20.7 per hundred thousand inhabitants, bringing the country into second place, behind Venezuela (Waiselfisz 2005). The total number of registered homicides rose from 32,603 in 1994 to 48,374 in 2004, which constitutes an increase of 48.4 percent – far above the 16.5 percent rate of population growth for the same period (Waiselfisz 2006). In 2004, Brazil's rate of 27 homicides per hundred thousand inhabitants ranks it fourth in Latin America. This number is similar to those of Russia and Venezuela, and it is thirty to forty times higher than the rates for Britain, France, Germany, and Austria. "These hubs of violence were centered in the large state capitals and metropolitan regions up until 2004, when these areas began to level off and the violence spread into the countryside" (Waiselfisz 2007)

### **3.3 The health transition in Latin America**

The theory of epidemiological transition emerged as an attempt to build an analytical framework for understanding the dynamics behind causes of death, by summarizing the mortality decline and changes in worldwide epidemiological patterns. The term epidemiological transition refers to the linear long-term process of change in the health conditions of a population. More specifically, it explains how changes in the diseases and cause-of-death patterns are a result of interacting with the demographic, economic and sociological patterns that are characteristic of modernized Western countries (Omran 1971). It is supported by three fundamental authors: Frederiksen (1966), Abdel Omran (1971), Olshansky and Ault (1986). In addition, it has been revised by Horiuchi (1997).

Changes in epidemiological patterns are associated with stages (referred to as ages) experienced by societies in their process of modernization, with the proposed classifications being: The age of pestilence and famine; the age of receding pandemics; and the age of degenerative and man-made diseases. Each of them is associated with the predominance of a group of specific causes of death. The following three categories of determinants are associated with each stage of the epidemiological transition.

- 1) Eco-biological: this is related to the population's developed resistance to disease agents.
- 2) Socioeconomic: political and cultural factors determined by lifestyles, habits, hygiene, and nutrition.
- 3) Medical and public health: curative and preventive measures taken by health systems (Omran 1971).

At approximately the same time, Lerner proposed expanding on the concept of epidemiological transition by proposing the term "health transition" to include changes in the patterns of populations' responses to their health conditions (Lerner 1973). Caselli, Meslé, and Vallin have gone even further by proposing that changes in the mortality profiles during the epidemiological transition do not benefit all the countries or population groups equally (Caselli, Meslé et al. 2002). In that way, the health transition generally progresses unevenly and produces changes in some population groups that are more rapid than in others. Namely, it is the most favored segments of the population that benefit more rapidly from overall improvements than do the rest of the population. Consequently, the mortality reduction

process occurs in successive stages of divergence/convergence among subpopulations. Favored populations are pioneers in that they benefit from initial advantages that lagging (less favored) populations will eventually catch up to (Vallin and Meslé 2004).

In their analysis of the causes of death in Latin America, Frenk et al. (1991) embraced the idea of the health transition in order to generate an explanatory model of changes in the region's causes and mortality patterns (Frenk, Bobadilla et al. 1991). They proposed a theoretical framework that summarizes the health transitions in Latin American mortality decline, as well as the determinants and evolution of the existing morbidity and mortality patterns comprising the region's epidemiological profile (Frenk, Frejka et al. 1991). By linking changes in mortality to the modernization process, they show that differences in mortality patterns persist because of the different social and economic modernization processes experienced by the countries, but also because of the modernization of their health systems. In this way, several dimensions must be considered when analyzing the health transition in Latin America.

Later on, Frenk et al. (1996) evaluated five main attributes of the epidemiological transition in order to explain changes in mortality patterns in Latin American countries: 1) changes in the age structure of mortality; 2) changes in the predominance of causes of death; 3) duration and timing of changes; 4) social distribution of health profiles; and 5) sequence of epidemiological eras (Frenk, Bobadilla et al. 1996). They conclude that Latin American transitions are in contrast to the classical stage of the initially proposed epidemiological transition, namely in that they are characterized by:

-A *superposition of stages* that have a simultaneous incidence of infectious diseases with those of a chronic and degenerative nature.

-A *counter-transition*, which concerns the reappearance of previously controlled infectious diseases such as malaria, dengue, or cholera

-A *long transition*, in which there is no clear resolution of the transition process, but rather a continuous stagnation in the duality of epidemiological profiles.

-An *epidemiological polarization*, where stages overlap due to gaps in urban and rural socio-economic development; it means that the unequal contexts determined by social class generate different epidemiological profiles (Frenk, Frejka et al. 1991).

The health transition in Latin America occurred at different paces and with different characteristics in each country. Argentina and Uruguay were the pioneers in the health transition by starting experiencing changes during the last two decades of the nineteenth century. Chile, Costa Rica, Cuba, Colombia, Mexico, Panama, Paraguay, and Venezuela followed the changes when their mortality decline began during the second and third decades of the twentieth century. Later on, Brazil, the Dominican Republic, Ecuador, and Peru began to catch up. Countries that experienced lower gains before 1980 increased their gains in life expectancy after 1980 (Palloni and Pinto-Aguirre 2011). For their part, the transition began rather late in Bolivia, Guatemala, Haiti, Honduras, Nicaragua, and El Salvador. Even during the nineties, when communicable diseases caused only 6 percent of registered deaths in Uruguay, they still represented 60 percent of total deaths in Guatemala (Chackiel 1999).

As stipulated in the framework of the health transition, differences in mortality levels among countries have decreased (converged) or increased (diverged) over the long term (Vallin and Meslé 2004). The region's greatest pioneer in shifting its epidemiological profile is Chile, followed by Costa Rica. They were not the initial pioneers in the health transition, having begun

their transition as late as the twentieth century; yet, they managed to catch up to and overcome the initial pioneer countries. Since the nineties, more than 60 percent of the deaths in both Chile and Costa Rica occur in their populations aged 65 and over. This change is best explained by the reduction in mortality from infectious diseases and perinatal conditions in the under-5-year-old population, but it is also due to the reduction in maternal and external causes of death. The next section details the pace and timing of the mortality decline in all countries.

### 3.4 Country heterogeneity

Despite overall improvements in life expectancy, country differentials persist in the levels and speed of change among Latin American countries. By the mid-twentieth century, the difference between Uruguay (the country with the highest life expectancy) and Haiti (the country with the lowest) was 28.5 years; sixty years later, in 2010, the difference between Costa Rica (the country with the highest life expectancy), and Haiti was reduced to 16.7 years (ECLAC 2016). To put this in a more global perspective, even though life expectancy since the nineties in Chile, Costa Rica, and Cuba exceeds the average for the most developed regions in the world, Haiti and Guatemala continue to have the lowest life expectancies.

Figure 3.1 displays life expectancy in all Latin American countries (in this figure it is kept the same four groups of countries according to their urbanization level displayed in Figure 2.2 in Chapter 2). The first group comprises most of the pioneer countries in life expectancy, meaning those with the highest life expectancy for most of the 1950–2010 period. In contrast, the laggard countries that make up the fourth group continue to have the lowest life expectancy for the whole period, despite their enormous improvements. Groups two and three consist of countries in which life expectancy levels remained close to the regional average but with heterogeneous patterns.

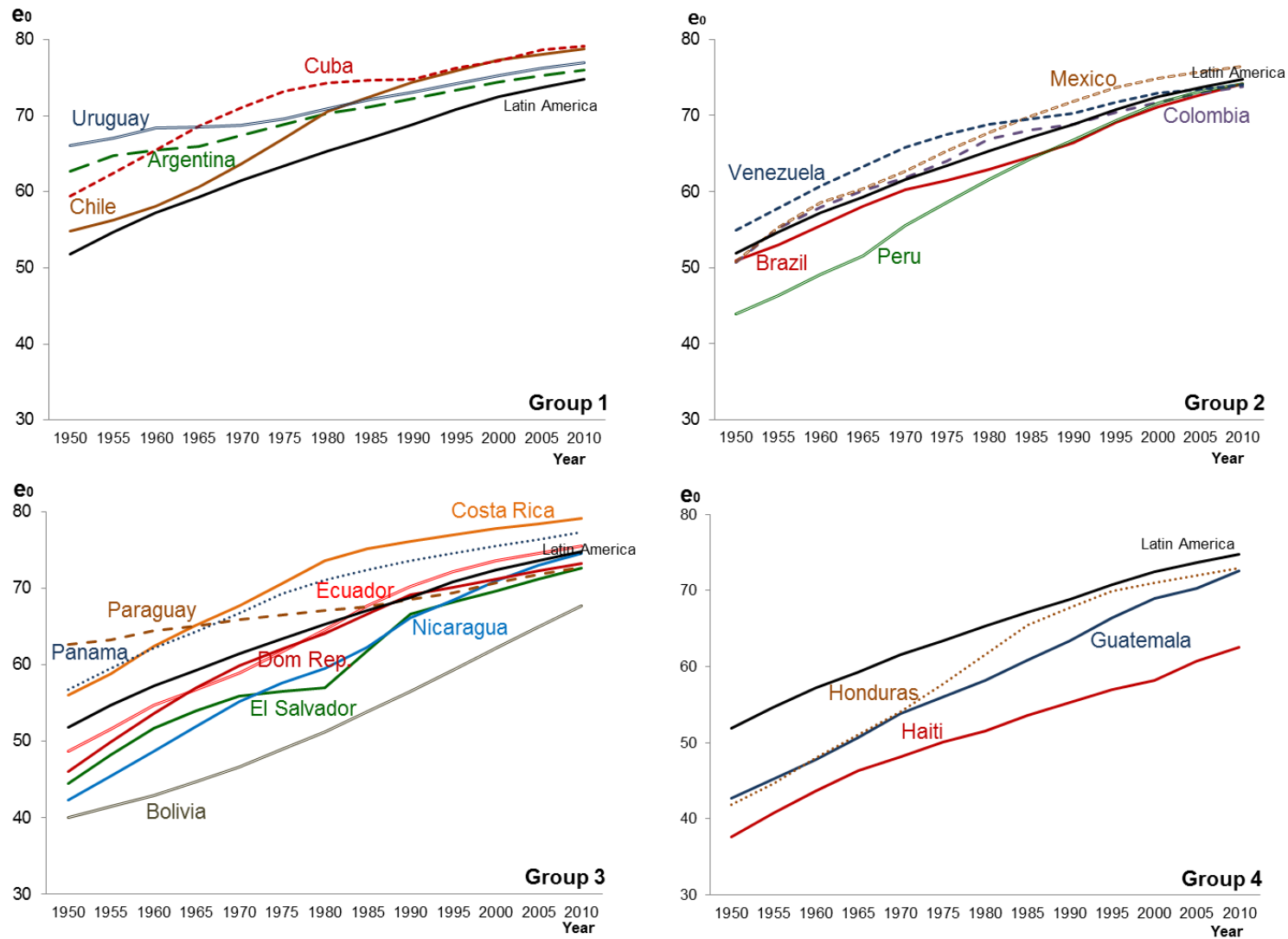
In the group of pioneers, there are Argentina and Uruguay, where mortality rates fell considerably during the first half of the century, are the countries with the smallest gains in life expectancy after the 1950s. In contrast, the countries with the lowest life expectancy during the fifties, Chile and Cuba, made the most gains in the recent period and surpassed the initial advantages held by Argentina and Uruguay. This group of pioneer countries in terms of life expectancy are missing Costa Rica and Panama, where life expectancy rose to the highest levels in the region, although their urban populations are not among the highest percentages in the pioneer group.

An analysis of long-term mortality trends in Costa Rica by Rosero-Bixby (1996) suggests that social homogeneity may be an important factor in the distribution of public health resources. Costa Rica raised its life expectancy from 46 to 63 years between 1940 and 1960, mostly due to the implementation of national cost-effective primary health care programs and the government's other public health measures (such as antibiotics, DDT, and vaccine distribution). A second breakthrough took place in the country in the 1970s, and life expectancy increased to 73 years at the end of the decade, just by targeting the rural populations with previous policies (Rosero-Bixby 1996).

The second group consists of Brazil, Colombia, Mexico, Peru, and Venezuela. All these countries showed impressive increases in life expectancy from 1950 to 1980, followed by slowing-down periods after the 1980s. Two reasons could explain their stagnation: the increasing proportion of external causes of death; and the continuing importance of cardiovascular diseases. All these

countries have been heavily affected by the epidemic of violence, with Colombia having the highest homicide rates for the period. External causes of death in Colombia represented 7.1 percent of the total deaths in 1960, and 23 percent by the end of the 1980s. The incidence of homicides at this moment was sixteen times higher than in Costa Rica (Ruiz and Rincon 1996).

Figure 3.1. Life expectancy at birth in Latin America, 1950–2010\*.



Source: CEPALSTAT. Compiled with data from the Latin American Demographic Center for the United Nations Economic Commission for Latin America and the Caribbean. \*I kept *Figure 2.2 Percentage of Urban Population* country grouping due to similar country patterns in life expectancy levels.

In addition to high mortality due to external causes, intermittent epidemics of infectious diseases slowed down the increase in Brazilian life expectancy from the 1970s to the 1990s. The number of annual cases of malaria reported in the country at the beginning of the 1990s was ten percent more than during the 1970s. Most of the cases were concentrated in the Amazon, a region awash with waves of industrialization and immigration (Sawyer 1996)

A much broader variety of countries is found in the third group. Paraguay had one of the highest life expectancies at the beginning of the period, but stagnated throughout the entire second half of the twentieth century. Also in this group, Ecuador, Nicaragua, El Salvador, and the Dominican Republic show more similarities among each other: they begin with low levels of life expectancy but later increase rapidly, especially after the 1980s. In the laggard group are Honduras, Guatemala, and Haiti. Another country that shared similar mortality patterns during the period was Bolivia, which is also classified in this third group because of its higher proportion of urban population.

In their analysis of convergence towards the mortality regimes of the developed world over the first 15 years of the twenty-first century, Alvarez et al. (2019) distinguished four main convergence clusters within Latin American countries: 1) the front runners Argentina, Chile, Costa Rica, Cuba, and Uruguay; 2) countries strongly affected by both external mortality and amenable diseases, such as Brazil, Colombia, Ecuador, El Salvador, Mexico, and Venezuela; 3) countries mainly affected by amenable diseases and with a low component of external mortality, such as the Dominican Republic, Guatemala, Nicaragua, Panama, Paraguay, Peru, and Uruguay; and, finally, 4) the countries lagging behind, Bolivia and Haiti (Alvarez, Aburto et al. 2019). With the exception of Costa Rica and El Salvador, these clusters do not differ much from the urbanization level clusters used in this research

### **3.5 Mortality differentials in Latin America**

Latin American countries hold the dubious privilege of being champions in inequality. As such, health inequalities are quite wide between social classes, areas of residence, ethnic, and gender, among others. Here, there are examined two of the major gaps: gender differential and urban-rural gap.

#### **3.5.1 Sex differential in mortality**

Life expectancy is higher for women than for men in Latin America, as in every world region, but the gap between male and female longevity varies among countries. In 2000, for example, women in Uruguay lived an average of eight years longer than men did, while the female advantage in Bolivia was only three years. The sex differential in life expectancy at birth is generally greater where the overall level is highest (Brea 2002).

While the difference between female and male mortality in Latin America tended to increase as mortality fell, this increase in the gap is due to the better performance of women in terms of non-communicable diseases (Arriaga 1970). From 1930 to 1960, female life expectancy in years made more gains than that of males in all registered years, being the greatest relative gains to the age group 15 to 44 years (Gabaldon 1965). This is because maternal mortality was extremely high in most Latin American countries at the beginning of the period, and its incidence contributed to narrowing the gender gap introduced by external causes of death among young adults. The risk of a woman dying from pregnancy or complications of childbirth

continued to decrease, dropping by 54 percent between 1970 and 1989; while only a few countries presently register high rates (Brea 2002).

Mortality differentials between men and women tend to be pronounced among young adults. In this age group, leading causes of death are accidents and violence, which kill more men than women. Exclusively due to external causes of death, the sex differential during the 1960s in Latin America was 5:1, i.e., for each female death, there were five male ones. For some countries at war, this differential rose to 10:1 (Gabaldon 1965). Since 1975, the country showing the widest sex differential is El Salvador, with around a 9- to 12-year difference in life expectancy at birth. Guatemala and Haiti are the countries with the smallest sex differentials, of around one year. Apart from the countries affected by violence – El Salvador, Brazil, Colombia, and Venezuela – the first countries to shift their mortality patterns in the region are Uruguay and Argentina, which also have the widest sex differentials, at around 7 years (ECLAC 2016).

By the end of the 1980s, violence was entirely responsible for young men (20–24 years) in Colombia having a 4.5 times higher risk of dying than young women, as well as for the sex differential in life expectancy at birth rising to almost eight years (Ruiz and Rincon 1996). Generally speaking, the sex differential has tended to widen even further in favor of women. Nevertheless, men were able to narrow the previous gaps and began to make greater gains than women in certain countries such as Chile, Mexico, Uruguay, and Venezuela during the 1990s (Chackiel 1999). Later on, a period of increasing violence in Venezuela and Mexico re-enlarged the gap. In Venezuela, differences in mortality reductions led to an increase in the sex differential in life expectancy from 7.19 years in 1996 to 8.76 years in 2013 in favor of women (Garcia and Aburto 2019). The highest contributions of external mortality to the life expectancy gap in the period 2000–2015 are seen in Brazil, Colombia, the Dominican Republic, Ecuador, El Salvador, and Paraguay (Alvarez, Aburto et al. 2019).

### **3.5.2 Urban-rural differentials in Latin American mortality patterns**

A link between urbanization and mortality has been seen in developing regions around the world, where studies have documented, on the one hand, higher urban rates of cardiovascular disease, cancer, and accidents; and, on the other hand, higher rural rates of maternal mortality and of respiratory and infectious diseases. These findings underscore the fact that urban and rural health profiles do indeed differ (Montgomery, Stren et al. 2003). The differences are a result of current gaps in living standards, access to services, and the particularities of livelihoods.

Living conditions in Latin American countries stand out for their unequal development along spatial lines, which is a result of goods and services becoming highly concentrated in cities and thus leaving rural areas behind (Prata 1992; Curto 1993; Schkolnik and Chackiel 1997). The rural characteristics in Latin America that have been identified as key factors in high levels of infant mortality are: lack of access to drinking water, lack of household sanitation systems, and teenage pregnancy (ECLAC-UNICEF 2008).

Numerous infant mortality studies have compared urban-rural gaps among countries, while data quality and coverage issues have made it difficult to assess regional-scale urban-rural differentials at adult ages in Latin America. Only a few countries have vital statistics that are good enough for allowing comparative studies of their main cities (mostly the capitals) or of urban-rural differentials in adult mortality, health and specific cause of death. Beyond its importance as a driver of increasing life expectancy, the focus on infant mortality is due to the

availability of data on all populations and of household censuses in the region. Most of the results obtained in those studies indicate that the highest levels of infant mortality have historically consolidated around rural inhabitants, the less educated, the indigenous, and afro-descendent populations. Even in countries that have already achieved low mortality rates, the risk of dying under five years old is up to four times higher among indigenous children compared to non-indigenous children, and the mortality of children born to mothers with less formal education is five times higher than children whose mothers received more education (WHO 2009). In Colombia, for example, mortality in children under five years old in 2010 was 11.3 times greater in the poorest quintile than in the wealthiest (PAHO 2012). Compared to urban areas, a higher concentration of the less educated, the indigenous, and afro-descendent populations, together with general poverty, are found in the rural areas of Latin America.

For the period 1970–2000, regional urban infant mortality in Latin America fell from 87 to 27 deaths per one thousand live births, while the rural counterpart dropped from 101 to 38. Changes in mortality levels were not constant: during the seventies, the urban-rural differential in infant mortality was 1.2 times higher; and in the nineties, the gap increased to 1.4 times. In the 2000s, the risk of dying in some countries such as Panama and Peru before the first birthday is nearly three times higher in rural than in urban areas (ECLAC 2010).

Spatial differentials emerged at the beginning of the urbanization process, when some areas developed more rapidly than others. For example, Brazilian infant mortality rates declined in urban areas, where industry prospered during the import-substitution phase of urban industrial development. Urbanization and industrialization cause environmental changes to communications, transportation, and sanitation infrastructures, and these changes favor declines in urban mortality rates (Oya-Sawyer, Fernandez-Castilla et al. 1987). In the long-term, these particular areas benefit more rapidly from the mortality decline than does the country as a whole. As far as the inequality of educational attainment is concerned, this is one of the main determinants in mortality reduction around the world, and throughout most of the twenty century, there are increases in the Brazilian rural area disadvantage when it comes to achieving higher levels of schooling. In fact, educational inequality between rural and urban populations is greater than any other type of socioeconomic inequality, whether it be class, gender, or race (Fernandes and Neves 2010).

A variety of factors associated with mortality levels are introduced by regional heterogeneity in a country's development, its urbanization levels, and the proportional importance of the largest cities in the overall population distribution. The very low levels of infant mortality in Buenos Aires and in Santiago de Chile are related to the high levels of income and improved health care; in comparison with other capital cities, whereas notably higher levels of infant mortality were registered in Bogota, and even more so in Mexico City and Lima. These levels are caused by differences in income, poverty, and deficient public health services (Jordan, Rehner et al. 2010). In all cases and regardless of current infant mortality levels in each city, these capital cities show much better outcomes than the averages for their respective countries

The long-held belief that indices of health like stunting, infectious disease, and mortality are better in urban than rural areas does not necessarily hold nowadays, particularly when taking into account the heterogeneity of the cities (Dufour and Piperata 2004). Infectious diseases due to general sanitation conditions and water quality have a greater impact on children's health and mortality in Bogota, Lima, and Mexico City; while it is significantly lower in Santiago de Chile, probably due to improved hygienic standards and the relatively good quality of piped water (Jordan, Rehner et al. 2010). Evidence suggests that consolidating the metropolization



process leads to infant and child mortality levels that may be negatively proportional to city size (Cohen 2006). Living conditions vary among the Latin American cities. In the same way that poverty has been associated with rural areas in the past, inequality is more prevalent in urban areas.

Urban-rural mortality differentials may act dissimilarly on adult mortality. Social inequalities are identified as one of the main causes of violence, as well as delinquent behavior in general. In this sense, young mortality may be explained by a different story than that of infant mortality. The effects of violence and external causes of death are more highly concentrated in the cities while, contrary to other mortality indexes, the levels of these effects are directly related to city size. The infant advantage in mortality shifted to a disadvantage for young adults (15 to 34 years old). Some countries of the region have seen increases in the degree of overcrowding, violence, the presence of gangs, and drug consumption (ECLAC 2008). Crime is particularly prevalent in Latin America's largest cities, where it disproportionately victimizes men living in low-income neighborhoods (Montgomery 2008).

In addition, the working age population's vulnerability is exacerbated by differences between city centers and their peripheries, particularly in terms of lacking access to services and exposure to environmental risk factors. The disorderly growth of the industrial sector directly influences biological, chemical and physical pollution, which in turn affects the population's health, especially those living in larger industrialized cities (PAHO 2007) and who are working in manufacturing or industry. In the past decade, few studies have dedicated any efforts to characterizing the region by comparing several countries. The same is true for patterns of mortality at older ages, when the mortality advantage seems to return to the city. This is especially the case in the largest cities, due to the higher concentration of specialized health care and services. However, no long-term comparative studies have focused on how this evolves in Latin American countries.

### **3.6 Conclusions**

The 1930 to 1960 period of city expansion, when new urban infrastructures were introduced, coincides with periods of fast mortality decline and reductions in infectious diseases at the national level. Mortality decline and urbanization were symbiotic processes that occurred simultaneously with urban population growth. This is because changes in the health services' size, distribution, organization, and technology played the most important roles in changing the region's epidemiological profile.

Life expectancy increased due to reductions in infectious and parasitic diseases, just as it did during the health transition. The pioneer countries in mortality reduction were the most urbanized (Argentina and Uruguay), and the pioneer subpopulations were those living in the urban areas, mostly people in the largest cities – particularly the capitals. Costa Rica and Chile eventually caught up with the pioneers' initial advantage, while less urbanized countries in the region currently maintain high levels of mortality, especially infant mortality.

At the beginning of the twenty-first century, the period considered in this analysis, most of the countries had an epidemiological profile dominated by deaths due to circulatory diseases. The exception lies with the pioneer countries, who managed to pass directly into a cause-of-death structure where degenerative diseases like neoplasms play a more predominant role (Argentina, Chile, Costa Rica, Cuba, and Uruguay); while a large number of deaths caused by

infectious and parasitic diseases continued to concentrate in a few laggard countries (Bolivia, Guatemala and Haiti). The reduction in circulatory diseases has become the greatest challenge for most Latin American countries because it has not reached the expected levels, especially for the oldest ages.

At the same time, the scenario favors a slowing down of the region's mortality decline, namely as a result of epidemic outbreaks, a rise in diabetes, and the spread of violence-related deaths. The slowdown in life expectancy after the 1990s also coincides with the deterioration of public services due to, on the one hand, the economic crises suffered by most of these countries in the previous decade and, on the other, the health care systems being privatized and outsourced. Access to effective health care and medications became more limited, mostly as a result of stagnation in public health expenditures. From this period on, changes in mortality are more greatly associated with individual access to commodities such as housing, clothing, nutrition, transportation, and access to medical care.

Spatial mortality differentials seen in urban–rural areas emerged at the beginning of the urbanization process, when some areas developed more rapidly than others did. All across the region, *the import substitution* economic period was marked by a notable urban advantage in mortality that underscores the cities' concentration of power. In essence, urban mortality has declined faster than rural during the urbanization process.

## **4. “URBAN BIAS” WHEN ANALYZING MORTALITY**

The historical advantages in terms of economic development and distributions of public resources among the urban areas in Latin America have been discussed in previous chapters, as well as the path of the mortality transition among the countries. Hence, in order to analyze the impact of urban bias on cause-of-death patterns, this chapter is dedicated to explaining how this research links both processes: urbanization and mortality through the urban bias. In order to do so, the first aim of this chapter is exposing the core of the research, its research questions and hypotheses. The second one is to explain the criteria behind the selection of some Latin American countries to develop the analysis. The third aim is to describe in detail all arrangements made in dividing the territory in order to guarantee a reliable comparison among the selected countries and within data sources over time. In this way, I establish the geographical and temporal framework of this research.

This chapter is divided into five sections. Through the first one, the urban bias framework is used to expose the research questions and hypotheses toward the urban bias in causes of death analysis. The second section explains the criteria considered for selecting the Latin American countries studied in this research. The third is devoted to comparing how the countries selected for this analysis define urban-rural areas in their demographic databases. It also explores in the literature the idea of urban-rural as a continuum and its operationalization. In the fourth section, I explain the original contributions of this research: the homologation in both geographical and technical terms of all political administrative divisions into spatial groups gathering cities according to their sizes. This section also addresses the homogeneity of the spatial groups in terms of their urban and rural populations. Finally, some brief conclusions are provided.

### **4.1 Urban bias in Latin American mortality**

As it is said in previous chapter, urbanization and development have undeniably had a positive relationship in Latin America. Urban areas, the largest cities and even more the capital cities have historically hold an advantage in terms of development in the region, and this advantage has been notorious throughout the evolution of mortality patterns. Although some studies have examined the rural–urban differential in mortality risks in Latin America, especially in infant mortality, systematic attempts to understand the factors explaining the rural–urban gap are limited.

The favoritism towards the cities in the distribution of public spending on goods and services summarized on the ‘urban bias theory’ may be explaining this differential in mortality, due to the privilege role given to the urban space when development policies have been put into place in the region. The concentration of some goods and services in urban areas may be an indication of convenience and efficiency to achieve their mortality decline. This is because countries passing by rapid urbanization process required both, continuous expansion of good and services to rural areas, at the same time that an intensification of public policies with greater impact on the increasing urban areas.

Structural adjustments that took place during the import substitution phase of the Latin American economics, as well as the neoliberal and pro-decentralization economic policies did not change the distributional urban bias in terms of public spending on goods. The urban

advantage remained even when the countries passed by periods of economic recessions that implied cuts in public expenditures at national scale. It does not mean that cities were untouched by economic crises, what certainly happened is that cutting public expenditure made difficult for the countries to stop the negative effects introduced by the rapid urbanization, and at the end public goods and services were neither concentrated in all urban areas nor accessible to all urban population. It means that even when it is in the large cities that wealth is concentrated, this wealth is unequally distributed in both public expenditure and in the access that individuals have to it. An analysis of the under-five population mortality living in the Brazilian state of Sao Paulo using census data from 1970 to 1991 found higher mortality in urban areas than in rural only when the results were adjusted for household wealth (Sastry 2004). This result indicate that the advantage of the urban areas nowadays may be relying on the higher concentration of non-poor population more than the setting itself.

Along with increasing inequalities in the cities, recent lifestyle changes, including poorer and more industrialized diets, increased smoking, increased obesity, and the so called 'epidemic of violence' have been mainly seen in the region as characteristic of urban areas. In the framework of this research, I wonder whether these changes are shifting the previous urban advantage set by the urban bias or the urban advantage is persistent in the region

#### **4.1.1 Research questions**

Studying causes-of-death pattern and its changes considering the urban-rural distinction might allow identifying the impact that the historical 'urban bias' distribution on resources allocation has in the health outcomes of the countries. If there are better provision of healthcare in the urban areas then, they should be correspondently having less incidence of deaths, specially those diseases which lethality is canceled out by preventing the conditions to develop or by their early detection in comparison with rural areas. In the same way, an indication of the existence of an urban bias, it is that health transition continues being more advanced in urban area than in rural. Otherwise, if lifestyle changes -including increasing violence in the cities- have shifted the advantage in to disadvantage.

I mainly wonder: Can the "urban bias" be traced through urban-rural differences in mortality? And does taking these differences into account shed light on the drivers of the health transition in the region? More specifically, I inquire: Do Latin American countries have different mortality patterns when considering urban and rural areas separately? Do differences between urban and rural settings come from specific cause-of-death and age-specific mortality levels and trends? Can the urban bias in resource allocation be perceived through the amenability of causes of death in Latin American countries?

#### **4.1.2 Hypotheses**

In this sense, my main hypothesis is that: Urbanization and development are tightly linked in Latin America because concentrating goods and services in the most urbanized areas –urban bias in resource allocation- consistently results in resources being strategically used to promote a rapid mortality decline and to drive the health transition at the national level, in a context of rapid urbanization. More specifically, I hypothesize that:

-There is a persistent urban advantage in mortality in Latin America. This advantage is concentrated mostly in the largest cities. Thus, their initial level and trends during the period of

analysis are the most advanced in terms of mortality decline in comparison with the rest of the country. The urban advantage remains, regardless of the level of urbanization and mortality maintained by these countries.

-The urban advantage is perceivable through differences in age-specific mortality trends. In the largest cities, the reduction in adult mortality is moving toward a rectangularization of the survival curve; whereas in towns and rural areas, decreasing infant mortality is still the main contributor to changes.

-The urban advantage comes mainly from the differential impact of amenable causes of death, as their incidence rates are higher in rural areas than in urban areas. This means that using causes of death as an outcome makes it possible to follow the urban bias in resource allocations across the national territory, because amenable causes imply that deaths from certain causes would not occur if timely and effective interventions were given.

## **4.2 Countries selected**

In an attempt to answer the research question considered here, a selection of countries has been made. The criteria cover the majority of urbanization processes in Latin America, as well as the different stages of the region's health transition. Past chapters have identified three main characteristics of urbanization in Latin America: the total proportion of urban population in the country, the urban growth rate, and the importance of the capital city within city networks. Based on these classifications, seven countries have been chosen for this research: three countries with high urbanization levels in 1995, three with medium levels, and one with low levels. In these seven countries, a variety of urban growth and types of city systems are found. At the same time, life expectancy is considered as a proxy for each country's stage of the mortality transition. Thus, four countries are found to have higher life expectancies than the Latin American average in the year 1995, while three have lower expectancies (see Table 4.1).

Figure 4.1 indicates the countries with high urbanization levels: Chile, with long-term high urbanization levels and a monocentric city system; and Venezuela and Brazil, with accelerated urban growth and polycentric city systems. Among these three countries, it is possible to distinguish Brazil's lower life expectancy in the year 1995 from the Latin American average, while Chile and Venezuela have higher life expectancies. On the other hand, Mexico and Colombia have medium urbanization levels in 1995 but rapid urban growth and polycentric city systems, while Peru has a monocentric system. Mexico has a life expectancy greater than 69 years in the year 1995, while Colombia and Peru have lower ones. To complete the group, Ecuador is added. Ecuador has long-term low levels of urbanization and a bicephalic city system, combined with a life expectancy that is higher than the Latin American average in 1995.

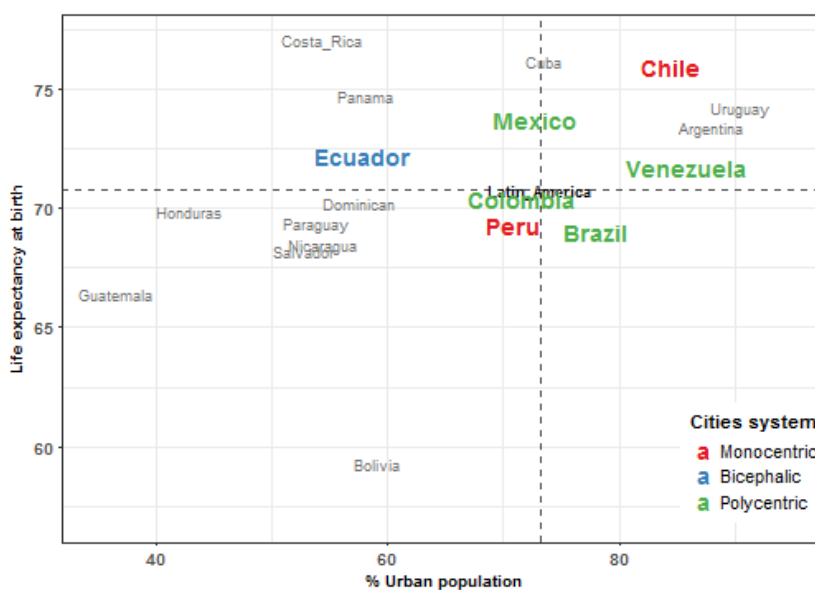
These seven countries representing different scenarios in terms of urbanization process, city system and mortality transition, gathered the 77 percent of the population in Latin America in the year 1995.

Table 4.1 Selected countries

% Urban Population in 1995	Life Expectancy in 1995	
	Higher (>69 years)	Lower (<69 years)
<b>High</b> (>80%)	Chile Venezuela	Brazil
<b>Medium</b> (60% to 80%)	Mexico	Colombia Peru
<b>Low</b> (<60%)	Ecuador	

Source: CEPALSTAT. Databases and statistical publications, in [http://estadisticas.cepal.org/cepalstat/web\\_cepalstat/estadisticasIndicadores.asp?idioma=i](http://estadisticas.cepal.org/cepalstat/web_cepalstat/estadisticasIndicadores.asp?idioma=i) consulted 04.02.2019.

Figure 4.1 Proportion of urban population, city system type and life expectancy in Latin American countries in 1995



Source: Source: CEPALSTAT. Databases and statistical publications at [http://estadisticas.cepal.org/cepalstat/web\\_cepalstat/estadisticasIndicadores.asp?idioma=i](http://estadisticas.cepal.org/cepalstat/web_cepalstat/estadisticasIndicadores.asp?idioma=i) consulted 04.02.2019.

### 4.3 The definition of “urban” in Latin America data sources

National governments have not universally adopted a definition of urban areas. Instead, a variety of definitions are now in use. National Institutes of Statistics in Latin America compile data considering a combination of primary and secondary criteria for agreeing upon a definition of urban. They have defined an “urban space” according to: political boundaries (political-administrative hierarchy), population size or density of the village (thresholds vary between countries), economic function, landscape (appearance of the physical structure), the amount of

urban equipment, number of services and so on. Even the definition per se of what constitutes an urban area varies over time in a single country.

Clearly, the fact that different criteria are employed to define urban areas complicates comparisons, both between different countries and sometimes within the same country over time. Even when using a fixed set of criteria, an area’s own population dynamics may lead to classification changes from urban to rural or vice versa from time to time. This reclassification occurs mainly to reflect changes brought about by urban growth (Cohen 2006; Dyson 2011), for example, when the total population and density change at the country level, thus changing the initial threshold (e.g. urban definition changes from 2,000 to 2,500 inhabitants); or also when a particular city’s initial category is reassessed due to population growth or decline (e.g. A city passes from being considered large to medium-sized when others large cities increased their sized).

Table 4.2 summarizes all the criteria used to define urban areas in the census rounds of the seven selected countries. Census definitions are shown because they represent the systematic efforts of national statistics offices to clarify and update their criteria. As illustrated, Venezuela, Mexico, Brazil and Ecuador have maintained fixed criteria to define urban areas over time; while Chile, Peru and Colombia have changed over the years. Nonetheless, population size and political-administrative hierarchy appear to be the most considered criteria when defining urban areas.

*Table 4.2 Classification of census definitions of urban and rural according to primary and secondary criteria: 1950 to 2000*

Secondary Criteria	Primary Criteria			
	Population size	Equipment / Services	Productive activity	Political-administrative hierarchy
Population size	Venezuela Mexico	Chile (1970)	Chile (1992 and 2002)	Colombia (1964, 1973) Peru (1972, 1981, 1993 and 2007)
Landscape	Chile (1982)	Chile (1960)		
Political-administrative hierarchy	Peru (1940)	Peru (1961)	Chile (1952)	Brazil Colombia (1951, 1985, 1993, and 2005) Ecuador

Source: Rodríguez, J. (2002) *Distribución territorial de la población de América Latina y el Caribe: Tendencias, interpretaciones y desafíos para las políticas públicas*, Serie Población y Desarrollo, N 32 (LC/L.1831-P), Santiago de Chile, Economic Commission for Latin American and Caribbean, Population Division.

Population size is the most used criteria to distinguish urban from rural areas and it also varies among countries. For the 2000 census, Chile and Colombia consider agglomerations of 2,000 inhabitants as a threshold for defining urban areas; and Venezuela, Mexico and Peru instead use 2,500 inhabitants. For its part, Ecuador considers urban areas to be those in which agglomerated dwellers have access to public services; while in Brazil only the legal geographical limit attached to the smallest political administrative unit (distritos municipales) is recognized as urban.

Without denying that the urban/rural distinctions adopted by national statistics offices are somehow empirically useful in explaining demographic behavior, this lack of a common framework makes cross-country comparisons and aggregations difficult. Indeed, the concept of

urban is an abstraction that involves multiple distinctions, even though they all have two things in common: 1) the differences between urban and rural populations are usually seen in gradients rather than kind, and 2) most every aspect that might be considered nowadays often allows for substantial overlap when considering urban and rural populations (National Research Council 2003).

#### **4.3.1 Toward a non-dichotomous urban definition approach**

Many of today's rural settlements have acquired characteristics that in the past were associated mainly with urban settlements. Many countries have seen an explosion in the number of conurbations, large urban areas resulting from the merging of neighboring towns across rural areas. All these new forms of urban distribution are better expressed when *urbaness* is defined as a continuum rather than a dichotomy (Cohen 2006; Dorélien, Balk et al. 2013). In this sense, there seems to be a consensus among experts to replace the standard dichotomous definition of urban with a rural-urban gradient, in which it is possible to operationalize the *urban continuum* (Champion and Hugo 2004). The idea of a gradient means that there are several distinctive states wherein these two concepts (urban and rural) are better represented.

Traditionally, when the urban-rural relationship has been recognized in cross-country and long-term mortality analyses in Latin America, it has tended to be described in terms of simple urban/rural dichotomies. However, if urban growth is accompanied by development (as in the Latin American cases) for evaluating "the restructuring and relocation of production, social and economic fragmentation and spatial reorganization, a basic polarization turns out to be inadequate" (Montgomery, Stren et al. 2003).

The recognition of the importance of city systems and the relevance of intermediate-sized cities in the Latin American urbanization processes prompts us to not give a wide berth to the dichotomous approach to urban/rural analysis. Rather, in contrast, I prefer to embrace the idea of a rural-urban continuum. This is not in fact an original idea. Via migration and urbanization process studies in Latin America, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has highlighted the importance of using the city as a geographical unit for demographic analysis in the region. What is more, all Latin American cities have been identified and classified using their population size as an indicator (Rodríguez 2002; ECLAC 2005). However, advances in the matter have focused on census data and not on registration system data; and they have done even less in terms of combining several sources of information, as any mortality research requires. To face this technical challenge, a brief review is presented on how the concept of an urban continuum has been operationalized in the specialized literature. Later on, I will describe the necessary arrangements made to match this concept with the political administrative hierarchy that is considered as criteria for defining urban areas.

#### **4.3.2 City size as an urban-rural gradient proxy**

The idea of a gradient suggests a continuum that puts at one extreme the most urban stage and at the other the most rural one. To illustrate, let's consider a range between the most densely metropolis and the most dispersed settlement, in which several intermediate states coexist. For defining a city size, lots of criteria could also be employed. A pretty common one is its



population size. Thus, population size has been used as a crude proxy for more fundamental city characteristics for which data are lacking. This is because it is assumed that the number of inhabitants also reflects the size of the territory, the complexity of the social, political, and economic systems, the development of public structures and services, and so on.

Even when it is probable that city size and the quality of public-sector management are not strictly correlated, larger cities have larger municipal staffs and greater total resources to deploy than small cities do (National Research Council 2003). This is the same for private services, enterprises and businesses that serve as public sector providers. In the same way, average health outcome measures such as “height-for-age” of children living in the largest cities tend to be better than elsewhere, and those from bigger urban areas in general enjoy better health than children in smaller urban areas (Montgomery, Stren et al. 2003). In Brazil, for example, a gradient in mortality levels according to city size (from low levels in the largest cities to high levels in small towns) were seen throughout the mid-twentieth century (Oya-Sawyer, Fernandez-Castilla et al. 1987). Hence, cities could be classified according to an idea of hierarchy in which the biggest cities are on the top and the smallest ones on the bottom.

In short, by understanding that the urban-rural relationship could be measured as a gradient and agreeing that the limits of the relationship are better defined when linking cities to their population sizes, it is possible to classify city clusters that better summarize the current urban-rural relationship. Here, a new decision must be made: Which are the most suitable and comparable cuts in population size that will gather the most analogous areas in all the countries?

As a reminder, the aim of this study is: 1) to compare countries with remarkable differences in population size<sup>2</sup> and urbanization levels while 2) recognizing the importance of the metropolization process across the Latin American region. Therefore, our initial instinct is to separate the *main city* –usually the capital — from the rest. As stated previously, it is usual to find in Latin American countries a high degree of demographic concentration in the main cities<sup>3</sup>. The main cities could be comparable between countries if they are defined as those that concentrate the biggest proportion of the national population and centralize the countries’ most important institutions regarding the economy, government, society and culture, regardless of their absolute population size.

So far, I have identified the need for having at least three levels: “main cities”, “other cities” and “non-cities” (or rural). These “other cities” give an idea of an existing heterogeneous pool, diversity of sizes and relative importance of the cities. Naively, it is possible to say the “other cities” group could at least be divided into three sub-groups, with big, medium and small cities being probably the most appropriate. However, any definition is imprecise, not only because of the conceptual complexity but also because the notions of big, medium and small imply an urban system of reference. Once again, cities with more than 500,000 inhabitants can be

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<sup>2</sup> Using the year 1995 as reference, according to ECLAC’s estimation, Brazil had around 164,614,688 inhabitants at the same time that Ecuador had just 11,703,174 inhabitants. As expected, their respective “main cities” also differ significantly in population size.

<sup>3</sup> Even though not all countries maintain the same urban structure of having just one city with absolute primacy, the majority of countries in the Latin American region present this characteristic. Two exceptions are Ecuador and Brazil, which show “bicephalic” primacy (or double-headed supremacy), in which two cities share economic-political power (Rodriguez, 2002). In both cases, economic power is concentrated in one city, which also has the highest number of inhabitants in the country (Sao Paulo in Brazil and Guayaquil in Ecuador), while the other city serves as the official political capital (Brasilia, founded in 1960 in Brazil and Quito in Ecuador).

medium-sized in Brazilian and Mexican urban systems but considered big in Chile and Peru, countries where the primacy of the main city have overwhelmed other settlements.

To accomplish the goal of creating suitable city size categories in the Latin American context, the specialized literature points out different amounts of inhabitants by which it is advisable to set the limits for distinguishing cities by their sizes. In this sense, a 20,000-inhabitant limit is conventionally used in comparative studies as a guarantee for urban conditions (Villa and Rodriguez 1998). This means delineating settlements with 20,000 inhabitants as the first cut-off for defining a city. That said, regardless of the definition of urban adopted by each country, towns with less than 20,000 inhabitants are closer to rural areas than to urban centers that exceed this limit. In this way, “non-cities” or rural areas are all settlements or dispersed land with less than 20,000 inhabitants.

Bearing this in mind, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has catalogued all Latin American cities with more than 20,000 inhabitants as well as their respective political-administrative divisions and inhabitants, which they did for the year 2000 in a document titled “Latin America: Urbanization and Urban Population Trends” (ECLAC 2005). They identified 1668 cities with more than 20,000 inhabitants in the seven countries selected for the study. It is obvious that the current number of cities is related to the size of the national population; thus, Brazil and Mexico are those with more overall cities, and Ecuador and Chile the ones with fewer cities.

Of the 1668 cities with more than 20,000 inhabitants, only nine could be considered as main cities. The rest of the cities belong to the heterogeneous pool containing a variety of sizes and territorial extensions. When analyzing the Latin American urbanization process, in which metropolization and several stages of deconcentration of the largest cities have played important roles in defining the existing city systems, one can see that cities with more than 500,000 inhabitants nowadays have a slower growth rate and more consolidated peripheries. Thus, 500,000 inhabitants seem to be a reasonable second threshold of city size for separating big cities from all the others. At the same time, and as said in previous chapters, deconcentration policies of the largest cities in Latin America have acted in favor of small (20,000 to 50,000 inhabitants) and intermediate-sized cities (50,000 to 499,000 inhabitants), giving them quite similar demographic and living standard patterns over recent decades. These similarities are even more accentuated in the most populous countries. Then, clustering small- and intermediate-sized cities also allows gathering homogeneous areas.

In summary, cities could be divided into 3 initial groups: 1) the main or capital city; 2) big cities with more than 500,000 inhabitants; and 3) intermediate-sized and small cities between 20,000 and 500,000 inhabitants. The results are shown in Table 4.3. Another important issue emerges: Ecuador has no representation for the big cities group. This is because the two main cities in Ecuador (Quito and Guayaquil) are the only urban centers with concentrations of more than 500,000 inhabitants.

Above all, comparisons among countries are necessary, so this research must indeed be satisfied by having representations for all created categories in each country as well as a balanced population distribution. In order to ensure the representativeness for all groups from this point on, the main and big cities are deliberately gathered together in order to avoid the issue of non-existing big Ecuadorian cities. Finally, all countries’ space are classified into three groups: 1) main and large cities (all cities with more than 500,000 inhabitants); 2) medium-sized and small cities (those with between 20,000 and 500,000 inhabitants); and 3) towns and rural areas (all settlements with both less than 20,000 inhabitants and dispersed populations).

Once the spatial groups have been established by city's size, the next important step is to identify the area/population belonging to a given city, because the size of a city's population is a function of how and where the physical boundaries are drawn. So, any estimate of the size of a particular city needs to be clarified in terms of whether it is an estimate of the size of a central city, the greater metropolitan area, or a wider planning region. Indeed, it can accurately be said that all the capital cities in Latin American countries are declining or expanding in population, depending on how their boundaries are defined.

Table 4.3 Number of cities according to population size

Country	City by size			
	Main	Large (>500,000 inhab.)	Medium-sized and small (500,000 to 20,000 inhab.)	Total >20,000 inhab.
Brazil	2	21	714	737
Chile	1	2	64	67
Colombia	1	7	133	141
Ecuador	2	0	44	46
Mexico	1	20	309	330
Peru	1	2	95	98
Venezuela	1	6	94	101
<b>Total</b>	<b>9</b>	<b>58</b>	<b>1601</b>	<b>1668</b>

Source: Latin American and Caribbean Demographic Centre (CELADE) — Population Division (2005) Latin America: Urbanization and Urban Population Trends

#### 4.3.3 Political-administrative structure in the demographic data

Several criteria are used in the definition of the formal administrative boundaries of the city; the contiguous inhabited territories with urban levels of residential density; all areas under the direct influence of transport and communication networks; and so on. In any case, “it is possible to be arbitrary and not include large numbers of people living contiguous to the city ‘proper’ at the urban fringe, even if they were included in the official statistics” (Cohen 2006). Furthermore, if social infrastructure investments have historically been greater in cities, the physical distance to services may play an important role — i.e., not just the fact of being inside the city, but of proximity to it. The populations of surrounding non-cities may still have access to the same services. In this sense, a city's extended zone of influence could also be representative.

Beyond any ideal definition of city boundaries or boundaries that are more suitable for this research, one issue must be reviewed from a more technical dimension: the political-administrative hierarchy arrangements in which all demographic data are captured and made available. In general, Latin American register data has no direct affiliation to cities as a geographical reference. In the seven selected countries, settlement identification as a geographical variable could be found in all censuses, but not in all statistical registration systems, nor in population estimates. Instead, it is possible to identify at least three common levels of political-administrative divisions for all countries' demographic data (see Table 4.4).

A Major Administrative Division (MAD) is equivalent to a French *région* or a *state* in United States of America; while a second level of Minor Administrative Division (MIAD) is similar to a *county* in the United States of America or a *département* in France. Both of these divisions have

local elected authorities, autonomous structures and budgets (Rodriguez and Cunha, 2015). A final, occasionally used level is the Sub-Minor Administrative Division (Sub-MIAD), which corresponds to a *township* in the United States of America or a *commune* in France. In some countries, this level exists only in big or medium-sized cities as a sub-region or neighborhood; in others, it resembles the cities themselves inside a particular MIAD. In the Chilean case, it does not exist at all.

Table 4.4 Political-administrative hierarchy in 2000's censuses.

Country	Urban Definition	Political-Administrative Hierarchy		
		Major Administrative Division	Minor Administrative Division	Sub-Minor Administrative Division
<b>Brazil</b>	Political and administrative delimitation	27 Entidade Federativa	5507 Município	10238 Distritos municipais
<b>Chile</b>	>2000 inhab. >250 Turistics dwellings	54 Provincias	342 Comunas	
<b>Colombia</b>	Continuous dwellings from cities center	33 Departamento	1114 Municipio	7510 Centros poblados
<b>Ecuador</b>	Political and administrative delimitation	24 Provincia	220 Canton	1149 Parroquia
<b>Mexico</b>	>2500 inhab.	32 Entidad Federal	2443 Municipio	7419 Localidades
<b>Peru</b>	>100 Occupied Dwellings	25 Departamento	195 Provincia	1834 Distritos
<b>Venezuela</b>	>2500 inhab.	24 Entidad Federal	335 Municipio	1091 Parroquia

Source: National Statistics Institutes from the seven selected countries

Considering the way that Latin American data is structured and the technical impossibility of identifying cities in all the demographic sources required for this research, Minor Administrative Divisions seem to be the lowest aggregation level (and the closest to a city level) in which it is possible to compare over time the seven selected countries.

#### 4.4 Minor Administrative Division and Cities

All National Institutes of Statistics in the seven selected countries have related their MIADs to their cities. In this way, MIADs for all countries could be classified according to the size of the city/cities they contain. MIADs from all countries are grouped into three spatial groups for this

research (see Table 4.5). Because the data from different sources are collated and the political-administrative structures in the seven selected countries are hardly static, synchrony becomes an appealing attribute. Yet, when official changes are made to political-administrative units in the seven selected countries, they are not necessarily incorporated at the same time into all data sources. This could be because changes are performed in the middle of the census period or due to delays in updating vital statistics registration databases. Either way, it is not surprising to find in one specific year that a country has two MIADs recently divided from an older single MIAD, which is referred to as two in the registered birth database but is still only one in the registered death database.

*Table 4.5 MIADs associated with the spatial group in official political-administrative structures of the 1990s, 2000s and 2010s*

Country	Spatial groups											
	Main & large (>500,000 inhab.)			Medium-sized and small (500,000 to 20,000 inhab.)			Towns & rural (<20,000 inhab.)			Total		
census round	1990s	2000s	2010s	1990s	2000s	2010s	1990s	2000s	2010s	1990s	2000s	2010s
<b>Brazil</b>	279	313	318	674	685	726	3538	4509	4521	4491	5507	5565
<b>Chile</b>	40	42	43	65	68	70	230	232	233	335	342	346
<b>Colombia</b>	32	32	32	129	130	130	870	952	961	1031	1114	1123
<b>Ecuador</b>	9	11	11	38	40	40	124	169	173	171	220	224
<b>Mexico*</b>	82	83	83	299	301	301	2024	2059	2072	2405	2443	2456
<b>Peru</b>	4	4	4	57	59	59	127	132	133	188	195	196
<b>Venezuela</b>	40	46	46	98	104	104	142	185	185	280	335	335
<b>Total</b>	<b>486</b>	<b>529</b>	<b>529</b>	<b>1360</b>	<b>1387</b>	<b>1430</b>	<b>7055</b>	<b>8238</b>	<b>8278</b>	<b>8901</b>	<b>10156</b>	<b>10245</b>

Source: Censuses.\* Mexico includes counties and 15 of Mexico City’s districts.

One way to maintain accuracy in measuring events and population-exposed-to-risk seems to be classifying a MIAD’s geographical territories into the spatial group gathering cities by their sizes at one unique point in time and following them through the whole period while maintaining the same classification. To be more precise, MIADs are classified according to the population size of the city they contained in the year 2000. With this classification, MIADs are not only fixed per se but so are their geographical territories at that unique point in time. Consequently, it is the spatial reference that is being followed backward and forward through different sources, thus maintaining their original classification.

Fixing MIAD’s geographical territories ensures keeping historically accurate events and person-years-lived attached to the same physical space. So, independently of whether or not the number of MIADs included in each spatial groups varies over time, the spatial groups maintain the same geographical territories for the whole period. This strategy implies that when new MIADs are created, it is necessary to: 1) backwardly follow split MIADs when they keep the same spatial group; or 2) force the classification in order to assure matching several data sources (in cases where a split MIAD does not preserve the same category within the spatial group). For a better understanding, each case is illustrated using an example below.

Case 1: Splitting MIADs within the same spatial group. A former MIAD has been divided into two, both containing cities whose sizes allow them to be classified within the same category as

the spatial group. To exemplify, the Chilean *comunas* of *Iquique* and *Alto Hospicio* were up until 2004 unified under the *Comuna de Iquique*, the territory and population that they separately cover nowadays. Iquique has a medium-sized city of the same name, and it had 144,417 inhabitants in 1992. In contrast, the territory later known as *Comuna de Alto Hospicio* had just 5,588 inhabitants in the same year. However, ten years later, in 2002, Alto Hospicio's population grew to 50,215 inhabitants, of whom 50,190 lived in the city with the same name. Both the cities of Iquique and Alto Hospicio are classified — according to their population size in the year 2000 — into the cluster of medium-sized and small cities, even though just the Iquique territory theoretically belongs to the same cluster before splitting. This type of official change in the political administrative division does not affect the coherence of categorization.

Case 2: Splitting MIADs with different city sizes. A new small MIAD is created from part of an older and bigger MIAD. The two MIADs must be classified differently, but in order to combine all the sources needed, the new one keeps the old category. One good example of this is the Venezuelan *municipios* of *Ocumare de la Costa de Oro* and *Mario Briceño Iragorry*. *Municipio Mario Briceño Iragorry* contained until 1999 both territories and is part of one of the main Venezuelan cities. In contrast, the new MIAD *Ocumare de la Costa de Oro* has historically had less than 10,000 inhabitants, of whom most are concentrated in a seaside village. The new MIAD does not have the condition to be classified in the main-and-large-cities group, but it is categorized as such anyway. The main reason for this is practical: it would otherwise not be possible to combine all sources (censuses, registers of death and birth, and population estimates) for the period of analysis.

At this point, it is necessary to return to previous discussion because MIAD territories indeed have in some cases more than one city, while in others one city may constitute several MIADs. For example, Quito contains three MIADs (*Cantones* in Ecuador): Rumiñahui, Mejía and Quito. In contrast, inside one particular MIAD is perhaps gathered what could be considered by each country to be either an urban or rural population; e.g., one MIAD containing one small- or medium-sized city and several dispersed populations. In any case, *urban* areas have been scaled in degrees when MIADs have been grouped according to the size of the city they contained; so *urban* in main cities refers to urban areas with more than 500,000 inhabitants, while *urban* in the towns-and-rural-areas group denotes urban areas with less than 20,000 inhabitants. In the same way, the proportion of rural population found in the MIAD main-and-large-cities group could easily correspond either to middle-class suburbs or to slums, which are sufficiently dispersed to not be considered urban by the country's official definition, but they have enough proximity to the main-and-large-cities' goods and services. Instead, rural areas in the towns-and-rural-areas group could be lacking in any opportunities due to proximity. Thus, the concept of an urban-rural relationship is kept as a gradient.

Table 4.6 shows the population distributions of the three spatial groups as well as their urban population proportions, according the official definition of *urban* in each country. The proportional distribution is quite close to one-third of the total population for each group. The main-and-large-cities group has the larger proportion, although Peru and Ecuador are exceptions in this pattern. Peruvian medium-sized and small cities concentrate more population than their main and large cities; and the proportional weight in Ecuador is almost equal between the main and large and the medium-sized and small cities groups. In addition, in MIADs grouped as main-and-large-cities group, at least 91 percent of the population is urban (exceptionally Ecuadorians have 84 percent), while in the towns-and-rural-areas group, the maximum percentage of urban population is 61 in Venezuela.

Aside from the urban-rural composition differences between groups, the population structures are also dissimilar. Population distribution by age, sex and urban-rural in the rounds of the 2000s censuses are shown in Figure 4.2. The structures display considerably different shapes according to city size for all the countries. It is clear that the towns-and-rural-areas group pyramids have broader bases; this means that the majority of the populations are younger. This happens not just due to a fertility effect, but also because of the remaining flows of rural-urban migration in the region, which at different levels reduce working-age populations in these areas. Quite the opposite occurs in the population structure of the main-cities group: this population is the oldest for all the countries (the young adult population is proportionally larger than other age groups).

*Table 4.6 Proportion of population and urban population in the spatial groups 2000s censuses round*

Country	Proportion of total population by spatial group			Proportion of urban population by spatial group			
	Main & large	Medium-sized & small	Towns & rural	Main & large	Medium-sized & small	Towns & rural	Total
<b>Brazil</b>	40	30	30	96	87	56	81
<b>Chile</b>	44	34	22	99	87	60	87
<b>Colombia</b>	43	28	29	97	81	40	76
<b>Ecuador</b>	37	37	26	84	62	28	61
<b>Mexico</b>	40	31	29	97	78	40	75
<b>Peru</b>	37	39	24	99	77	38	76
<b>Venezuela</b>	48	37	15	98	87	61	88
<b>Total</b>	<b>40</b>	<b>32</b>	<b>28</b>	<b>96</b>	<b>82</b>	<b>49</b>	<b>79</b>

Source: 2000s census rounds

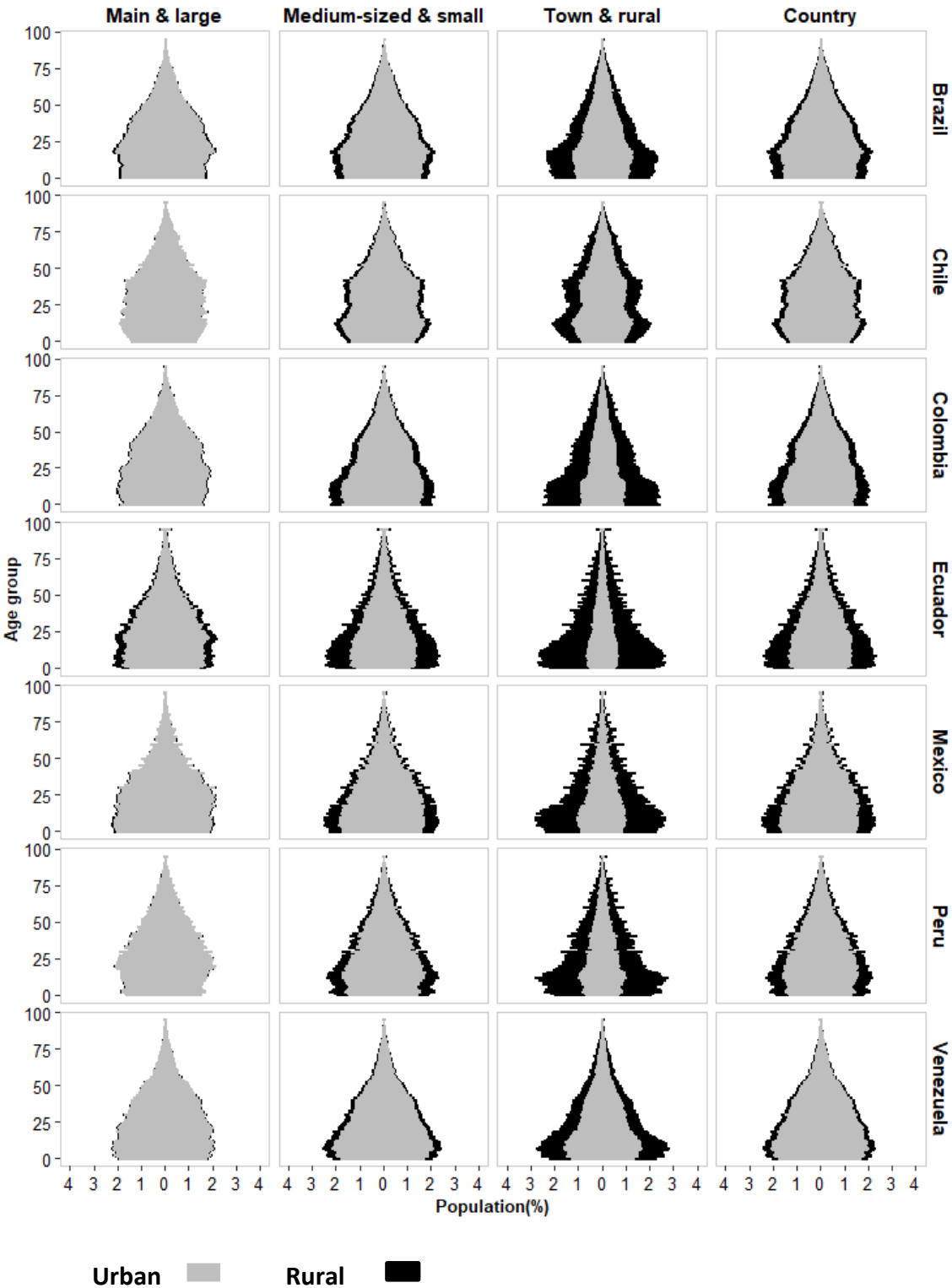
#### 4.5 Conclusion

Seven countries have been selected for investigating whether it is persistence the urban advantage in mortality in Latin America, and its link to the historical urban bias in resource allocations. They were chosen based on the path of their urbanization processes, their cities' system structure and their stages in the mortality transition. The seven are Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela. Each one of them defines "urban population" differently throughout their demographic database. I face the challenge of achieving comparability by adopting a non-dichotomous concept of urban-rural relationship, calls "urbaness". This term implies a continuous approach to the urban-rural space, which results into a more appropriate definition for analyzing living conditions nowadays.

Urbaness is captured in this research as indicative of an urban gradient by ordering cities according to their population's sizes. In this way, spatial group are defined by the dynamics of the historic demographics of the cities, described in the previous chapter. Three spatial groups have been identified in each country: main and large cities group, medium-sized and small cities group, and towns and rural areas group. Spatial groups are followed through different demographic databases by the Minor-Administrative Divisions (MIAD) officially attach to the cities by the national statistic offices in every country under analysis. Among the three groups,

some proportions of both urban and rural populations are found. Although they do not refer to the same qualitative characteristics. In the next chapters, a data inventory and assessment will give the time framework of this research base on the data availability at MIAD's level.

Figure 4.2 Urban and rural population distribution in 2000s censuses



Source: 2000s censuses



## 5. LATIN AMERICAN DEMOGRAPHIC DATA

Nowadays, it is possible to find all over Latin American countries a large number of specialized demographic and health surveys, censuses and register data; however, that vast source of information varies in periodicity and scope. It is only in recent decades that most of the countries have carried out regular censuses and developed infrastructures to manage continuous vital statistics registration.

Several regional programs have been set in motion over the years to encourage all countries to consolidate and improve population statistics systems. The biggest promoter, undoubtedly, has been the United Nations Economic Commission for Latin America and the Caribbean — ECLAC. Its Population Division, founded in 1957<sup>4</sup>, focuses on technical support and enhances the production and analysis of demographic data. One of the most recognized achievements of this office is the development of the computer program “REtrieval of DATa for small Areas by Microcomputer” — REDATAM. From 1987 up to now, REDATAM has been used for almost all Latin American countries at their National Statistical Offices, either for data processing or for online data consulting via the REDATAM Webserver. ECLAC’s permanent assistance to Latin American countries has resulted in standardized procedures, formats and structures in all Latin American demographic data. Moreover, ECLAC developed historical and comparative thematic databases. The best known of these are focused on international migration (IMILA), internal migration (MIALC) and Indigenous and Afro-descendant populations (PIAALC), all of which are publicly available.

Currently, the census databases of each national statistical institute in the seven selected Latin American countries can be acquired directly in REDATAM format, as a text file, in summary briefs and as computer files from the Pan-American Health Organization (PAHO), OECD databases, World Health Organization-WHO, United Nations Yearbook and IPUMS International, among others. National statistics institutes traditionally use census data to estimate yearly populations and their structures. Methodologies implemented in the countries may vary, even though all of them follow ECLAC recommendations and programs.

Similarly, vital statistics registration systems have existed in some Latin American countries since the mid-nineteenth century. Births, deaths, marriages and divorces are the four events registered in the selected countries. Permanent initiatives from the Pan-American Health Organization (PAHO) have supported both strengthening and the homogenization of vital statistics registration in the region in order to make them comparable. Together with censuses and vital statistics registration, there is a vast system of surveys to examine the lack of quality in the previous sources. In fact, specific demographic surveys were designed in the 70s and 80s to study in depth fertility as well as maternal and child mortality.

Considering the aim of this research, this chapter is dedicated to providing the detailed demographic data that is available in the region as well as to providing a historical assessment of this data. It is centered on three sources: census enumeration, vital statistics registration data, and population estimates. The chapter is divided into five sections. The first three provide a general description of the main demographic data sources of the region. Respectively, they

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<sup>4</sup> An agreement between the United Nations and the government of Chile titled the Provision of Technical Assistance for the Establishment of a Latin American Demographic Centre was signed on 13 August 1957, beginning what would later be (1997) officially recognized as the Demographic Division on the United Nations Economic Commission for Latin America and the Caribbean.

are census enumerations, vital statistics registration systems, and population estimates. The fourth section summarizes a detailed review of the historical errors found in the data; and, finally, brief conclusions.

## 5.1 Census Enumeration

Only a few Latin American countries have long-term traditions of compiling demographic statistics dating back to the nineteenth century and even before. Some of these are Argentina, Chile and Cuba. It is in 1910 during the first International American Conference (IAC) in Buenos Aires, Argentina that a regional call was made for carrying out regular censuses. The results of this call are seen only up until 1940, when the existence of databases for comparative purposes was pointed out as a regional main concern. During that year, and through the constitution of the Inter-American Statistic Institute (IASI), standardizations on methodologies, questionnaires and periodicity began to be implemented. Hereinafter, IASI created the Americas Census Program (COTA) to assist and support all Latin American censuses from 1950 to 1980. As a result, six of the seven selected countries managed to carry out censuses continuously from 1950 on (see Table 5.1 for detailed information).

Censuses are the most important source of demographic data for most of the countries in Latin America, mainly because they are the only sources by which it is possible to link information for the whole population on several levels (individual, household, dwelling, community, city, MIAD, etc.) and in regard to various dimensions (fertility, mortality, migration, education, income, employment, etc.).

Some variations in definitions and strategies for conducting censuses are found across the region and among the seven selected countries. The main ones relate to the definition of the census itself and the enumeration unit of analysis. Countries such as Ecuador, Chile and Peru have traditionally used “*de facto*” censuses (the enumeration of individuals wherever they are found); while Brazil, Colombia, Peru and Venezuela have chosen “*de jure*” (enumeration of individuals according to where they usually live). Similarly, the enumeration unit also has differed from one country to another. Undoubtedly, the most common unit has been the *household*<sup>5</sup>, but Mexico is an exception in that it instead counts the *dwelling*<sup>6</sup>. These particularities as well as the incorporation of different technologies and levels of specialization have had differential effects on their census quality and coverage (Tacla Chamy 2006).

About the census itself, the problem that is relatively mentioned the most in the region refers to confusions regarding who should or should not be included in each enumeration unit. “*De facto*” censuses are likely to misreport travelers or people in transit, specifically by identifying where they are found at that moment as their place of usual residence. By comparison, the usual problems with “*de jure*” censuses are linked to difficulties in interpreting the concept of habitual resident inside a household or dwelling. Both double reporting and omission may be found in the two types of censuses (Del Popolo 2000). Nevertheless, experience has led to more improvements in coverage when a “*de jure*” census is implemented (Aliaga 2010). Internal migration information is the most sensitive to the type of census that is conducted. In a “*de facto*” census, three different geographical precisions must be declared for each individual:

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<sup>5</sup> *Household* is commonly defined as one or more people who live in the same dwelling, whether they are relatives or not, and who also share meals or living accommodations.

<sup>6</sup> *Dwelling* is a structurally separate accommodation, either containing a single household space or several household spaces sharing some facilities.

place where census occurred, place of residence, and place of previous residence. In a “de jure” census, there are only two: places of current and previous residence. When information is missing for one of the variables, it is impossible to have any reference for changes in residence.

The completeness of census enumerations and their quality are highly variable, not just between countries but also between censuses in the same country (see Table 5.1). This is mostly because omission levels in population counts do not always follow a linear improvement pattern but may fluctuate sharply, following circumstantial conditions (Palloni and Pinto-Aguirre 2011). For instance, and contrary to what might have been expected, assessments have shown that 1980s censuses do not show substantial improvement in both quality and coverage compared to previous ones. It is likely that the problems observed are linked to the economic crisis and political conflicts that affected the region during that period (Chackiel and Arretx 1988). Overall, census omission has varied in the seven selected countries from 10.6 percent (Colombia, 1973) to 1.8 percent (Chile, 1982).

Some countries have used post-enumeration surveys to conscientiously calibrate more precisely their estimates; while, others have done it through indirect methods, such as through demographic components methods or via census conciliation. In all matters, an official correction has been introduced to all counts. The main corrections — from 1950 to 2000 — aim to compensate for: 1) sex differential omission (men have historically suffered higher proportions of omission than women in all Latin American population counts); and 2) age differential omission (the under-five-year-old population is more likely to be omitted than any other population age group). These problems were substantially overcome during the 2000 and 2010 census rounds (Tacla Chamy 2006).

## **5.2 Vital statistics registration system**

In order to produce real-time data at the national and local administrative levels, two basic characteristics must accompany all civil registration and vital statistics: universality of coverage and continuity. The efficiency of the vital statistics system depends on several aspects, for instance, from how the administrative procedure is established, to whether or not it is linked to health services, to perceived family benefits from the registration itself. “In most countries, births are more likely to be registered than deaths, mostly because the perceived benefits of birth registration to families are more direct and immediate than those of death registration” (AbouZahr, Savigny et al. 2015).

Since the end of the nineteenth century, official vital statistics systems have been established in Latin America, although at that time they could only offer approximations of vital records at the national level. It is only after 1950 that more regular information by age and sex started to be produced in the majority of the countries (Palloni, Pinto et al. 2015). Even though nowadays they all have consolidated vital statistics systems, the scope of coverage on civil registration has historically varied. To illustrate, Chile has had virtually complete vital statistics since a long time ago. Others, such as Peru and Colombia, continue in recent years to have a high level of under-coverage, around 20 percent (PAHO 2014). In between, Ecuador, Venezuela, Brazil and Mexico have experienced steady improvements over time.

A recent Pan-American Health Organization review of the Latin American vital statistics system (PAHO 2007) shows somewhat homogeneous characteristics in the structure, processing and validation of the information derived from vital events in the seven countries selected for this

research. All of them have specific legislation for standardizing and defining the civil registration act, as well as for even coding manuals and specific formats to gather the information.

*Table 5.1 Availability of population censuses and official omission, 1850-2015*

Country	Census before 1950*			Census 1950 and after						
	Period	Year		1950	1960	1970	1980	1990	2000	2010
Brazil	<1900	1872, 1890	Year	1950	1960	1970	1980	1991	2000	2010
	1900-1950	1900, 1920, 1940	Type	De jure	De jure	De jure	De jure	De jure	De jure	De jure
			% Omission	4	4.2	3.6	2.7	3.7	2.8	2.4
Chile	<1900	1854, 1865, 1875, 1895	Year	1952	1960	1970	1982	1992	2002	2012
	1900-1950	1907, 1920, 1930, 1940	Type	De facto	De facto	De facto	De facto	De facto	De facto	De jure
			% Omission	6.3	4.5	7	1.8	2.4	4.3	9.2
Colombia	<1900	--	Year	1951	1964	1973	1985	1993	2005	--
	1900-1950	1905, 1912, 1918, 1928, 1938	Type	De jure	De jure	De jure	De jure	De jure	De jure	--
			% Omission	8.9	3.2	10.6	8.2	6.7	4.9	--
Ecuador	<1900	--	Year	1950	1962	1974	1982	1990	2001	2010
	1900-1950	--	Type	De facto	De facto	De facto	De facto	De facto	De facto	De facto
			% Omission	8.5	8	3.4	4.3	5.5	6	4.5
Mexico	<1900	1895, 1900	Year	1950	1960	1970	1980	1990	2000	2010
	1900-1950	1910, 1921, 1930, 1940	Type	De jure	De jure	De jure	De jure	De jure	De jure	De jure
			% Omission	8.9	9.8	8	5	4.3	3.9	3
Peru	<1900	1876	Year	--	1961	1972	1981	1993	2007	--
	1900-1950	1940	Type	---	De facto	De facto	De facto	De facto	De facto	--
			% Omission	--	3.3	3	4.5	3	3.3	--
Venezuela	<1900	--	Year	1950	1961	1971	1981	1990	2001	2011
	1900-1950	1926, 1936, 1941	Type	De jure	De jure	De jure	De jure	De jure	De jure	De jure
			% Omission	3	3.6	4.6	7.5	9.1	7.8	6.5

Source: Economic Commission for Latin America and the Caribbean, Population Division, 2012 Revision — Principales cambios en las boletas de los censos latinoamericanos de las décadas de 1990, 2000 y 2010. \*Palloni, A.; Pinto, G.; and Beltran-Sanchez, H. (2015). "Two centuries of mortality decline in Latin America: From hunger to longevity". October 2015.

Three types of structures could be identified in the vital statistics systems of the seven selected countries: 1) a centralized information system, meaning a single entity responsible for producing the statistics (such as Ecuador, Chile and Colombia); 2) a decentralized system, wherein several official statistics offices produce the information (Brazil, Peru, and Venezuela); and 3) a mixed system that combines elements of the centralized and decentralized system (Mexico). In all cases, a combination of registry offices and other institutions plays a role in the process. Normally, health system authorities are involved when births and deaths occur.

It is not only in the production but also in the official publication of vital statistics can one find more than one institution involved. In such cases, it is expected that the published information will be consistent. Yet, Brazil and Venezuela continue to present differences in their published statistics. Historically, data coming from health ministries and national secretaries tend to have higher numbers of vital events than those coming from registration systems.

In all countries, there are legal national frameworks for regulating the definitions of events as well as institutional feedback (at different levels) for coproduction or validation of the information. A variety of formalized review protocols standardizes the review of individual manual questionnaires as well as the automatic algorithms that are applied to the databases for correcting any inconsistency in the information, while several methods are used to cross-validate information. In Chile and Mexico, cross-checking databases at the local and regional level are established as a method for quality certification (see Table 5.2). In the same way, local or regional under-registration studies are constantly done on Brazilian, Colombian and Peruvian vital registration systems; while Venezuela and Ecuador search for consistency in their historical vital event patterns in order to ensure quality (PAHO 2007).

Table 5.2 Characteristics of the vital statistics registration systems

Country	Institutions Involve		Institutional Feedbacks	Coherent outputs	Review protocols		Quality certification
	Production	Publication			National level	Local level	
Brazil	2	2	yes	not	MQR	ADR	Local under-registration studies
Chile	1	1	--	--	MQR	Not	Crosschecking databases
Colombia	1	1	--	--	MQR	MQR	Regional under-registration studies
Ecuador	1	1	--	--	Not	MQR	Coherence in historical patterns
Mexico	2	2	yes	yes	ADR	MQR	Crosschecking databases
Peru	2	1	yes	--	MQR	Not	Regional under-registration studies
Venezuela	2	2	not	not	ADR	ADR	Coherence in historical patterns

Source: \*\*PAHO. (2007). "Situación de las Estadísticas Vitales, de Morbilidad y de Recursos y Servicios en Salud de los países de las Américas (Informe Regional)". November 2007. MQR= Manual Questionnaire Review/ ADR=Automated Database Review

To be sure, generalizations could be made to characterize statistic registration systems in the seven selected countries; however, some processes and particularities must also be distinguished in the framework of this research. In this case, procedures related to three vital events are described and characterized: births, deaths and migration.

**5.2.1 Birth registration**

When it comes to registering births, all seven countries involve both civil registration systems and health institutions, mostly at the local levels through the register office and either the hospital or the district health office. A unique individual birth certificate is issued in all countries by the health institution or authority witnessing the event. Civil authorities recognize this certificate later in a separate act. In Colombia, Chile, Ecuador and Brazil, birth registration must be done as a separate task outside the health institution. This means that even when the birth has occurred inside a hospital, parents must go to a separate official place of civil registry, such as a public notary, where both parents and their documentation are necessary to formalize the act. Mexico follows the same separate processes of using both a health office and a registration

system; however, the physicians or midwives who witness a delivery are required to report the birth to the civil registry judge within the following twenty-four hours (Manckenzie 2009). By comparison, most of the health centers (hospitals and clinics) in Peru and Venezuela have public notary offices on the premises to facilitate the process (Duryea, Olgiati et al. 2006). Parents are the usual persons authorized to register births, although Mexico is an exception in that it legally allows grandparents to do so. In addition, special documents are requested for authorizing birth registrations in all countries under special circumstances such as orphanhood or adoption.

The parent's official identification documents and marriage certificate are requested in most of the countries for completing the registration. In general, the process has no excessive costs associated with it (see Table 5.3). However, it is not so easy for some marginalized populations to cover all the expenses involved, particularly the transportation costs. The registration act may require commuting: 1) from the place of occurrence to the place of residence (in cases where they are different); 2) to the closest civil registry offices in another city (in cases where there are not a sufficient number in the country) (Harbitz, Benitez et al. 2010). These extras costs increase differentials in the registration among subpopulations.

All countries establish periods of different lengths for the proper registration of the birth certificate issued by health authorities. Mexico is the country with the longest period of time (180 days) while Brazil and Venezuela have the shortest (see Table 5.3). Copies of all birth certificates are sent to different offices (civil and health authorities) before being processed and published as statistics.

*Table 5.3 Birth registration period and costs*

Country	Birth registration period	Late Registration penalty	Costs	% Estimated under-registration*
<b>Brazil</b>	15 days	not	US\$ 5.95	8.9
<b>Chile</b>	60 days	not	US\$ 4.75	1
<b>Colombia</b>	30 days	not	0	10
<b>Ecuador</b>	30 days	yes	US\$ 2	15
<b>Mexico</b>	180 days	not	0	14,2
<b>Peru</b>	3 to 30 days	not	US\$ 7.95	7
<b>Venezuela</b>	20 days	not	0	8

Source: Harbitz et al. (2010). Inventario de los registros civiles e identificación de América Latina y el Caribe. Inter-American Development Bank, New York, September, 2010. \*2008-2009 UNICEF's evaluation

Coverage assessment based on long-term population estimates highlight that half of Latin American countries have had at least 90 percent coverage of overall births at the national level for the last 50 years. The proportion of estimated unreported births in the region went from 57.3 percent in 1955-1960 to 15.6 percent in 2000-2005. The latest ECLAC and UNICEF evaluations estimate birth under-registration for the 2005-2010 period to be below 10 percent for the entire Latin American region. Indubitably, these improvements have occurred neither linearly nor simultaneously for all countries. Ecuador, for instance, made their greatest improvements during the years 2000 to 2005, after changing their civil identification system. Meanwhile, Brazil managed to reduce birth under-registration by more than half in the period

of 1999 to 2009 (from 21 percent to 8 percent), which they accomplished by creating a parallel registration procedure within the health system<sup>7</sup> (ECLAC 2014; UNICEF 2016).

No historic sex differentials have been found in registered births (UNICEF 2016). However, and despite overall improvements, internal differentials in coverage persists between political-administrative units, ethnic groups and social stratus. Birth registration rates are very unequal according to sub-populations inside the countries, and under-registration seems to affect more the most marginalized population segments: Indigenous peoples, Afro-descendants, migrant children and the children of migrants and poor families living in rural, remote or border areas (ECLAC 2011). Mexico is a good illustration of such diversity. National coverage on registered births has been estimated at 78.8 percent during the year 1999, and at 85.8 percent ten years later. Nevertheless, this improvement is concentrated on specific administrative units. In 2009, Jalisco and Aguas Calientes (states located in the central area) had 100 percent coverage while Chiapas, an agrarian and the southernmost state, hardly achieve at 60 percent (UNICEF 2016).

Lack of universal coverage is not the only problem for birth registration. The delays in incorporating births into the statistics turn out to be determinants. For instance, even in Chile, where birth coverage has been virtually complete for a long time, late registrations represented 1.5 percent of total births in 2005 (ECLAC 2014). In the same vein, the Ecuadorian National Statistics Institute officially considers live births registered even four years after their occurrence to be “complete data” in terms of the final and conclusive information (INEC 2016). Countries always take different measures to continuously reduce the time between the occurrence and the registration of the event. Fines and late fees are enforced to motivate parents not to delay the registration after a certain period<sup>8</sup>. Also, mobile “registration campaigns” have been deployed over recent years as a way to increase birth registration in isolated areas and recover delayed registration in several countries (Duryea, Olgiati et al. 2006).

### 5.2.2 Death registration

Regardless of where a death occurs in the seven selected countries, the only entities allowed to issue a medical certificate of death and its cause are public and private health facilities, forensic doctors, and in some cases any qualified health personnel acting as a replacement. The medical certificate itself has no value for civil or legal procedures without proper registration. The death registration constitutes a separate act wherein (at least one) close relative of the deceased presents the medical certificate of death to an official place of civil registry. Over recent decades, registration of death has become mandatory for access to cemeteries and legal burial grounds in all seven selected countries.

The proportion of deaths receiving medical certificates has been increasing considerably in these countries since the sixties. By the first decade of the twenty-first century, more than 90 percent of registered deaths had medical certificates in most of the countries (see Table 5.4). This improvement could be related to the continuous expansion of the public health system.

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<sup>7</sup> In 1991, the Unified Health System Informatics Department (known as DATASUS for its Portuguese acronym) was created, with the aim of providing all the information systems and computer support necessary for planning, operating, controlling and maintaining the national databases.

<sup>8</sup> Unfortunately, this type of measure could act against its own aims for a specific population. A good example of this case refers to some Indigenous ethnic groups who usually wait a certain period of time before naming their children. When the time for naming the children arrives, it is already considered a delayed registration. Fines and increased costs for registration contribute to increase the under-registration of these subpopulations (ECLAC, 2011b).

Likewise, the proportion of deaths that occurred in public or private health centers among total deaths also increased.

*Table 5.4 Proportion of registered deaths with medical certificates*

Country	1960	1970	1975	1980	2004-2006
Brazil	--	--	--	--	93.7
Chile	72.1	72.6	83.4	89.6	99
Colombia	47.5	65.7	72.1	80.9	99.5
Ecuador	3.1	43.6	49.6	64.5	87.9
Mexico	--	75.8	78.5	87	97
Peru	44.2	--	--	66.6	--
Venezuela	--	79.4	83.1	--	99.7

Source: Bay, G.; Orellana, H. (2007). La calidad de las estadísticas vitales en la América Latina, Paper presented at the expert workshop on the use of vital statistics: scope and limitations, Santiago, ECLAC, December 13 and 14, 2007.

It is during the eighties that most of the countries established a mandatory unique individual death certificate. The formats of these death certificates have been modified on several occasions in order to improve their quality or to add new information. Even so, the main information remains susceptible to comparison over time. Both official death certificates and previous death summary acts are based on medical certificates issued by health authorities in each country.

Medical certification in all countries has followed norms and protocols established by the International Classification of Diseases (ICD) and all its revisions since the fifties. This means that besides providing basic identification for the personal identity and the deceased's place of living, they also provide a description of the events that led to the death. As Table 5.5 shows, changes in the ICD's versions have been incorporated more or less at the same time for all the countries.

*Table 5.5 International Statistical Classification of Diseases revisions*

Country	1950-1959									1960-1969									1970-1979									1980-1989									1990-1999									2000-2010													
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
Brazil																			IX									X																															
Chile	VI			VII						VIII						IX									X																																		
Colombia	VI			VII						VIII									IX									X																															
Ecuador	VI			VII						VIII						IX									X																																		
Mexico	VI			VII						VIII						IX									X																																		
Peru																			VIII									IX									X																						
Venezuela	VI			VII						VIII						IX									X																																		

Source: National health statistics institutes in each country. Dark areas represents periods without information at the national level.

Regarding coverage, less than half of Latin American countries in 1960 had what could be classified as satisfactory records (less than 20 percent under-registration). Throughout this period and, consequently, later in time, an age differential in coverage was still found. In the eighties, one-third of Latin American countries had less than 20 percent under-registration for adult mortality, but only five were found with the same levels for under-fifteen-year-old mortality. Maximum under-registration in this period was in the 0 to 14-year-old and 50-or-over



groups. The same age differential pattern occurred with cause-of-death information. Furthermore, for all countries and age groups, male cases had better coverage than females (Jasper-fajer and Orellana 1994).

In recent years, regional coverage in death registration has been estimated<sup>9</sup> at 78.9 percent (2000-2005). The huge improvement in regional coverage observed from 1950 to 1980, when the proportion went from 26.4 percent to 72.5 percent, has decelerated. From the eighties to the beginning of the twenty-first century, the improvement in coverage was only 6.4 percent. Considering the seven selected countries (see Table 5.6) independently of the speed of progress, all countries show an increasing coverage of deaths. For the whole period, Chile presents the highest proportions and Peru the lowest, regardless of the method or source used for the estimation.

As mentioned before, cause-of-death data has been progressively included in Latin America registration systems. In the 1960s, only four countries had acceptable statistics by cause-of-death. This number increased during the 1970s and, by the end of the 1980s, all countries (except Peru and Colombia) had at least 80 percent of deaths with known causes and complete information (Jasper and Orellana, 1994). Coverage and the proportion of completed information were closely related until the beginning of the 1990s; but after that period a more variable relationship between quality and coverage is observed.

*Table 5.6 Estimated under-registration of deaths*

Country	1944-1945(ù)	1950-1960(ù)	1960-1965**	1975-1980***	1980-1985	1990-1995(#)	2001(¤)	2010-2012(\$)
<b>Brazil</b>	--	11.5	34.4	19.6	15.4	17,3	12.3 - 24.7	4 - 9
<b>Colombia*</b>	6.6	3.9	10.1	26.5	11.5	24,4	>24.8	>20
<b>Chile*</b>	25.1	21	3.7	6.3	1.1	-0,4	<2.3	<4
<b>Ecuador</b>	--	26.2	12.8	18.9	14.6	16,7	>24.8	10 - 20
<b>Mexico</b>	11.7	14	11.3	9.3	4.2	8,9	2.4 - 12.2	<4
<b>Peru</b>	--	51	42.6	35.7	46.8	--	>24.8	>20
<b>Venezuela</b>	14.5	13.4	24.8	9.4	8	9,9	2.4 -12.2	4 - 9

Source: Jasper and Orellana (1994). "Evaluacion del uso de las estadísticas vitales para estudios de causas de muerte en América Latina". Notas de Población, nº 60: pp 47-77. CELADE, Santiago, Chile. \* Own country reported information. \*\* Chackiel, j (1996). "La investigación sobre causas de muerte en America Latina". Notas de Población, nº 44: pp 9-30. CELADE, Santiago, Chile. \*\*\* Demographic yearbook estimate. (¤) PAHO (2005) "Atlas de indicadores básicos de salud en las Américas, 2001". (ù) Palloni et al. (2015) "Two centuries of mortality decline in Latin America, from hunger to longevity". (\$) PAHO. (2014). "Basic indicators". (#) Bay, 2015. América Latina: diferencia relativa de las defunciones totales (por cien) implícitas en las estimaciones y proyecciones de población y las defunciones registradas y disponibles según quinquenio, 1950-2005

Even more recently, Mikkelsen et al. (2015) evaluated the quality and coverage of vital statistics registration in the seven selected Latin American countries, among others. Using data collected by the Global Burden of Disease for each country's civil registration system, they created a Vital Statistics Performance Index (VSPI)<sup>10</sup>, wherein six components are evaluated: completeness of

<sup>9</sup> Reference estimated by the United Nation Economic Commission for Latin America and the Caribbean(ECLAC), obtained from population projections using the difference between implicit and observed deaths.

<sup>10</sup> Mikkelsen et al. (2015) built a vital statistics performance index (VSPI) as a proxy for data quality to evaluate yearly and by country. The VSPI metric is transformed into an index that ranges from 0 to 100 to evaluate all civil registration and vital statistics systems worldwide since 1980. VSPI is applied to both adult and infant mortality.

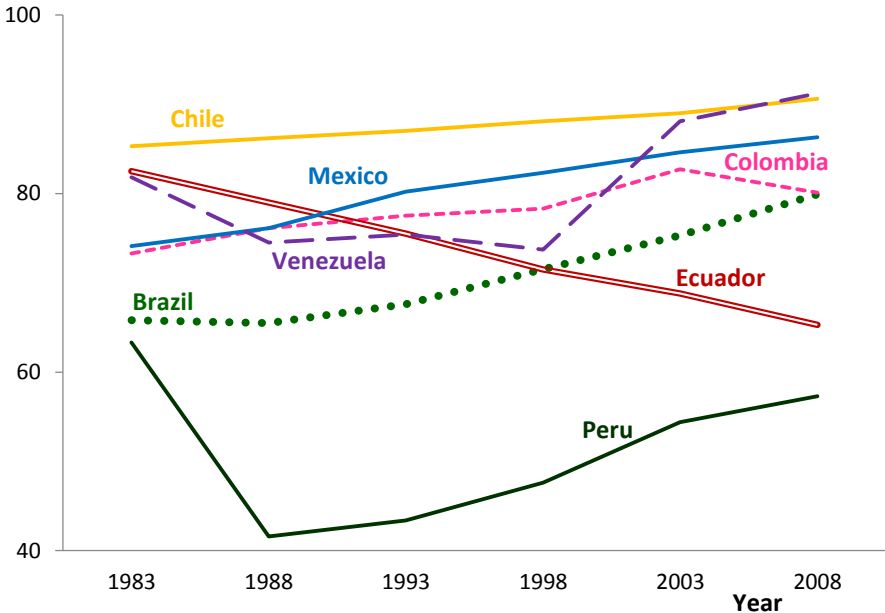
death reporting, quality of death reporting, level of cause-specific detail, internal consistency, quality of age/sex reporting, and data availability (i.e., timeliness). Through the VSPI, they concluded that vital statistics registration in Chile, Venezuela, and Mexico since 2005 presented very high quality standards (VSPI higher than 95 out of 100), followed by Brazil and Colombia (see Figure 5.1). In six of the seven countries, they pointed out the considerable improvements in the coverage and general quality of the data reported by the systems. As an exception, Ecuador has consistently increased vital statistics coverage over time, but not the quality of the reported data (Mikkelsen, Phillips et al. 2015).

**5.2.3 Migration registration**

Migration is defined as the transferal of residence from a place of origin to a place of destination across a geographical (or administrative) boundary. To capture population movements due to changes of residence, a population registration system is commonly used. However, none of the seven countries have an annual population registration system for following these changes of residence; thus, the only information available comes from census data.

Two types of migratory movements are followed in Latin American censuses: international and internal migration. Both are studied according to the time of occurrence: *permanent migration* is defined as having a current place of residence that is different from the place where the person was born; and *recent migration* refers to a recent change of residence. The time limit is set mostly in the previous 5 years before the census. For most of the countries, the geographical reference is the equivalent of a United States’ county or French *Département*.

Figure 5.1 Vital Statistics Performance Index (VSPI).



Source: Mikkelsen et al. (2015) "A global assessment of civil registration and vital statistics systems: Monitoring data quality and progress." The Lancet; Vol. 386. October 2015, pp. 1395-406.

A group of questions is dedicated in censuses to build a geographical and time reference. These may vary between censuses and countries. Table 5.7 gives a general view of the questions

regarding recent (internal migration and external or international emigration) as well as permanent migration. The age reference of the interviewed populations also varies; they may ask either population above 5 years old or the entire population regardless of the age.

Because of the nature in which information is declared on the census, there is an enormous lack of data regarding international emigration in all Latin American countries. Five of the seven selected countries (Ecuador, Mexico, Colombia, Peru and Brazil) included in their latest censuses questions about members of the household who have emigrated in previous years. Of course, these questions give information only when some members of the household have remained, but not when all members have emigrated. To have access to complete information, published data gathered by the World Bank and ECLAC in all censuses around the world turns out to be useful for taking stock of international migration.

*Table 5.7 Migration questions in census rounds*

Country	Census round	Recent Migration				Permanent Immigration	Interviewee
		Internal		External			
		Geographical reference	Time reference	Geographical reference	Time reference		
Brazil	1990			--	--		
	2000	County	Open Interval	--	--	County	All
	2010			County	Open Interval		
Chile	1990						
	2000	County	5 years before	--	--	County	>5 year old
	2010						
Colombia	1990			--	--		>5 year old
	2000	County	5 years before	County	Open Interval	County	All
	---						
Ecuador	1990			--	--		All
	2000	County	5 years before	County	5 years before	County	>5 year old
	2010				Previous census		All
Mexico	1990	State		--	--		
	2000		5 years before		5 years before	State	>5 year old
	2010	County		County			
Peru	1990			--	--	County	>5 year old
	2000	County	5 years before	County	Open Interval	--	All
	--						
Venezuela	1990	City					
	2000	County	5 years before	--	--	County	>5 year old
	2010	County					

Source: ECLAC. (2012). Principales cambios en las boletas de los censos latinoamericanos de las décadas de 1990, 2000 y 2010. Series Manuales N° 80, Santiago, Chile, 2012.

Overall, a general enhancement in the quality and coverage of the vital statistics registration systems has been achieved. Evidently, targeted improvements are still required in order to overcome existing errors. Later, I present a brief description of the persistent and generalized errors found in the data. Despite everything, both birth and death registrations have acceptable coverage levels for all the countries for the period this research focuses on (2000 to 2010).

### **5.3 Population estimates**

Latin American population estimations and projections by sex and age group are carried out by the National Statistics Institutes in each country in collaboration with ECLAC's population division. For this purpose, PRODEM (DEMographics PROjections), an interactive system, was designed for assisting demographers and users with similar knowledge to prepare official population estimates and projections. The system contains two modules: one for national and major areas, and the other for sub-areas. The method applied is the demographic component method that corresponds to an adaptation of the projection programs ABACUS and RUP (Rural-Urban Projections), which were developed by the United Nations Population Division (Tacla Chamy 2006).

The biggest challenge is related to estimating migration, especially in some countries with important levels of migration, such as Mexico and Ecuador. Lack of continuous population registration hinders accurate estimations of return migration or migration flow. In order to solve this problem, estimated migration information via the Roger-Castro model is used to incorporate migration flow levels (Bay 2012), using censuses as reference data.

At the beginning of the twenty-first century, all seven selected countries reviewed and updated their long-term national population estimates and projections by taking into account the latest census rounds. Chile, Ecuador, Peru and Venezuela carried these out jointly with ECLAC's population division; while the National Population Council (CONAPO) in Mexico conducted a first phase, followed by a more definitive one in collaboration with ECLAC. Correspondingly, Brazil combined census and survey data to update their estimates. The latest reviews of population estimates have included probabilistic models in some components, mainly mortality and fertility estimates. Subnational population estimations are carried out completely under the criteria of the National Statistics Institutes.

Some challenges could be found when using population estimates. The main challenge is the limit in the final age group interval, which is usually 80 years old or more. Decades ago, this situation was not problematic, as most of the Latin America population was concentrated in younger ages. However, the 60 and older age group has been increasing its relative weight in the total Latin American population, from a mere 5.6 percent in 1950 to 9.9 percent in 2010. From this group, it is the 80 and older age group that shows growth rates even more appreciably higher (ECLAC 2011). Having population estimates up to 80 years old hampers the possibility for accurate and detailed analysis of this growing population group.

Another important issue is the fact that specific age estimates are not published yearly for all levels of subnational populations in all countries. Normally, estimates by single year of age are available for the main national subdivisions. For the smallest geographical divisions or political-administrative levels in most of the countries, only population by sex and five-year or ten-year (Mexican case) age groups are available.

## **5.4 Historical error found in data quality assessment**

In 1978, Chackiel and Macció made the first attempt to assess Latin American demographic data in terms of the main quality issues and the need to have methods for its evaluation, correction and adjustment. Since then, great progress has been made. This section is dedicated to explaining the main data quality patterns found in all demographic data in the region. Three issues are highlighted because of the interest they received in the specialist literature over time: age misreporting, usual place of residence declaration and ill-defined causes of death.

### **5.4.1 Age misreporting**

It is well documented in the demographic literature how age misstatement could lead to misleading results in mortality estimates. As the simple construction of estimates requires deaths and person-years lived, accuracy is affected when there is under/over age statements in one or both sets of data. Two specific problems have been found in Latin American demographic data related to age declaration: overstatement and digit preferences.

Latin American data have been submitted to several historical assessments in regard to age misreporting. The results on age misreporting from an analysis using indirect techniques on Chilean data from the seventies suggest that: 1) the tendency to overstate age is less in registered deaths than in populations counts; and 2) female age of death misreporting is often higher compared with males (Florez-Valderrama 1983). Dechter and Preston (1991) also confirmed these findings in Mexican and Venezuelan data from 1960 to 1982. They applied ratios of projected/current populations for open-ended-cohorts using data collected from censuses and death counts, thereby proving that age declarations in censuses are likely to be more exaggerated than in death data (Dechter and Preston 1991). Their results also mention a large sex differential: misreporting in female census data at older and very old ages tends to be more severe than for males — except in Venezuela, where no sex differential appeared.

The most dramatic impact of this differential pattern (overstating age in registered deaths and population counts) is that it misleads the reported life expectancy and the pace of years gained in life expectancy. If age overstatement in deaths is higher than age overstatement in the population, then mortality rates will be systematically biased downward at older ages. This bias would result in an overestimation of life expectancy for the older population, and it would give the misleading impression that the pace of gains in life expectancy is occurring more rapidly than is in fact happening (Palloni and Pinto-Aguirre 2011). In contrast, larger overstatements of age in registered deaths would misleadingly indicate a slower increase in life expectancy than would indeed be occurring.

More recently, there is empirical indication that age overstatement has experienced noticeable improvement over time in Latin American data. A historical evaluation of census age declaration has shown a significant reduction in digit preference and age overstatement, finding that it has maintained acceptable levels since the 80s census rounds for most of the countries (Ricon 1986). Still, some countries continue to show signs of deficient age declaration even in the most recent periods. Almost without exception, the enduring presence of age misstatement generally affects the data for ages over 40 or 45 in all countries (Palloni, Pinto et al. 2015).

#### **5.4.2 Declaring usual place of residence**

Both birth and death certificates include variables that refer to the geographical location of the mother's usual place of residence (in case of births) or the deceased's usual place of residence. In the same way, when a "*de facto*" census takes place, declaring one's usual place of residence is required.

Considering sub-national statistics, place of residence becomes one of the most important variables because misreported information could in fact impede accurate linking and event to the actual population exposed its risk. The literature has presented historical evidence on the dubious quality of the habitual place of residence information reported in both registered data and "*de facto*" population censuses (Jasper-faijer and Orellana 1994). Many informants and interviewers are suspected of declaring the place of occurrence of the event — birth, death or census — as well as the place where they have been interviewed instead of the place of residence.

Consequently, when geographical areas are distinguished, it is the big cities and urban centers with the largest birth and death concentrations, because place of occurrence is only an indicator of the hospital infrastructure and medical services network (ECLAC 2014). Few advances have been made for exactly estimating the proportion of cases under these conditions, neither in the seven selected countries nor in Latin America overall, mainly because a direct assessment is necessary. As a result, most of the demographic studies have been conducted at the national level.

#### **5.4.3 Ill-defined causes of death**

The proportion of deaths with ill-defined causes or without medical certification is one of the main indicators of overall register quality. There is general consensus that a strong relationship exists between coverage and these two indicators (Marinho 2012). In this sense, the Worldwide Health Organization (WHO) standards establishes that a deficient record occurs either when 10 percent of registered deaths are coded in the chapter of ill-defined causes in populations over 64 years old or when it exceeds 5 percent in populations under 65 years old (WHO 2016).

In 1965, none of the seven selected countries had registered less than 5 percent of deaths as ill-defined in populations under 65 years of age. Forty years later in 2000, Venezuela, Mexico, Chile and Colombia have already achieved proportions lower than 5 percent of total registered deaths (see Table 5.8). Brazil, Ecuador and Peru, in contrast, continue to present more than 10 percent of ill-defined causes even in recent years (Bay and Orellana 2007).

The increase in medical certification has played a major role in reducing the proportion of ill-defined causes of deaths. However, the latest studies have clearly shown that the proportion of ill-defined causes of death is not enough to account for the magnitude and typology of the current errors in basic cause of death information. Beyond the ill-defined causes of death in Chapter XVIII (R00-R99) of the International Classification of Diseases (ICD-10), there are other causes that could be referred to as "less useful", which study allow checking errors in the certification process (Lozano-Ascencio 2008).

Table 5.8 Proportion of Ill-defined causes of deaths

Country	1965	1978*	1980-1985	1995-2000	2005**
Brazil	39,7	--	21,4	14,8	13,7
Chile	13,5	10,8	6,5	3,1	1,75
Colombia	7,7	8,6	8,7	4,2	2,8
Ecuador	21,7	16,5	15,7	13,2	--
Mexico	18,6	8,9	5,4	2	2,1
Peru	13,7	8,4	7,7	13,7	--
Venezuela	25	14,2	12,2	1,6	0,8

Bay, G.; Orellana, H. (2007). "La calidad de las estadísticas vitales en la América Latina, documento presentado en el Taller de expertos en el uso de estadísticas vitales: alcances y limitaciones". Santiago, CEPAL, December, 13th and 14th 2007. \*Chackiel, j "La investigación sobre causas de muerte en América Latina". Notas de población 44, CELADE. \*\*PAHO. (2007). "Situación de las Estadísticas Vitales, de Morbilidad y de Recursos y Servicios en Salud de los países de las Américas (Informe Regional)". November 2007.

"Less useful" basic causes of death coding (or "garbage code") are considered to be codes referring to: 1) non-fatal diseases, 2) intermediate causes of death, 3) immediate causes of death, 4) non-specific causes of death and 5) properly ill-defined causes of death (Naghavi, Makela et al. 2010). Coding of the basic causes of death is tied not only to the training and experience of physicians and coders, but also to the different algorithms used when the underlying cause is assigned through computer programs. Ribotta (2014) uses this idea of less useful basic causes to evaluate the WHO's 2000s Statistical Information System data — WHOSYS. His results show that in five of the seven selected countries a big proportion of deaths are classified as type 2, consisting of "intermediate" causes of the underlying disease. Ecuador has a higher proportion of properly ill-defined deaths, while Venezuela has a relatively important proportion of non-specific causes of death (Ribotta 2014)

## 5.5 Conclusions

An inventory of the demographic data available in the selected countries gives us an idea about the vast demographic sources in Latin America. Different assessments at the national level of the registry data tell us that improvements in their coverage occurred during recent decades at the national level, while some problems associated with the quality remain. These problems tend to be worse for some countries. The same happens with the path of improvement, which also varies from one country to the other. In this sense, Chile has historically the best coverage and very few improvements in the general quality of the registry data over recent decades, while Colombia, Peru and Ecuador come from lower coverage levels and have focused on increasing their reporting.

When accounting for all demographic data produced (census, population estimates, surveys and registry data), there are at least four scenarios in the countries selected for this research regarding data quality for the period of analysis 1996 to 2010:

1) In Mexico and Brazil, it is possible to find vast information collected in specialized surveys and censuses; but the vital registration system is still deficient, particularly in some Brazilian regions. In both cases, large improvements have been seen regarding coverage of the registry data and decreasing ill-defined causes of death. What is more, through census and specialized surveys, additional information on migration and infant and adult mortality provided the necessary information to produce their population estimates.

2) Chile has the opposite situation, with a historically efficient vital statistics registration system but considerable omissions and discontinuities in population censuses and surveys.

3) Ecuador and Venezuela have acceptable levels in both types of sources, but different availability of their results. Ecuador has updated and made available all their information in micro-data format, and Venezuela provides only delayed aggregated data.

4) Peru and Colombia have deficient coverage and quality levels in censuses and vital registration, but also continuous specialized surveys.

Despite all differences and overall improvements, issues regarding common errors historically identified in the data seem to persist in the first decade of the twenty-first century. Age overstatement and ill-defined causes of death are joined with the remaining proportion of under-coverage in mortality data at the national level. Later chapters will evaluate the presence of these issues in city groups in order to allow verification of possible spatially bias deficiency/efficiency in the data management.



## 6. DATA ASSESMENT AND CORRECTIONS

Mortality analysis in Latin America can be traced back to studies published by Stolnitz (1965) and later by Arriaga (1968), who produced the first historical life tables for the majority of the countries. Some other references are found from a more global perspective by Preston (1976), when accounting for mortality decline worldwide. Since then, lack of accuracy in the data has always inhibited producing a historical and comparative analysis. The aim of this research is to analyze causes of death patterns, doing so by analyzing the basic elements of accurate mortality rates; this means ratios of both accurate numbers of deaths and accurate population exposed to risk. The finished work will build consistent and comparable estimates across time and space, which is a prerequisite to any attempt to achieve reliability in the estimates; in this sense underreporting and the poor quality must be estimated and adjusted

Biased estimates are a consequence of both inaccuracies in the data and errors in the assumptions involved in producing the estimates. The yearly number of deaths comes from vital statistics data managed by the Brazilian, Peruvian and Venezuelan ministries of health, and by the Chilean, Colombian, Ecuadorian and Mexican National Statistics Institutes. Population at risk is taken from local estimates and projections made by national statistics institutes, based on census data. Both types of data are susceptible to rearrangements due to errors or simply from adapting to the spatial groups built in this research design.

As has been said, registered vital events data in Latin America historically have coverage and quality problems. Even when lots of them have been overcome, a proportion of under-registration in the data and misreporting remains: age, place of residence and causes of death persist. Looking forward to determining and correcting these errors, this research applies indirect mortality estimations to both infant and adult mortality as a complementary tool to evaluate registered data. These indirect estimates are constructed by combining registered data with population censuses and migration estimates.

This chapter is dedicated to assessing the quality of the demographic data in the seven selected Latin American countries (Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela) at the country and spatial group level. The chapter is divided into six sections. The first one explains the content assessment measures used to evaluate the quality of the data; while the second section describes in detail: 1) the indirect methods considered to determine the coverage of the registered death counts, and 2) how migration estimates are produced and included in the determination of the coverage. A third section is used to display in detail the results obtained from the specific content and coverage assessment.

The fourth section of this chapter summarizes all assessments made in the data based on two statistical analyses: Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). Here, spatial-group sub-populations are classified according to the quality of their data. A fifth section is dedicated to explaining how comparability in the data is expected to be achieved by considering five general arrangements. Finally, the sixth section provides a brief conclusion.

All the information gathered and analyzed in this chapter goes beyond the timeline of this research (2000 to 2010). The idea is to foresee patterns and thresholds on estimates for the specific period of analysis based on long-term trends (whenever possible). What is more, previous mortality estimates are reviewed and considered for comparing and refining the results. Table 6.1 shows all the information used in this chapter; the intention is not only to let

the reader know all data sources, but also to establish the timeline allowed by “data availability” in order to address comparability concerns.

## **6.1 Content assessment measures**

Data coming from censuses and vital statistics registration are evaluated in this section. In an attempt to determine the quality of all basic variables, the proportion of missing or unknown information is explained. Then, specific indexes are used to analyze the quality of basic variables such as age and sex. Inquiries on the distributions of age and sex are fundamental to any process of data assessment, and age bias interferes with the good execution of indirect methods of estimation. These indexes are useful for comparative purposes, and their results can be easily interpreted.

### **6.1.1 Sex preference**

All demographic statistics are subject to error in sex declaration, and this is the reason why evaluating the consistency and orderliness of the data by sex constitutes the first step in the analysis. To achieve this, the sex ratio and the United Nations Age-Sex Accuracy Index are applied to registry and census data. Sex ratio (SR) is the ratio of the number of males to 100 female cases (population, deaths, birth, etc.). In mortality data, since female mortality is typically lower than male mortality in most populations, the sex ratio should reflect this differential (Moultrie, Dorrington et al. 2013), at least until advanced ages. This is not because men die more, but sooner than women do. The absolute number of female deaths could be larger than males when the population structure is driven by a bigger proportional weight of older individuals. However, by age group, male mortality is expected to be higher in most ages (except older) as an indication of good data quality. In contrast, it has been seen that male births are higher than female ones when no bias by sex preference is introduced due to sex-selective abortion and gendercide. The natural male-to-female birth sex ratio hovers around 105 to 100.

The United Nations Age-Sex Accuracy Index (UNASA) is constructed from the sum of three components: (1) The sum of the sex ratio (SR) by age group, which helps to determine if there is any discrepancy in the declaration with respect to sex in the total distribution of the population; 2) mean age deviation for men (IRA-h); and 3) mean age deviation for women (IRA-m). These components are obtained by normalizing the distribution of the population aged 5 to 69 (Pimienta and Bolaños 1999). The sum of the component in absolute terms is combined to get one single index. An index below 20 is indicative of accurate data; while above 20 indicates the data is losing accuracy.

Table 6.1 Data available

Database	Period of analysis																										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
<b>Brazil</b>																											
Census		x									x																
Deaths					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Chile</b>																											
Census			x										x														
Deaths	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Colombia</b>																											
Census				x												x											
Deaths				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Ecuador</b>																											
Census	x											x															
Deaths	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Mexico</b>																											
Census	x										x																
Deaths	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Peru</b>																											
Census				x												x											
Deaths													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>Venezuela</b>																											
Census	x											x											x				
Deaths											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Births											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Population											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

### 6.1.2 Age preference

In some of the sources used in this research, age is given as the product of an informant's statement, like census data. The incorrect reporting of age has been one of the content errors that are most considered in assessing the quality of demographic sources. This has been associated with the educational level of the population and deficiencies in the official identification of people, including failures relative to the information collection itself or an inadequate informant. Errors tend to manifest as preferences for some particular digit (generally 0 and 5) and increasing or decreasing the true age (Pimienta and Bolaños 1999). Even in data sources that are traditionally not fuelled by an informant's declaration — such as registry data — it is possible to find digit preference in age declaration. This is because having an official identification document is a recent phenomenon for some countries in Latin America. Therefore, the earliest issued official identification documents relied on self-declaration, particularly for aged and Indigenous populations in rural areas.

Two main problems have been identified in Latin American demographic data regarding age misdeclaration: age heaping and age exaggeration. To verify the quality of age statements, the Myers Blended index (MBI) is applied for evaluating digit preference in age declaration, then age-group ratios are created for determining the existence of age exaggeration.

Age heaping usually — but not always — takes the form of concentrations in the age distribution of the population using ages that end in numbers according to how the age variable in the census is collected or derived. The Myers Blended index (MBI) is used to determine the preference that may exist for any digit in the declaration of age. It is estimated from separating the population by sex in order to evaluate the quality of the data independently (Riçón 2010). This decision relies in the fact that male and female heaping patterns could be different.

The intention is to assemble a hypothetical distribution of the population between 10 and 79 years of age. Then, population is divided into ten groups according to the final digit of the age declared. Each digit group must represent 10 percent of the total population considered, because it is assumed that the population is equally distributed into the ending digits. The difference between the expected and real distribution is taken as a preference (if positive, i.e., above 10) or a rejection (if negative, below 10). The sum of the absolute differences can vary from 0 to 180 per one-digit preference. The lower the index obtained, the weaker the attraction for a specific final digit; therefore, the data will be better quality (Chackiel and Macció 1978). MBI takes into account attraction or rejection by all digits. A 0-to-5 index indicates low attraction level, 5.1-to-15 an intermediate level, 15.1-to-30 a high one and over 30 is very high.

For its part, it is possible to use age ratios to provide a useful indication of possible undercounts or displacements between age groups. Traditionally, exaggerations in the stated age tend to be concentrated in advanced ages (Coale and Kisker 1986). To verify its existence, ratios of ten-year-length cuts from populations over 60 years of age are examined in all data sources. Ratios of 60-and-over populations to those aged 70-and-over, 80-and-over and 90-and-over are calculated. The higher the ratios obtained, the greater the chances of exaggerations in declared age (Agostinho 2009). There is no fixed limit set on the ratios for establishing the presence of age exaggeration, but a comparison between the seven selected countries should give results in which the country with the most aged population structure has higher ratios than countries with young population structures. In this case, the Chilean population structure is the one with

the most aged population structure; hence, its ratios are used as a limit for evaluating the presence of age exaggeration in all the countries.

### **6.1.3 Ill-defined causes of death**

The cause of death section on the death certificate represents a medical statement about diseases or circumstances that lead to the death. It provides an etiologic explanation for the order, type, and association of events resulting in death. Events or causes leading to death can be: 1) multiple, meaning they result from the combined effect of two or more conditions; 2) unrelated, meaning they arise independently of each other; or 3) causally related to each other. In any case, one single underlying cause is identified on the death certificate. This underlying cause is the one considered for the analytical purposes of this study. When the underlying cause that starts the etiologic sequence is not specific or leaves doubt as to why it developed, it is mostly classified as ill-defined.

There are two ways to broadly assess the quality of the underlying cause of death data for the seven selected countries. The first one is to account for missing information, i.e., the proportion of cases in which no cause of death is identified. The second one considers the proportion of death classified as ill-defined from total deaths.

Ill-defined causes of death are classified in Chapter R of the 10<sup>th</sup> revision of the International Classification of Diseases (ICD-10), and it is known as “symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified”. This chapter includes symptoms, signs, abnormal results of clinical or other investigative procedures, and ill-defined conditions for which no diagnosis that is classifiable elsewhere is recorded. In general, categories in this chapter could be designated “not otherwise specified”, “unknown etiology” or “transient”.

Ill-defined causes of death come from an inadequate certification probably due to insufficient knowledge of the disease that caused death, lack of training of the physicians or to superficiality (D'Amico, Agozzino et al. 1999). As has been said in previous sections, most of the studies have pointed out how in recent decades Latin American countries have managed to improve the quality of the underlying cause of death declaration. This is particularly because of the increase in certified deaths by a medical practitioner, as has been said in previous sections of this chapter. Although some issues regarding the expertise and scope of the practitioner remain, e.g., practitioners may have never had prior contact with the deceased or access to relevant medical records.

Thus, higher proportions of missing data and cases classified as ill-defined causes of death would be indicative of worse quality data than lower ones, because they indicate a lack of precision in the data. I determine their proportions in the registered deaths of the seven selected countries in order to explore the general quality of the data used in this research.

## **6.2 Coverage estimate**

One of the biggest problems found in Latin American registered death data is its coverage. Most of the studies evaluate national-level coverage, but none assess coverage of the vital statistics registration system at the city level. One way to measure this is through the use of indirect methods that allow critical evaluation of their quality based on cross-checking against census-based estimates. In a strict sense, the term "indirect" is used to qualify some

demographic techniques that produce estimates of a certain parameter based on information that is only indirectly related to its value (UN 1986). Historically, indirect methods for mortality are split into methods for estimating infant and adult mortality separately.

Here, data from eighteen population censuses are used in order to evaluate the coverage of the vital statistics registration system for each specific spatial group in all countries. Censuses from 1990, 2000 and 2010 are analyzed to follow trends in infant and adult mortality and determine inter-census levels of coverage. Four of the seven selected countries have three censuses available for the mentioned period: Brazil, Ecuador, Mexico and Venezuela. The other three — Chile, Colombia and Peru — rely on two censuses (see Table 6.2).

Official omissions represent the absence of cases recognized by the national institutes of statistics in each country after evaluating the census. Official omissions vary according to the country and census round. In general, omission has been evaluated at less than 10 percent for all the countries, and the decline in this proportion is seen over time (see Table 6.2). Compared to the others, the highest omission rate in a census has historically been found in Venezuela and the lowest in Brazil. This difference could depend on the strategy undertaken by the countries. Brazil, for example, uses a dual questionnaire: a short one given to the whole population and another, more complex one to a population sample. In contrast, Venezuela uses one complex questionnaire for the entire population.

*Table 6.2 Basic census characteristics*

Country	Decade								
	1990			2000			2010		
	Year	Type	% Omission	Year	Type	% Omission	Year	Type	% Omission
<b>Brazil</b>	1991	Jure	3.7	2000	Jure	2.8	2010	Jure	2.4
<b>Chile</b>	1992	Facto	2.4	2002	Facto	4.3	2012	Jure	9.2*
<b>Colombia</b>	1993	Jure	6.7	2005	Jure	4.9	--	--	--
<b>Ecuador</b>	1990	Facto	5.5	2001	Facto	6.0	2010	Facto	4.5
<b>Mexico</b>	1990	Jure	4.3	2000	Jure	3.9	2010	Jure	3.0
<b>Peru</b>	1993	Facto	3.0	2007	Facto	3.3	--	--	--
<b>Venezuela</b>	1990	Jure	9.1	2001	Jure	7.8	2011	Jure	6.5

Source: Official omission according to ECLAC Population Division.

Nevertheless, the completeness and quality of some variables need to be checked beyond official omission. Completeness of information in variables like age, sex, and the Minor Administrative Division (MIAD) of usual residence are fundamental for applying indirect methods of mortality estimation. This also applies to recent migration (MIAD of previous usual residence) and summary birth history. All these variables have been checked for the proportion of missing information and the quality of their contents. The evaluation was made by means of the previously mentioned index, and the results indicate that there is good enough quality in the census data to apply indirect methods for determining coverage of the vital statistics registration system at the spatial group level for all the countries during the period 2000-2010. Annex A shows the detailed results from assessing the data quality of the censuses, used to apply indirect methods.

### 6.2.1 Infant mortality coverage estimation

In order to estimate and correct infant mortality where there exists a possible lack of universal coverage, a combination of methods and technics has been applied. First, national-level estimates published in 2013 by the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME) are used to determine infant mortality coverage at the national level, specifically via comparison with each country using the registered death-to-birth ratios calculated for this research. The difference found between UN IGME and registered death-to-birth ratio estimates is considered as the national under-registration estimate.

Once a national estimate of coverage is made, an indirect estimation method (specifically, Trussell's variant of the Brass method) is applied to summary birth history data collected in censuses from 1990 to 2011 at the city-group level for this research. The indirect method for census data finds the differential between each spatial group respect to infant mortality at national level, and this is used later to estimate the specific under-registration index, which I do by combining it with previous national coverage estimates. Because the period of reference from indirect census estimation varies and does not provide annual estimates, a set of linear regression models is built to produce yearly spatial-group differential estimates. Finally, both national under-registration and spatial-group differential estimates are combined into a yearly *coverage index*. This index is used to correct infant mortality rates obtained separately from registered data by spatial groups and sex. Below is a detailed explanation of the methods and steps followed.

#### National under-registration ratios.

Great efforts have been made worldwide to produce reliable infant mortality estimates for all countries. One of the most recent initiatives is the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). They produce infant mortality rates by combining all sources of information and estimates from each country (IGME 2018). Long-term yearly UN IGME estimates are the result of a Bayesian B-spline Bias-reduction model (Alkema, New et al. 2014). Reliable UN IGME estimates are available from 1955 until 2015 without sex distinction.

A rapid comparison between UN IGME estimates and registered death-to-birth ratios (both sexes combined) is used as an initial proxy of the under-registration found by country for this research. UN IGME produces estimates for total infant mortality, males and females included. Due to there being no evidence in previous studies of a sex differential in registered data coverage in Latin American countries, the same under-registration ratio (URR) is applied to both male and female infant mortality for each country  $C$  in time  $t$ .

$$URR_{C,t} = \frac{\text{registered death-to-births ratios}_{C,t}}{UN\ IGME\ IM_{C,t}} \quad (6.1)$$

These yearly ratios allow both: 1) maintaining annual variation in the rates, which is tremendously important to infant mortality due to its high sensitivity to the socio-economic crises that commonly occur in Latin American countries (Romero 1999); and 2) adjusting the changing levels of under-coverage due to improvements in the vital statistics systems found by previous studies.

## Infant mortality gap by spatial group

There are two main indirect methods used for estimating infant mortality: one is based on *complete birth history data* (collected mainly through surveys), and the other on *summary birth history data* (obtained mainly from censuses). *Complete birth history data* from Demographics and Health Surveys DHS has been proved to be a more adequate source for estimating infant mortality. However, surveys are normally designed to be representative of the national level. In some exceptional cases, it is possible to find DHS represented at the Major Administrative Division level, but none at the Minor Administrative Division (MIAD) level has been considered in the sample design. This makes census data as the only possible source for applying indirect methods to infant mortality in this research.

This part is dedicated to estimating the difference in infant mortality between city groups and the national level, using the *summary birth history* (SBH) contained in the census data of the seven selected countries. Consequently, I gather the information referred to the aggregated *number of children born alive* and the aggregated *number of children still alive* by women known as Summary Birth History (SBH) at spatial group level, in the 18 censuses from the seven selected countries. The SBH does not provide enough data for direct calculation of infant mortality, due to deaths not being located explicitly in time and a lack of precise exposure times. Without information on the time when births and deaths occurred, the analysis is model through an indirect approach that considers average exposure-time from the mothers' age, duration of marriage and/or first birth.

Through fertility and mortality model age patterns, the proportions of children ever born dead to women who are grouped by age are converted into a standard life table function (Moultrie, Dorrington et al. 2013). This method is based on the proportion of dead children by mother's age and is known as the Brass method (1968). The proportion of dead children is the ratio of children ever born (CEB) and still alive (CSA) from women in age group  $x$  to  $x+5$ :

$$D_{(x \text{ to } x+5)} = \frac{CEB(x \text{ to } x+5) - CSA(x \text{ to } x+5)}{CEB(x \text{ to } x+5)} \quad (6.2)$$

There are several variants of this method; this research applies Trussell's variant. Trussell's variant (1975) is built on a previous modification of the original Brass method conducted by Sullivan (1972). In Sullivan's variant, a set of multipliers is used to capture mortality patterns, which are calculated by means of a regression approach to Coale and Demeny's family life tables. Trussell added a set of parity ratios to determine the fertility patterns underlying those of mortality. The parity ratios are calculated separately for women grouped according to their age. The underlying logic is that the oldest women's children have longer years-lived exposure, and the difference in the number of CEBs between groups of women group indicates an above average date of birth. Thus, parity ratios  $P$  are estimated by contrasting the proportion of women age  $x$ -to- $x+5$  to women age  $x+5$ -to- $x+10$  with children ever born (CEB):

$$P_{(x \text{ to } x+5)} / P_{(x+5 \text{ to } x+10)} = \left( \frac{CEB(x \text{ to } x+5)}{\text{women}(x \text{ to } x+5)} / \frac{CEB(x+5 \text{ to } x+10)}{\text{women}(x+5 \text{ to } x+10)} \right) \quad (6.3)$$

Thereby, it is possible to estimate from the SBH data infant mortality levels for a period of about 15 years prior to data collection. In this sense, younger women's responses to the



proportion of their children who have died reflect the mortality experience of young children in the recent past. Meanwhile, older women's responses reflect the mortality experience of older children (UN 1986).

Some assumptions underlie the model and its variant, the most important of which is that fertility and mortality have remained constant in the recent past. This is because changes in fertility patterns cannot be captured by ratios of average parities obtained from cross-sectional data. In consequence, the fertility experience cannot be replicated for any cohort of women, and the method will thus not provide a good index of the distribution in time of births (UN 1986). Breaking the assumption of stability causes some problems in the results obtained.

In the seven countries, the assumption of stability in fertility patterns is without doubt broken. However, recent specialized literature has analyzed the specific impacts of this broken assumption. Furthermore, it is possible to find a set of recommendations for overcoming miscalculations in using the method. One of the main problems is that infants of young mothers appear to have higher mortality than average risk of death. Therefore, estimated rates from 15- to 19-year-old women are likely to be overestimating the true levels of infant mortality. Also suspicious are those based on mothers between the ages of 20 and 24 (ECLAC 2014). One way to overcome this issue is the following: through the method, seven estimates are obtained on each census; therefore, it is advisable to not take into account estimates derived from mothers aged 15 to 19 and 20 to 24. The most robust estimates correspond to women aged 30 to 34 (Hill, You et al. 2012).

Another issue is that when the age structure of fertility and mortality do not follow the model pattern, indirect estimates are systematically higher. This could be avoided by taking the model table that gives the best possible adjustment to recent changes in fertility and mortality patterns (Silva 2012). Analysis based on demographic microsimulation shows how the Brass method has a tendency to overestimate mortality levels as well as declining rates. Specifically, this method overestimates the levels of infant mortality by an average of 9 percent. In Latin America, where fertility and mortality have been declining rapidly, the overestimate could be 15 percent (Verhulst 2017). Because the intention of the Brass method is to capture existing gaps in infant mortality levels according to city-size groups for all countries and (as has been established in the specialized literature) also because the rates of demographic changes between different areas in Latin American countries are similar, any bias introduced as a result of broken assumptions would evenly affect all the estimated levels. This is true even though the following precautions are taken when estimating infant mortality levels using Brass method:

- Women with missing data on numbers of children ever born or numbers of children dead (or surviving), or both, are excluded from the analysis.

- Only the mortality levels of women in the age group 25 to 44 years old are considered for posterior analysis.

- West and South model life tables allow making better adjustments to the latest demographic trends in all countries.

Since, the period of reference for the indirect census estimates varies between the spatial-group infant mortality levels and national levels, they are estimated in a linear regression model. Three independent models are produced for each country to represent the ratio between each spatial group  $g$  and the national estimate at time  $t$ :

$$\widehat{Gap}_{(g, t)} = \beta_1 + \beta_2 * t \quad (6.4)$$

where,

$$Gap_{(g,t)} = \frac{nq_{1(g,t)}}{nq_{1(t)}} \quad (6.5)$$

### Coverage index

Finally, a yearly coverage index (CI) is built for each spatial group by country. This index is the result of combining the annual under-registration ratios (URR) at the national level and the linearly estimated spatial-group gap ( $\widehat{Gap}$ )

$$CI_{(g, t)} = \frac{IMR_{(g, t)}}{URR_{(c, t)} * \widehat{Gap}_{(g, t)}} \quad (6.6)$$

CI is calculated for both sexes together because there is no evidence of sex preference in vital event registration for populations under one year old. What is more, in regard to the estimates from the United Nations Inter-agency Group for Child Mortality Estimate (UN IGME) and summary birth history data collected in censuses for most of the countries considered, they are for the total population. Later, annual CIs are applied separately for male and female registered death-to-birth ratios for every spatial group by country.

### 6.2.2 Adult mortality coverage

The region has made great strides in compiling infant mortality estimates, especially since the second half of the twentieth century. These improvements are due mostly to the implementation of specialized surveys and adding questions about this category to the population census. However, the same path has not been followed for adult mortality estimates. The existence of incomplete records has not massively prompted Latin American countries to generate alternatives (Palloni and Pinto-Aguirre 2011). As a result, the uncertainty in adult mortality estimates at the national and sub-national levels has been determined by indirect methods that assume by default the existence of a large number of under-registered deaths. These indirect methods can be divided into three groups: (1) death distribution methods that assess the completeness of registered deaths relative to the census population; (2) methods based on inter-census survival; and (3) methods that convert close-relatives-survival rates into standard life table functions (Moultrie, Dorrington et al. 2013). The application of one over the other depends as much on the information available as on the correspondence of their assumptions.

Over the last decade, there has been consensus on the pertinence of using death distribution methods for Latin American mortality estimates. The main ones are: (1) the General Growth Balance method (GGB); (2) the Synthetic Extinct Generations method (SEG); and (3) a recent combination of both (Hill, Choi et al. 2005; Agostinho 2009; Hill, You et al. 2009; Hill and Queiroz 2010; Queiroz and O. T. Sawyer 2012; Dorrington 2013; Palloni, Pinto et al. 2015). Death distribution methods are specifically used in this section to determine the coverage of

the registered adult deaths in all the groups of cities and countries by sex. A global estimate for the period of analysis is obtained through the evaluation of death for ages 15 to 75. The results come in the form of proportions of death coverage that are later applied to all deaths except infants.

Independently of the method applied, population counts have to be reinforced by adding/subtracting migration effects. This is because the most complete setting of the initial and final population is a determinant for obtaining an accurate estimate of death coverage. Thus, this section includes a brief explanation of the state of migration data and the arrangements made for improving the population counts.

### Death distribution methods

Death distribution methods are based on the assumption of demographic stability in the population, meaning that the exits and entries of the population are equivalent for each age group. They use observed death structure and population distribution estimates to reconstruct the estimated death count. When applied to vital statistics, they compare the structure of registered deaths with the estimated population by means of census or survey data; and in this way they can calculate a unique differential (estimated-observed) for correcting all specific mortality rates (Hill, Choi et al. 2005). In order to produce accurate estimates, both methods are applied individually and in combination (i.e., GGB, SEG and GGB-SEG), in accordance with expert recommendations

By combining both methods, it is possible to take the strongest and most stable coverage estimates (Queiroz, Lima et al. 2013). In this way: the GGB is used to determine differentials in census under-enumeration, and the SEG calculates the proportion of coverage in adult mortality. The combination attempts to avoid miscalculation due to breaking the underlying assumptions. This is mostly because GGB is more sensitive to migration flows and misreporting age than SEG; but it also allows determining differentials in population counts in terms of census omission.

The first method to apply is the General Growth Balance method (GGB). This method was developed by Brass in 1975 and is recognized as the Brass Growth Balance method BGB. It comes from joining two concepts. The first is the basic idea of equilibrium, in which the strength of demographic components models a given population. The second is that the growth rates of the population of each age group are constant and invariant over time, and this is known as the stable population assumption (Hill 1987). Both imply that birth rates (entries of each age group) will be equal to the sum of the growth rates plus mortality rates (outputs of each age group), with the inputs and outputs being linearly related:

$$\frac{N(x)}{N(x+)} = \frac{D(x+)}{N(x+)} \quad (6.7)$$

where  $N(x)$  is the number of population with exact age  $x$  and  $N(x+)$  is the population aged  $x$  and older (entry rates), while  $D(x+)$  is the number of dead people aged  $x$  and older; thus rating the relationship between  $N(x+)$  (exit rates) and growth rates  $r$  (UN 1986). If observed  $D(x+)$  is incomplete, it must be multiplied by the coverage estimated coefficient  $C_{(x)}$ . Then:

$$\frac{N_{(x)}}{N_{(x+)}} = r + C_{(x)} * \left( \frac{D_{(x+)}}{N_{(x+)}} \right) \quad (6.8)$$

Since the relationship between the rates of input and output is linear, the estimate of  $C_{(x)}$  is equal to the slope of the line derived from the points  $N_{(x)} / N_{(x+)}$  and  $D_{(x+)}/N_{(x+)}$ . The method assumes the following. (1) Due to the base population being stable and closed; i.e., they maintain constant fertility and mortality over time and do not suffer the effects of migration in different age groups. (2) The population data are equal in terms of coverage of mortality data. (3) There is no misreporting of age (Agostinho 2009).

Hill (1987) constructed a variant of Brass's method, adapting it for use on non-stable populations. For its application, access to two population counts is needed, so that they can be compared in order to obtain the specific growth rates for each age group ( $r_{(x+)}$ ) (Hill 1987):

$$\frac{N_{(x)}}{N_{(x+)}} - r_{(x+)} = \frac{D_{(x+)}}{N_{(x+)}} \quad (6.9)$$

Further developments of the method allow estimating possible under-enumeration in population counts by incorporating mortality rates, the differential in census omission<sup>11</sup>, and registered death coverage (C) (Agostinho and Queiroz 2008):

$$\frac{N_{(x)}}{N_{(x+)}} - r_{(x+)} = \frac{1}{t} * \ln \left( \frac{k_1}{k_2} \right) + \frac{(k_1+k_2)^{\frac{1}{2}}}{C} * \frac{D_{(x+)}}{N_{(x+)}} \quad (6.10)$$

For its part, the SEG method is based on the extinct generations method developed by Vincent (1951), in which the number of people aged  $x$  at some past time can be estimated by gathering all deaths in the population at ages  $x$  and older. This is done when the last member of the cohort has died, leaving the entire cohort extinct (Vicent 1951). Preston and Coale (1980) combine the idea of extinct cohort with the assumption of stable populations (Preston, Coale et al. 1980). Therefore, age structures can be expressed as a function of current demographic data. These structures, as well as past and future demographic rates, are related to each other by age group growth rates. Then, the number of deaths should be consistent with the size of the population (Preston, Coale et al. 1980; H Preston and Bennett 1983; Horiuchi and Preston 1988). This was known as the Preston and Coale method (PCM).

Unlike the method developed by Brass, population structures in this method are estimated from death distributions (Hill and Queiroz 2010). If registration of deaths is accurate, the estimated population  $\hat{N}(x)$  must be equal to the observed population  $N_{(x)}$ .

$$\hat{N}(x) = \sum_{a=x}^w D(a) \exp(r(a-x)) \quad (6.11)$$

Bennett and Horiuchi (1981) relaxed the principle of stability by assuming that  $N_{(x)}$  for each five-year age group is approximately equal to the corresponding number in the stable population

<sup>11</sup> The first under-enumeration count is  $k_1$ , and  $k_2$  is the second one. The relationship between them establishes the differential.

(Bennett and Horiuchi 1981; Bennett and Horiuchi 1984). Growth rates calculated for the period between the two populations counts are used to expand death distribution as a stationary population (Hill and Queiroz 2010). This consideration is handled in the construction of life tables, which allow applying the SEG method transversally to the age distribution of current deaths. Likewise, it ensures that the age distribution of any cohort is equal to the population of the current period. Hence the number of deaths at age  $x$  at time  $t$  is equal to the number of current deaths plus the effect of  $\exp(-rt)$ . (Dorrington 2013). Thus,

$$\hat{N}_x = \hat{N}_{x+5} \exp(5 * 5r_x) + 5Dx \exp(2,5 * 5 r_x) \quad (6.12)$$

For more precise growth estimation, Bennet and Horiuchi's variant of SEG includes migration rates for each age group ( ${}_5NM_x$ ) as well as the differential of the censuses omission ( $\delta$ ). Then:

$$5r_x = \frac{\ln\left(\frac{{}_5N_x(t_2)}{{}_5N_x(t_1)}\right)}{t_2-t_1} - \frac{{}_5NM_x}{(t_2-t_1)({}_5N_x(t_1)*{}_5N_x(t_2))^{\frac{1}{2}}} + \delta \quad (6.13)$$

Each method has advantages and limitations; but, either way, some requirements are constant: 1) the completeness of the reporting of deaths has to be the same for all ages; and 2) there is no misreporting of age. The reason for these requirements is that none of the methods is designed to correct mistakes in population or death structure; they only adjust the level of estimated mortality. A version of both methods combined allows the differential of the censuses omission that is calculated by the GGB method to be incorporated into the SEG method. The idea is to produce mortality rate estimates, which have been adjusted from under-registration of death and isolated — as much as possible — from under-enumeration in population effects.

This section evaluates the pertinence of these methods under two criteria: (1) compliance to the linear relationship between entry and exit rates (GGB) and  $N_{x+5}/\hat{N}_{x+5}$  ratios (SEG and GGB-SEG); and (2) the estimate obtained at the national level must correspond with the estimate made in the assessment of previous registered data.

An important element to consider when applying these methods is the introduction of accurate net migration counts to the population. Disregarding or underestimating a negative net migration could be interpreted as lack of coverage, just as underestimating a positive net migration could hide under-coverage in mortality data.

### 6.2.3 Migration data

In Latin America, official population records are neither dedicated to reporting changes in residence within the country nor for the registration of foreign-born populations. The only sources available for the direct quantification of migration are censuses. All census rounds include questions in which migration is captured through differences in the current and previous place of residence (ECLAC 2014).

A time framework is necessary for referring to change of residence and type of migration. This can be *permanent* (used to estimate the cumulative stock of migration when referring to the

country of birth) or *recent* migration (when a time threshold is indicated, usually five years before the census). Each national institute of statistic sets all kinds of considerations at the moment of the census. Once again, because this research considers more than one country and more than one census round, definitions and boundaries differ. To illustrate, the ideal migration data required for this research must come as the inter-census net migration flows in order to be included when applying indirect methods for estimating adult mortality; but the period of migration in census data does not necessary cover the whole inter-census period.

Fortunately, all censuses available in the seven selected countries have included two questions for permanent and recent migration, and these two queries allow identifying and evaluating migratory flows over time. Moreover, all countries have collected in their censuses information at the Minor Administrative Division (MIAD) level. Through the recent migration question, it is possible to directly estimate the number of surviving migrants who have moved into and out of each MIAD since some prior point in time. This means the stock of migrants in each MIAD during the census. Then, the numbers of surviving migrants and stock are used to estimate the number of initial migrants in order to get a more proper estimate of the migration flows (Mx).

Table 6.2 shows the migration inter-census flows that can be estimated from the availability of census rounds in each country and the time thresholds established by the question. For most censuses except for those in Brazil, questions on the inter-census migration flows by age group and sex (Mx) are set at a five-year time threshold. In this timeline, net migrations are estimated by leaving out international emigration.

*Table 6.3 Periods of migration inter-census flows in the seven countries*

Country	Year													
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Brazil</b>	Mx (1990-2000)										Mx (2000-2010)			
<b>Chile</b>			Mx (1997-2002)											
<b>Colombia</b>						Mx (2000-2005)								
<b>Ecuador</b>	Mx (1996-2001)											Mx (2005-2010)		
<b>Mexico</b>	Mx (1995-2000)										Mx (2005-2010)			
<b>Peru</b>								Mx (2002-2007)						
<b>Venezuela</b>	Mx (1996-2001)											Mx (2006-2011)		

Undeniably, migrant stock, by definition, underestimates the flows of migrants into and out of a region or country, as it excludes information about return migration and commuting that may impact the contribution in person-years lived to both the origin and destination populations (Dorrington 2013). Overall, the inexistence of return migration and commuting data in the region places this research in the position of matching information based entirely on net migration. Net migration is measured through the approximation of the contribution of the migration flows into and out of MIADs for each spatial group.

At this moment, it is also necessary to distinguish between different types of migration: domestic and international migration. Information on domestic migration is collected through origin-destination matrices — by age groups and sex — from census information; while international migration data needs to be entirely produced in terms of distribution by age and sex. In order to estimate international inter-census migration flows by age and sex, this research approaches the counts using a combination of databases in several steps. Given the high incidence of international emigration observed in Latin America and the Caribbean over

recent decades and the lack of information on censuses to estimate them, one strategy to get information about people who have emigrated to other countries is to follow their "traces" in destination countries (ECLAC 2014). Of course, the strategy becomes more viable when the main destination is known and has concentrations of migrants from the same origin.

International immigration stocks (by sex and age) could be directly estimated from their own national census data in each country. On the other hand, international emigration stocks (only by sex) come from an annually linear interpolation of the five-year "international migrant stock: migrants by destination and origin" estimates, which are done by the United Nations Department of Economic and Social Affairs (DESA) and are based on worldwide census round estimates updated in 2015 (DESA 2015). Estimating the structures of the emigration stocks, two sources are combined for each country. On the one hand, the DESA total emigration stock by sex (Table B1. in Annex B: Migration estimates), and the proportional distribution of emigrants in their main destinations and countries of attraction.

The assumption is that the structure found in the main destination could represent the structure of all emigrants from the same country, independently of their final destination. In Table 6.3 is displayed the number of emigrants per thousand inhabitants, and the main destination for all countries by inter-census period. Mexico during the 1990-2000 period and Ecuador in 2000-2010 show the highest amounts of emigrants per inhabitants, while Brazil and Chile have the lowest. Regardless of the size of the international emigrant population for the countries, the main destination country for most of them is the United States. Chile and Colombia are the exceptions, as emigration for them is concentrated in Argentina (40 percent of Chilean emigrants during the period 1990-2000 were in Argentina) and Venezuela (36 percent of Colombian emigrants during the period 1990-2000 were in Venezuela).

*Table 6.4. Main country of destination and proportion of emigration by census rounds*

Country	1990's - 2000's				2000's - 2010's			
	Net migration (per 1000 inhabitants)	Main destiny		Net migration (per 1000 inhabitants)	Main destiny			
		Country	%		Country	%		
<b>Brazil</b>	4,0	EEUU	24	3,0	EEUU	21		
<b>Chile</b>	1,1	Argentina	40	--	--	--		
<b>Colombia</b>	10,0	Venezuela	36	--	--	--		
<b>Ecuador</b>	18,6	EEUU	68	48,1	EEUU	36		
<b>Mexico</b>	51,0	EEUU	98	22,3	EEUU	98		
<b>Peru</b>	13,9	EEUU	34	--	--	--		
<b>Venezuela</b>	5,7	EEUU	37	8,6	EEUU	32		

Source: United Nations, Department of Economic and Social Affairs, Population Division (2015). Trends in International Migrant Stock: Migrants by Destination and Origin (United Nations database, POP/DB/MIG/Stock/Rev.2015).

The total stock of emigrants by sex reported by the DESA is proportionally distributed into the total population structure of reported Latin American immigrants living in the United States in each country's respective census round. Two exceptions are Chile (1992-2002) and Colombia (1993-2005), where emigrant structure by age group and sex are taken directly from Argentinian (1991 and 2001) and Venezuelan censuses (2001 and 2011).

The number of Latin Americans living in the United States come from the IPUMS 5 percent samples of decennial United States censuses from 1790 to 2010 (Ruggles, Flood et al. 2018). The total of Latin Americans is used to establish the proportional distribution of all the countries in order to avoid bias in the sample size for specific populations (Table B2 in Annex B: Migration estimates). Once stocks of emigrants are estimated for each census round by sex and age group, it is possible to get the inter-census international emigration flow ( ${}_5e_x^F$ ). Then,

$${}_5e_x^F = {}_5e_{x+n,t+n}^F - {}_5e_{x,t}^F + \left(\frac{n}{2} * ({}_5e_{x,t}^F + {}_5e_{(x+n,t+n)}^F) * {}_5m_x^F\right) \dots\dots\dots(6.14)$$

where  $e^F$  represents the total number of people born in country  $F$  but are currently living in another country at age  $x$  and  $x+n$  at time  $t$  and  $t+n$ , and  $m_x^F$  is an estimate of the adjusted inter-census mortality rates of population aged  $x$  in the country of origin. The adjusted mortality rates come from the estimates made by the LAMBdA group (see Table B3 in Annex B: Migration estimates), which can be found in the inter-census period life tables (Palloni, Pinto-Aguirre et al. 2014). The biggest limitation is that international emigration could be included only for population counts at the national level and not at the spatial-group level. The same calculations are done for international immigration flows ( ${}_5i_x^F$ ):

$${}_5i_x^F = {}_5i_x^F + ({}_5i_x^F * {}_5m_x^F) \dots\dots\dots(6.15)$$

where  $i_x^F$  represents the total number of people living in a foreign country  $F$  before the time cut set by the census round in each country (mostly five years) at age  $x$ , and  $m_x^F$  is the mortality rate estimate by LAMBdA for the inter-census period of the country of destination. Because there is no mortality rate by spatial group, I calculate domestic migration flows using the national mortality rates by sex for all cases. Then, domestic immigration ( ${}_5i_x$ ) and emigration ( ${}_5e_x$ ) are approximated as:

$${}_5i_x = {}_5i_x + ({}_5i_x * {}_5m_x) \dots\dots\dots(6.16)$$

and

$${}_5e_x = {}_5e_x + ({}_5e_x * {}_5m_x) \dots\dots\dots(6.17)$$

After, inter-census international and domestic migration flows are estimated, net inter-census migration by age group and sex are calculated as:

$$Net {}_5M_x = {}_5e_x^F + {}_5e_x - ({}_5i_x^F + {}_5i_x) \quad (6.18)$$

Where net migration  $Net {}_5M_x$  is equal to international emigration  ${}_5e_x^F$  plus domestic emigration  ${}_5e_x$  minus international immigration  ${}_5i_x^F$  plus domestic immigration  ${}_5i_x$  by five-age group and sex for each spatial group and country



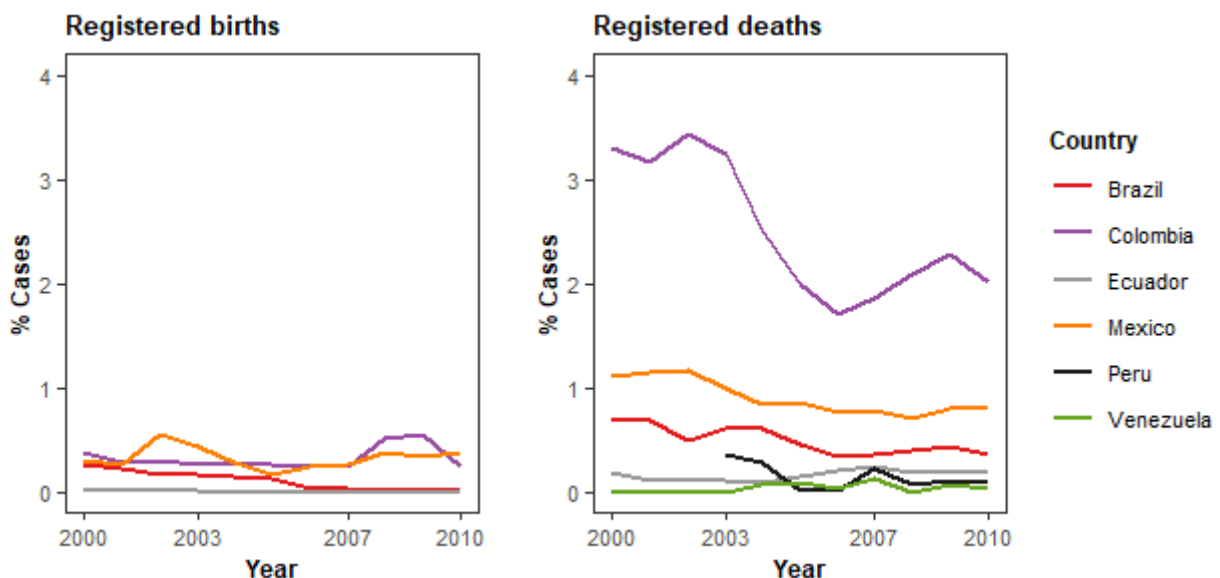
### 6.3 Specific assessment of death counts

Data completeness and quality vary according not only to the accuracy of the vital statistics system in each country but also to the stage during which all the data was gathered for this research. The registered data in Colombia, Brazil and Ecuador were downloaded from their official national websites. These databases have been adjusted and completed — as much as possible — to make them practical for non-specialized users. On the other hand, Chilean, Mexican, Venezuela and Peruvian databases were delivered directly by the official offices for use by specialized users and/or scholars.

#### 6.3.1 Completeness of content

Figure 6.1 shows annual proportions of registered births and deaths in the official databases, but with missing information in some of the basic variables (sex, age and MIAD of residence). Registered births with unknown information are less than 1 percent in all countries. One exception is Chile, which has complete information on the basic variables in both registered births and deaths. Peru and Venezuela show the same patterns of complete information only in registered births. The lack of cases with missing information must be linked to the total unreported cases, which are later treated as under-coverage<sup>12</sup>. This is because, in some countries, cases with partial information are not included in the final data bases; therefore, databases with complete information in some cases could be indicative of higher levels of under-coverage.

Figure 6.1 Proportion of cases with unknown information, 2000-2010.



<sup>12</sup> Peruvian death counts and Venezuelan registered births are the most critical example. In 2006, the number of deaths in the main-cities group population of Peru had a significant change in its trend. In this year, there are no reported cases with unknown information at the national level while, at the same time, an abrupt decrease in deaths occurred for the main-cities group registration. Another case is Venezuela's registered births for 2001. Male births have a suspicious increase in the main-cities group at the same time as an equivalent steep decrease in the towns-and-rural-areas group. This time, it seems births without complete place of residency information were relocated into the main-cities group's MIAD.

\*Chile has none reported case with unknown information, equally Peru and Venezuela have none reported cases with unknown information

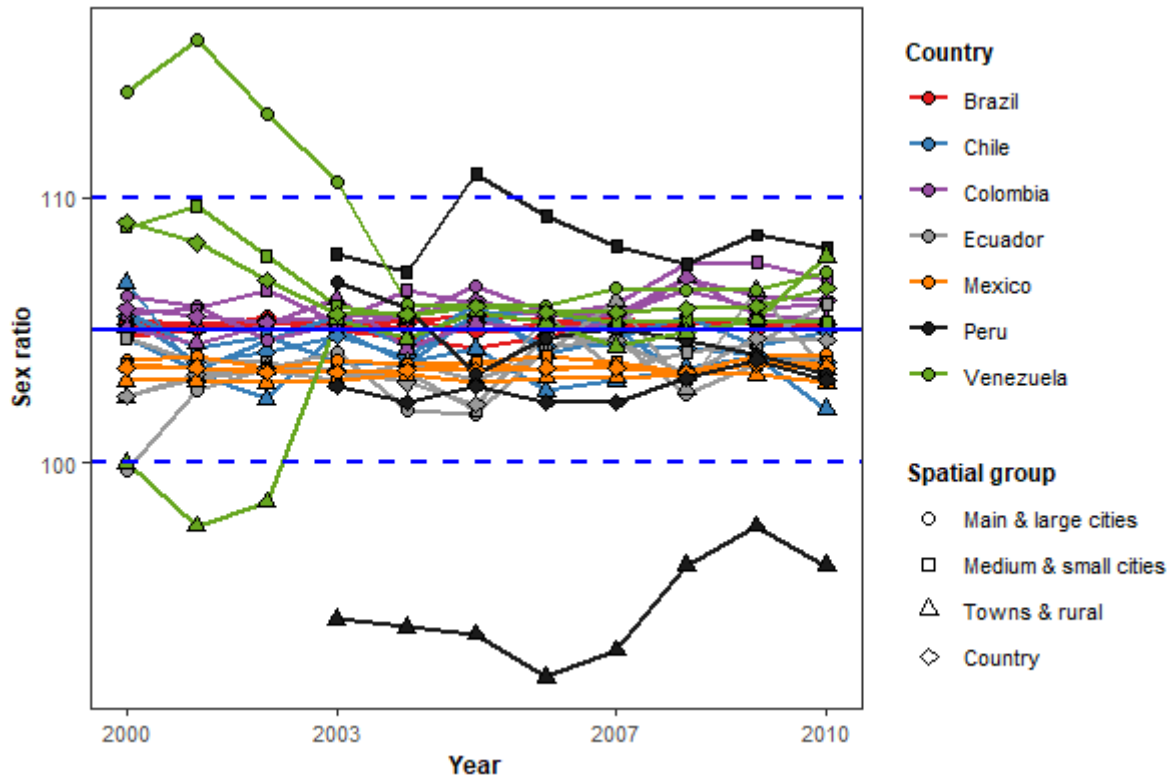
Colombia is the country with the highest proportion of cases with missing information in the basic variables. Even when it is possible to track the spectacular improvements, especially in registered deaths during the period, a clear step backward occurs in the year 2009 for both deaths and births. This disruptive pattern in registered mortality data in Colombia could be a consequence of fluctuating violent deaths during this period. This assumption relies on the fact that cases with unknown information are frequently concentrated in males at young ages whose deaths were caused by violence, and the usual missing information is the exact MIAD of residence. In the case of births, the mother's MIAD of residence is also the variable with higher proportions of missing information. Once again, the forced displacement of people is a well-known consequence of armed conflict in Colombia, and one of its effects may be seen in imprecise data on the mother's MIAD of residence.

### **6.3.2 Age and sex preference in the declaration**

Six countries were assessed for age preference and all seven for sex declaration preferences. This is because registered deaths in Colombia are published with aggregated age. From this point on, all results for the seven countries are given by the three spatial groups, and at the national level; therefore, a total of four estimates are expected for each country per calendar year.

Figure 6.2 displays the sex ratios of registered births for all the countries. Not having any indication of strong cultural sex preference, the sex ratios of registered births are expected to be at around 105, as occur in most countries. Abnormally, the Peruvian towns-and-rural-areas group indicates sex ratios of between 90 and 100. The same situation is seen in the Venezuelan towns-and-rural-areas group in the year 2001. These are an indication of fewer registered male births.

Figure 6.2 Annual sex ratios in registered births, 2000-2010.



Source: Registered birth databases in all the countries.

Venezuela’s 2001 sex ratios in the towns-and-rural-areas group is the inverse of the main-cities group. The presence of these abnormal values. Probably this comes from mother’s MIAD of residence being wrongly registered for a group of males. Male births whose mothers live in a MIAD of residence pertaining to the towns-and-rural-areas group were most likely identified as living in a main-and-large-cities MIAD of residence. This speculation relies on the fact that the year 2001 was the first one in which the civil registries were moved from the MIAD civil authority facilities to the main hospitals, which are located mostly in the main cities.

The annual sex ratios of registered deaths are displayed in Figure 6.3. Male deaths for every one-hundred females by five-year age group are shown for each year. Each year is represented in one line; the darkest line represents the first year of the period of analysis in each country, and the lighter line the last. Sex ratios suggest a greater concentration of male dead at young ages, namely, 15 to 35 years old. This male over-mortality is particularly higher in countries with well-known histories of high external causes of death in their epidemiologic profiles. Lower levels of sex ratios are seen at the oldest ages in all countries, as expected. This difference is in no way indicative of data quality but of mortality patterns.

Apropos age, the results of the Myers overall digit preference index are shown in Figure 6.4. As mentioned before, index values of less than 15 indicate acceptable declaration due to non-significant digit preference. In Figure 6.4, the Myers index by year, by spatial group, and by sex is displayed. Spatial-group values represented as points distinguished by color for each year and sex. Detailed digit preference analysis by each digit, country, groups of cities and sex are included in Annex C, Figure C.1.

Female registered deaths seem to be suffering larger problems with age declaration compared to males. Only Brazil and Chile present Myers indexes that are considered accurate for both

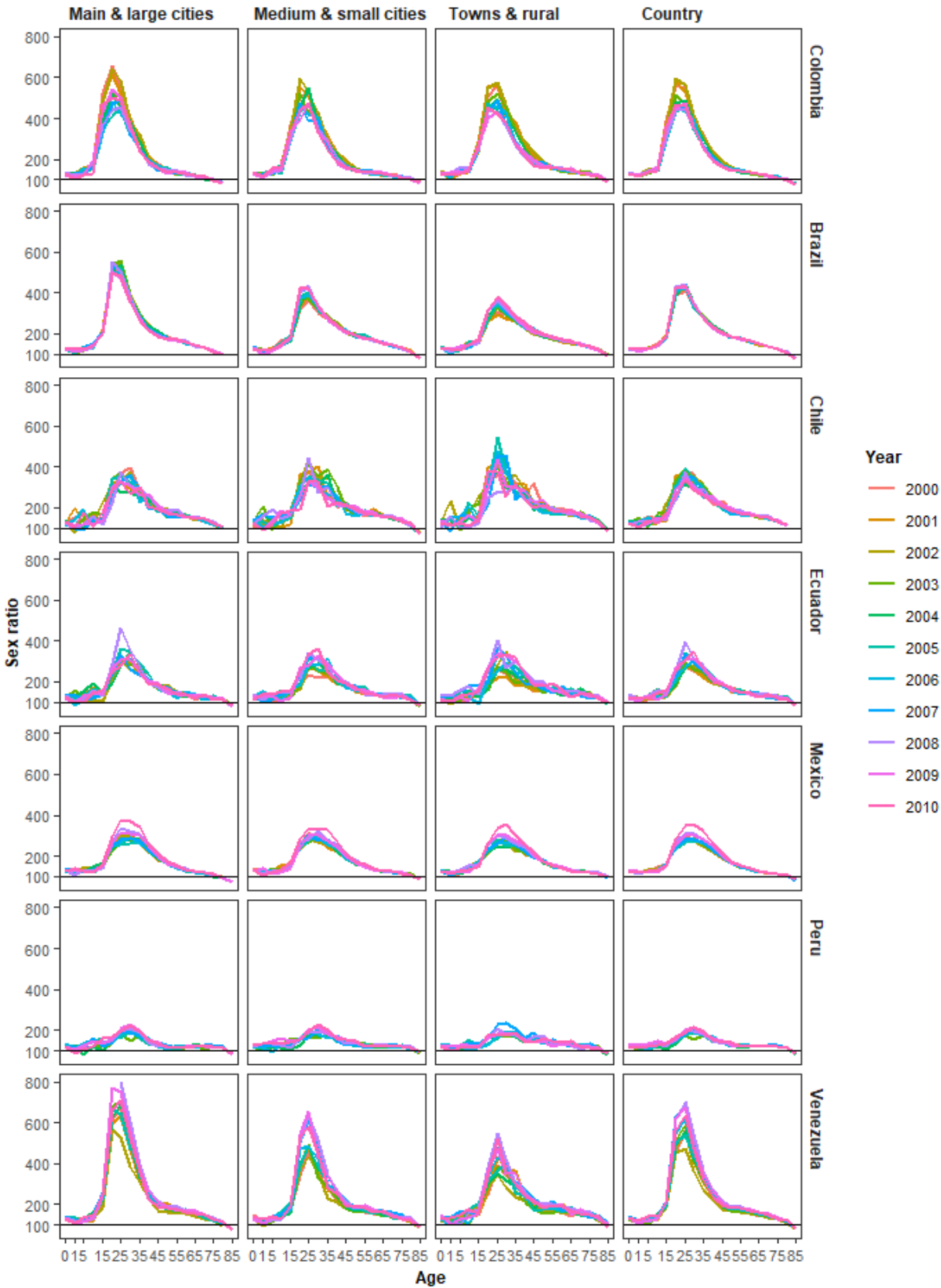
female and male registered deaths, while the rest of the countries linger with being labeled as having acceptable data with considerable improvement in the most recent years. As expected, the largest problems in each country are observed in the towns-and-rural-areas group. Only Ecuador and Chile show less difference among spatial groups.

In detail, there is a clear pattern for all countries in a preference for ages ending in 0 among both males and females during the whole period; yet, a recent substitution of preferences for ages ending in 5 in registered deaths among females is also notable in Brazil, Ecuador and Peru (see Myers digit preferences in Table C1 in Annex C).

For their part, Ecuador and Mexico are the countries with the biggest reduction in age preference during the period of analysis, regardless of the spatial group; the same improvement is noted for the Peruvian non-main-cities groups. Despite the different starting levels, all data hover around accurate levels of age reporting only by the end of the period. In summary, because most countries exhibit digit preferences, single age comparisons may lack accuracy.

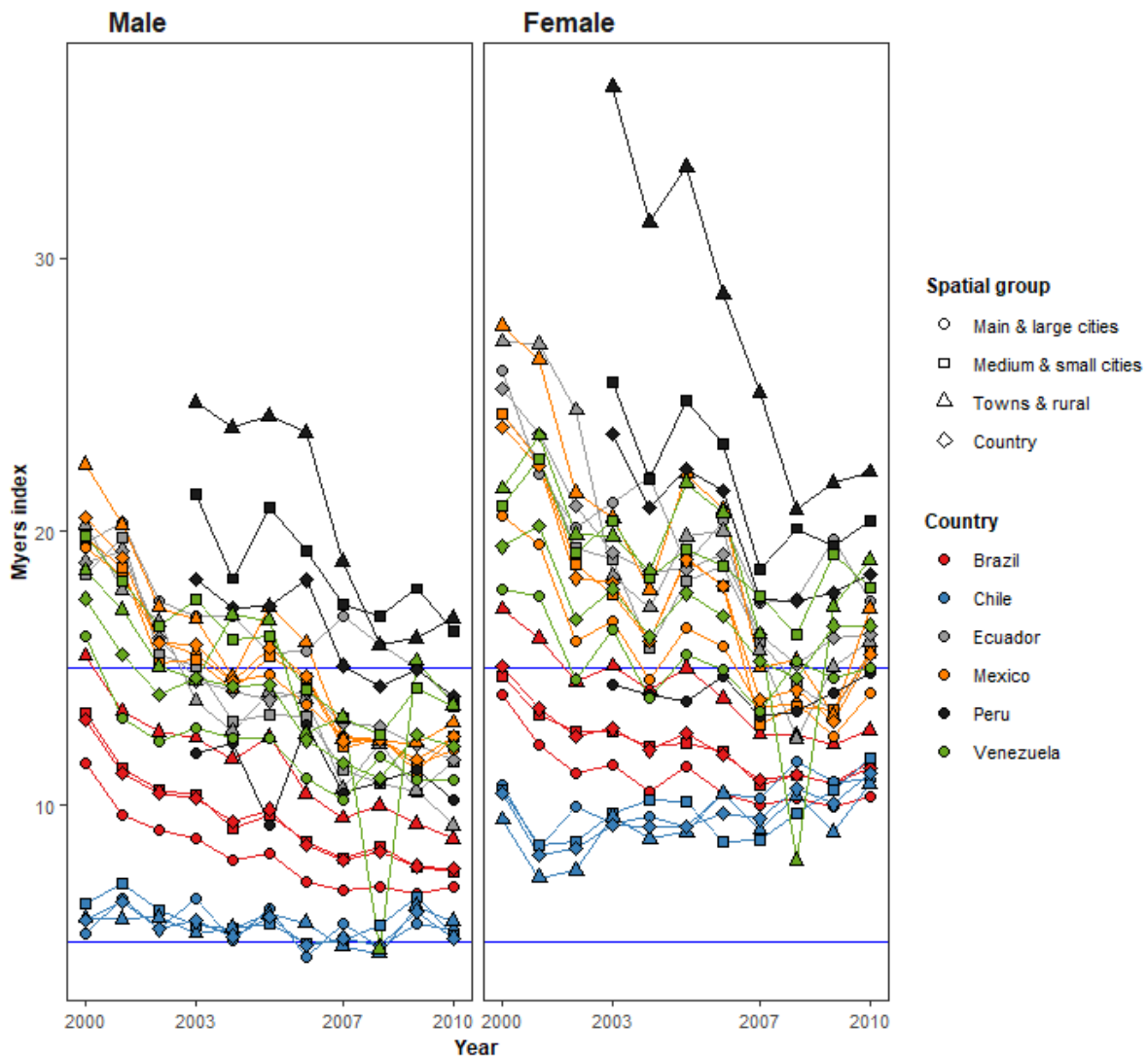
Another important issue when determining age misreporting is exaggeration, especially at older ages, as mentioned in previous studies of data assessment in Latin America. Age exaggeration is measured in three age cuts: exaggeration at ages 70 and over, 80 and over and 90 and over. The main intention here is to set the most convenient closing-age group in terms of comparability among the countries for future analyses. The ratio of declared age-of-death in Chile at age 60 and over to groups of ages 70, 80 and 90 is used as a benchmark for considering age exaggeration. The Chilean population is the most aged of the seven countries, ergo its ratios of death at age 60 and over to groups of 70, 80 and 90 and over are expected to be the highest of the seven countries. Any country or spatial group whose ratios are above those of Chile are considered to indicate that age exaggeration is present. Because the population structures are variables among the groups of cities (as seen in Chapter 4, Figure 4.1 Urban and rural population distribution in the 2000 census), groups of cities are evaluated separately. Then, the main-cities group in Chile is used only as a benchmark for all the main-cities groups in the six countries, and so on.

Figure 6.3 Annual sex ratios in registered deaths by spatial group and country, 2000-2010.



Source: Registered death databases in all the countries.

Figure 6.4 Annual Myers digit preference index in registered deaths by sex, spatial group and country, 2000-2010.

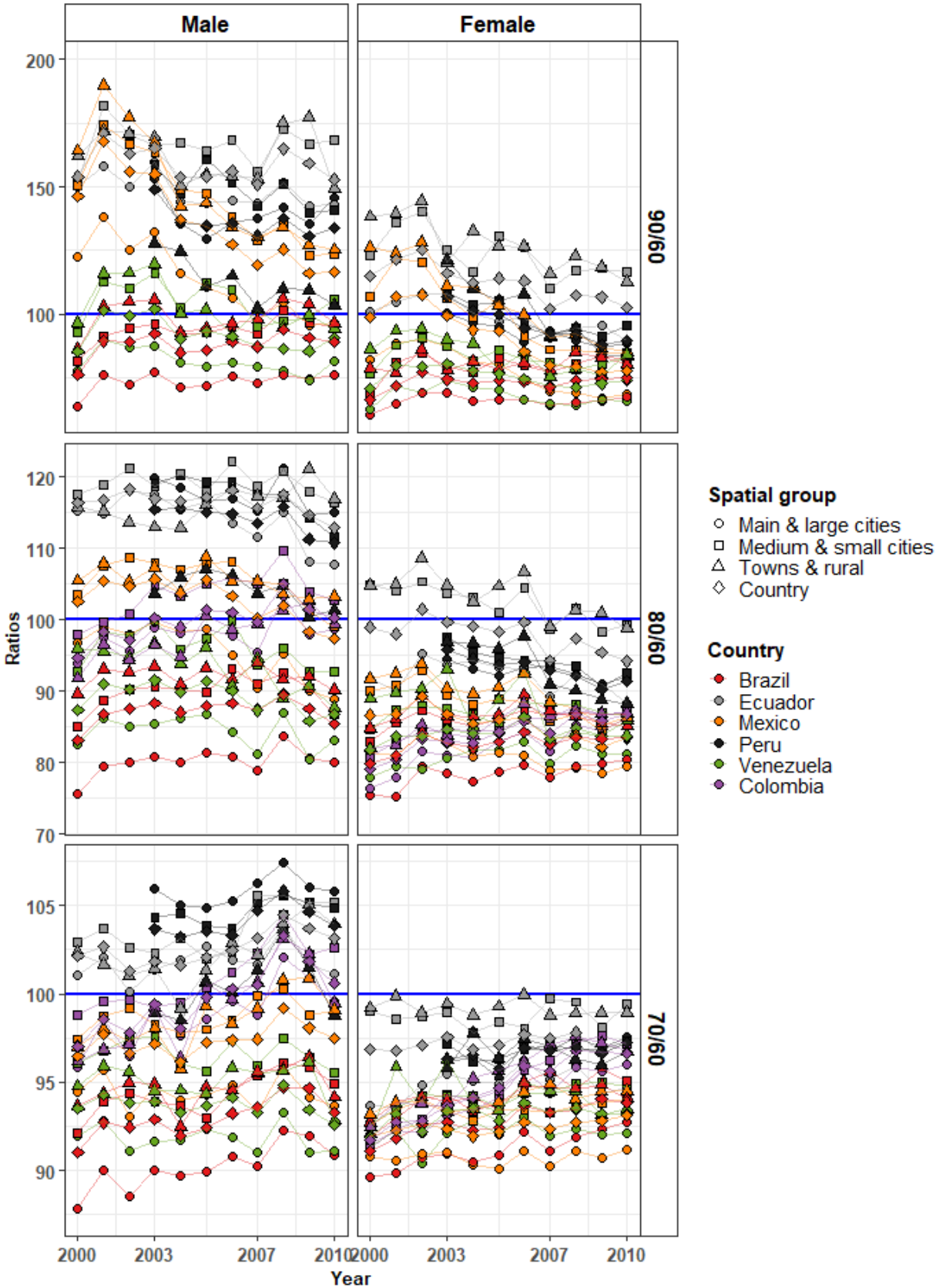


Source: Registered death databases in all the countries.

Figure 6.5 shows the ratios of each cut. At the top is the ratio of death at age 60 and over to that of 90 and over; in the middle is 60 and over to 80 and over; and at the bottom to 70 and over. Each country has its own color, and its groups are represented in different shapes. The blue line represents the Chilean ratios marked at 100, thus all groups above this line are considered to have age exaggeration.

Age exaggeration is noticeable for most of the countries at age 90 and over. Male death has considerably higher age exaggeration than female death in all the countries and for all ratios, without any sign of improvement in recent years. Female deaths in Brazil and Venezuela are the only populations without apparent age exaggeration, even for those over age 90. In contrast, male deaths in Ecuador and Peru have age-group ratios that start to become inaccurate over age 70 for all groups of cities. The Mexican pattern clearly varies, depending on the spatial group and sex. At age 80 and over, Mexican male deaths show age-group ratios above those expected for the towns-and-rural-areas group and this turns out to be even higher than for age 90 and over.

Figure 6.5 Annual age exaggeration ratios by sex, spatial group and country, 2000-2010.



Source: Registered death databases in all the countries.

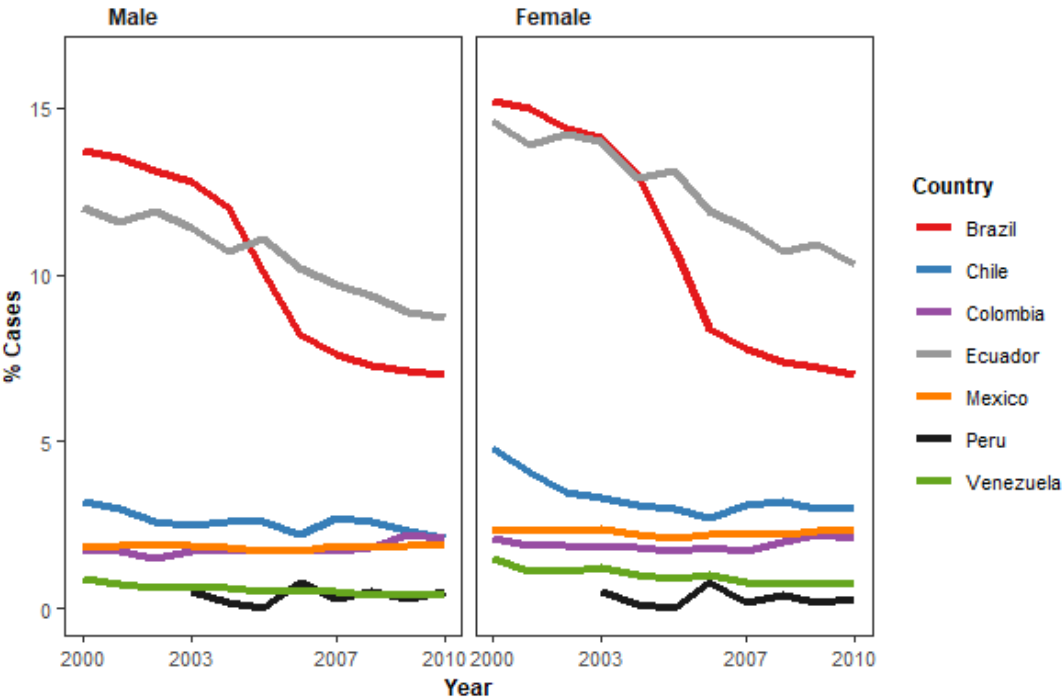
An integrated assessment of the data quality would help explain future findings when using indirect methods to estimate registered death coverage. Keeping only the individual descriptive perspectives for each database without comparing their mixed effects is indeed inappropriate. For example, the error effect would be cancelled out when estimating mortality rates if the same age exaggeration patterns were present in both death and population counts, due to the same increase in both numerator and denominator. Using census data, populations over 80 require special attention in some countries like Ecuador as well as the towns-and-rural-areas groups in Mexico and Peru (see Annex A for detailed information). However, age exaggeration in both censuses and registered deaths for males could make the effect even out. This would not be the same case for female deaths in the same countries, where bias is found only in the census data.

Bearing this in mind, aggregating the data into five-year-old age groups in countries like Peru, Mexico and Ecuador could more greatly guarantee better estimate quality, because female deaths maintain considerable levels of digit preference. In the same line, due to age exaggeration found in death counts for age 90 and over, an appropriate last open-ended age group would be age 80 and over. In contrast, Brazil, Chile and Venezuela present acceptable levels in all assessment indexes applied in this section.

**6.3.3 Assessment of causes of death completeness**

There are no cases without information in the underlying cause of death in the seven selected countries. All cases are classified according to the ICD-10, and the proportions and trends of ill-defined causes of death vary according to the country (see Figure 6.6). In general, there is a decline in the proportions, independently of each country’s level.

Figure 6.6 Proportion of ill-defined cause of death by sex and country, 2000-2010.



Source: Registered death databases in all the countries.



Mexico, Colombia and Peru — with less than 5 percent of ill-defined causes of death — are the only countries that have stagnated in the reduction. In contrast, Brazil and Ecuador show the greatest improvements, undoubtedly because of their still considerably higher levels of ill-defined causes. In between can be found Chile and Venezuela, where even though they have less than 5 percent, a continuous decline occurs during the period of analysis.

Despite particularity in trends and levels, a clear sex differential is found in the proportion of ill-defined causes of death. Ill-defined causes of death is greater among females; this could be because female deaths occur more and more at older ages, and also because the precision in determining cause of death tends to decline for advanced ages. At older ages, several causes could represent a competitive risk; thus, identifying a single cause could be challenging. Equally, when older people die, it is not unusual to find a lack of medical care and doctors who fail to properly maintain assignments and records — or even simply missing information.

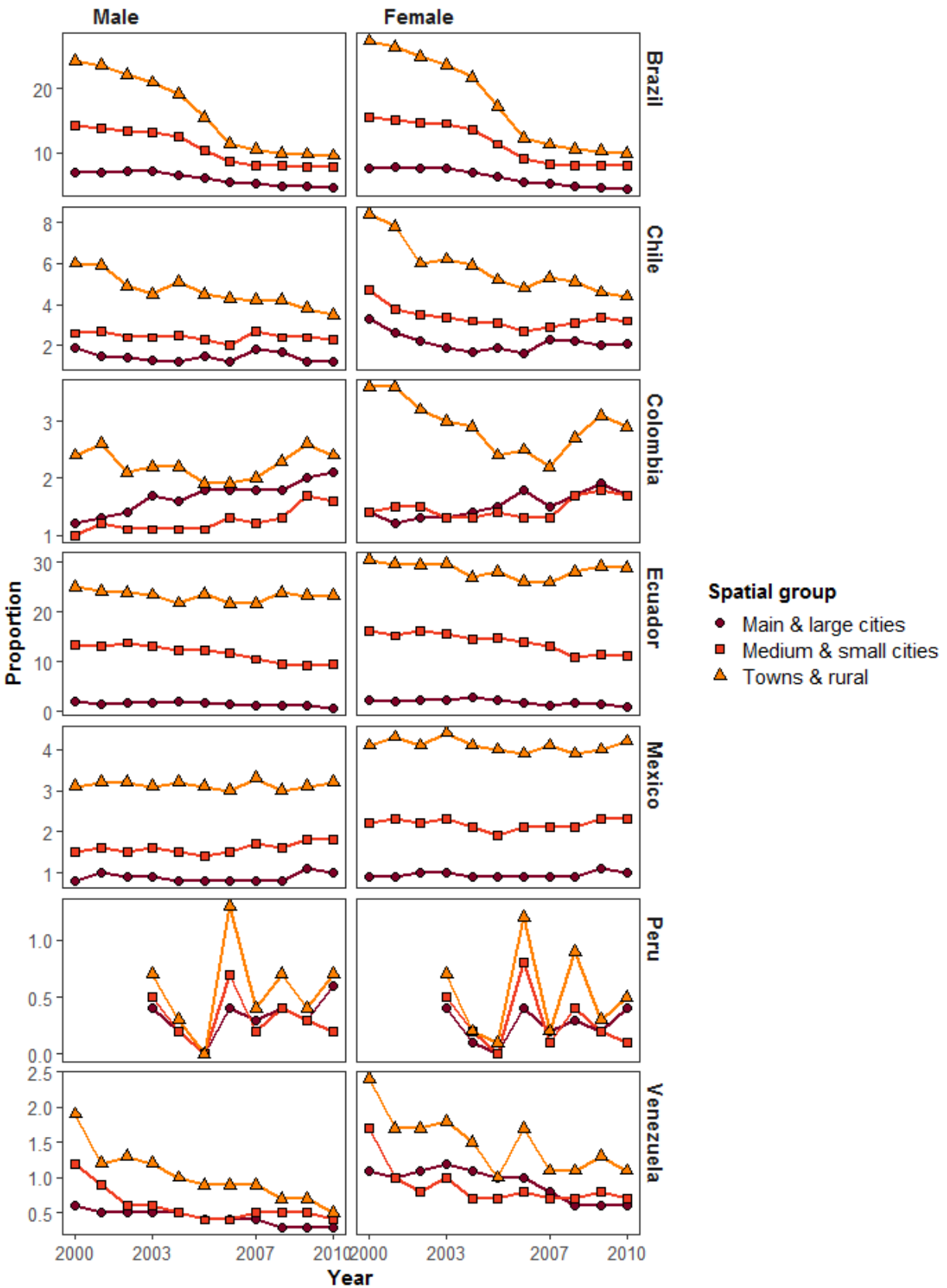
Colombia is the only country that shows no sex-differential. This exception could be due to the overuse of ill-defined in deaths resulting from violence-related deaths in which the intention is not determined; and these are concentrated mostly among males. The proportions of ill-defined by groups of cities and sex are shown in Figure 6.7. In all cases, the towns-and-rural areas group has higher proportions of ill-defined causes of death than any other spatial group. Peru is the only country showing a different pattern, in which there is no differential between groups of cities.

On account of the higher levels of the towns-and-rural-areas group, the greatest improvement could be expected in this group. However in Ecuador, Mexico and Peru, this expectation is not fulfilled. In Ecuador for example, the decline in the proportion of ill-defined causes of death at the national level is driven mostly by reductions in the medium-sized-and-small-cities group and not in the towns-and-rural-areas group. While in Mexico and Peru, the stagnation in the proportions of ill-defined is shared by all spatial groups. For its part, Colombia lacks improvement at the national level, and this is determined by both a minor decline in ill-defined proportions in the towns-and-rural-areas group, along with the main-and-large-cities and medium-sized-and-small-cities groups getting worse. The proportions of ill-defined causes of death found in main-and-large-cities and medium-sized-and-small-cities groups for Venezuela and Chile are similar in that they are considerably lower than the towns-and-rural-areas groups.

Following the sex differential seen at the national level, females always have higher proportions of ill-defined causes for all groups of cities. The Colombian, Mexican and Ecuadorian main-and-large-cities groups are the only cases in which male proportions of ill-defined deaths are higher than those of females.

In summary, most of the groups of cities and countries have proportions of ill-defined causes of death under 5 percent. Ecuador and Brazil are the countries with the highest proportions of ill-defined deaths, especially in the medium-sized-and-small-cities and towns-and-rural-areas groups. To be able to compare countries, a necessary arrangement must be made, and one suitable option seems to be a proportional distribution of ill-defined causes of death cases among the cases with defined causes. Special attention must be given to Brazil in this sense, particularly for time comparisons of the towns-and-rural-areas groups, due to significant changes made to the period of analysis.

Figure 6.7 Proportion of ill-defined causes of death by spatial groups, sex and country, 2000-2010.



Source: Registered death databases in all the countries.

### 6.3.4 Infant mortality coverage in registered data

Infant mortality rates (IMR) are estimated using registered birth and death data at national levels while adding female and male cases (see Figure 6.8; detailed rates by sex are displayed in Annex D, Figure D.1). These rates are directly calculated by using vital statistics officially published by national offices without any adjustment. Later on, these rates have been compared using estimates published by the UN IGME in its 2013 revision. On its side, figure 6.9 shows unadjusted registry data at national level and the UN IGME estimates. The difference found among these two estimations is used to build ratios called the under-registration ratio (URR) for each country.

It is possible to divide countries into three groups, according to their proportion of national coverage of vital events: 1) Chile and Venezuela have the highest and constant coverage for the whole period; 2) Mexico, Brazil and Colombia have increasing coverage; and 3) Peru and Ecuador have the lowest and constant coverage. These results follow the same tendency summarized in previous sections of this chapter discussing the historical evaluation of vital registration systems.

UN IGME estimates of IMRs take into consideration a set of different data, including censuses and surveys. UN IGME IMR estimates for Chile and Venezuela combine only registry and census data. Chile and Venezuela have higher levels of infant mortality when using registered data compared to using indirect methods on the census data. This could be due to better quality of the registered data than of the census data, or to abrupt changes in the registered data. From the previous literature review and data assessment, it is known that the Chilean vital statistics system appears to have better data quality than the censuses do. On its side, Venezuelan registered births show abrupt patterns as a consequence of changes in legal and administrative procedures during the period. However, when comparing census omissions, better coverage has also been reported in regard to the registry data of Venezuela.

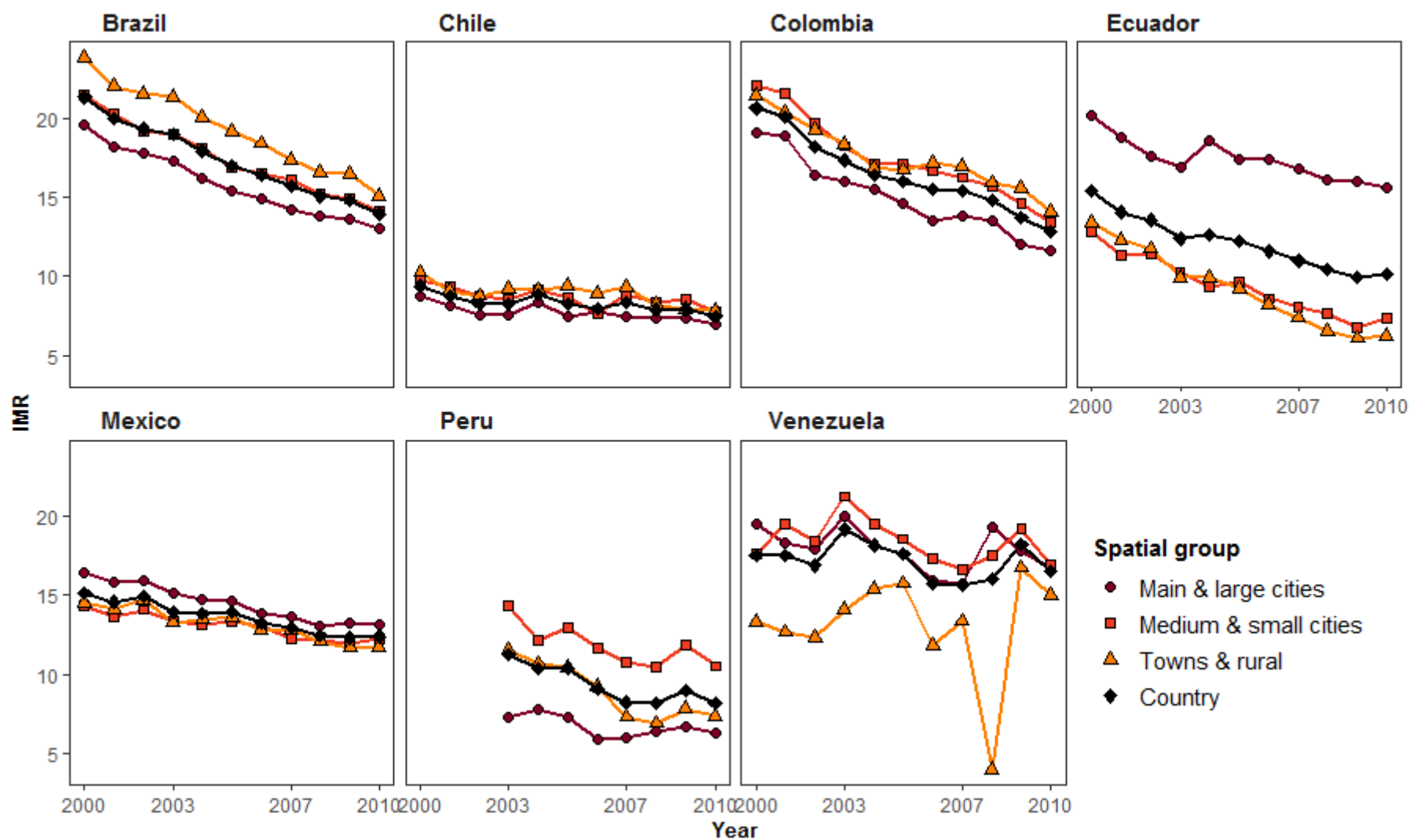
After computing URR at the national level, estimates by indirect methods on census data<sup>13</sup> are made in the framework of this research using West (Brazilian, Chilean, Colombian, Mexican and Venezuelan groups of cities and national levels), and South (Ecuadorian and Peruvian groups of cities and national levels) model life tables. Figure 6.10 displays the results obtained from using the indirect method on summary birth history data from 18 censuses conducted in the seven selected countries during the 1990, 2000 and 2010, by spatial group and at national levels

For all countries and censuses, there is a clear decline in mortality, with the lowest IMR levels in the main-and-large-cities group and the highest in the towns-and-rural-areas group. Chile and Venezuela seem to have both the smallest gap and the lowest levels of infant mortality during the period 2000 to 2010.

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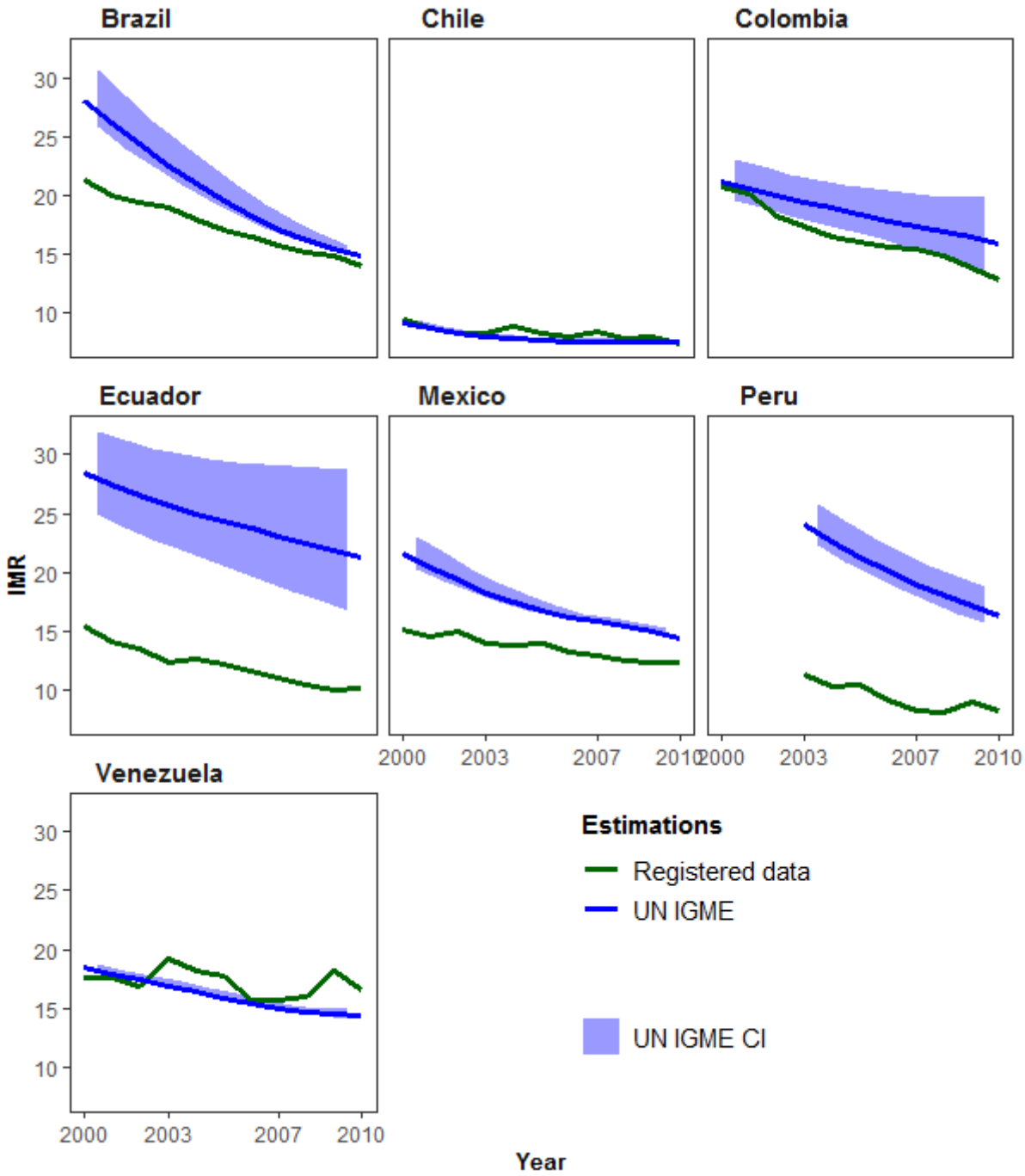
<sup>13</sup> A previous evaluation of census data (for details, see Annex A: Assessment of census data) shows that indirect estimates of infant mortality are feasible using census data due to the large information collected in summary birth history. In this sense, the Chilean and Mexican 1990 censuses must be treated carefully due to their high proportion of missing information (more than 7 percent). For more details, see Table A.1 Proportion of missing information in census data, in Annex A: Assessment of census data.

Figure 6.8 Infant mortality rates using unadjusted registry data, 2000-2010.



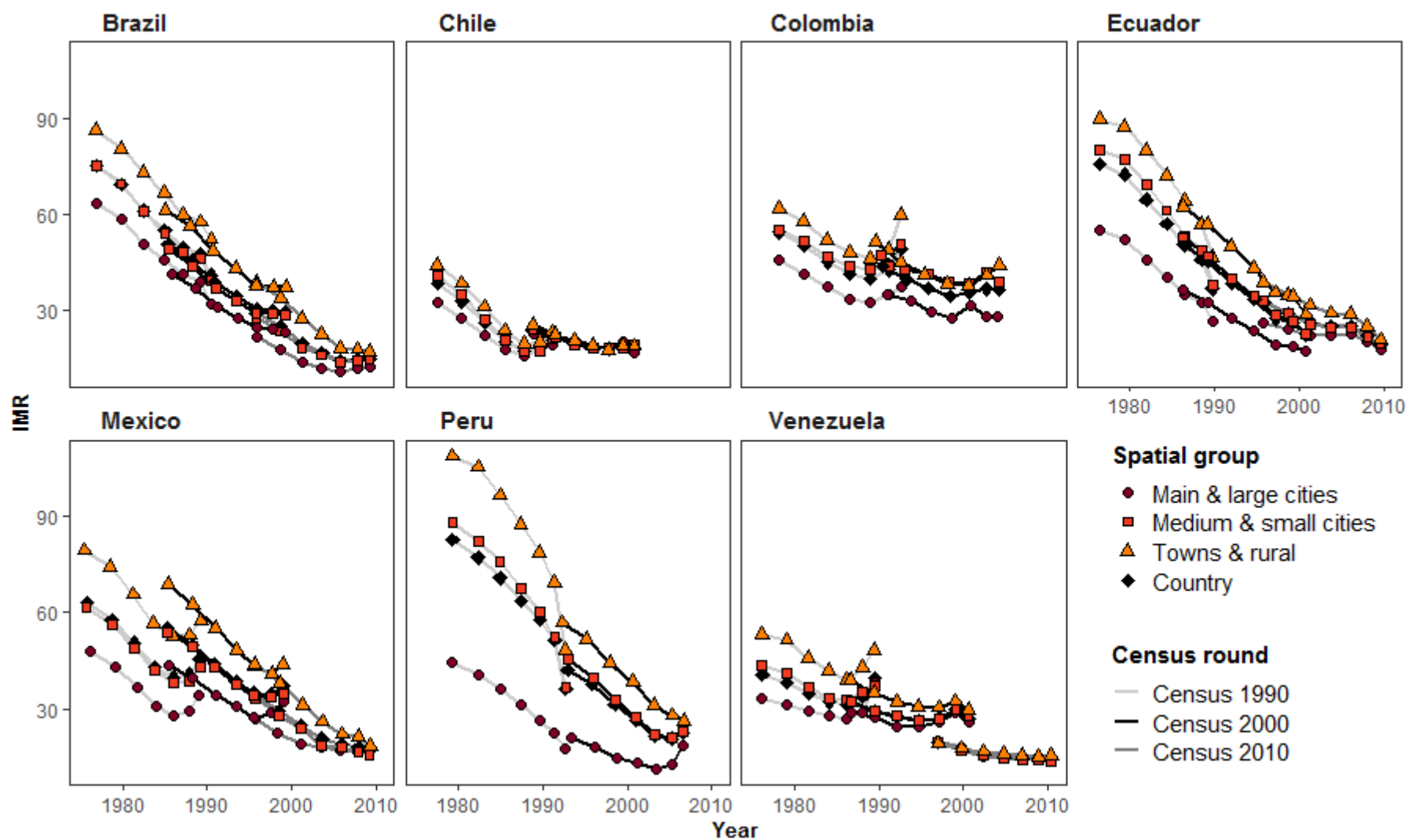
Source: Unadjusted registered death and birth counts both sexes included in all the countries.

Figure 6.9 National Infant mortality estimates, 2000-2010.



The indirect estimations, as expected overestimated the levels obtained from women aged 15 to 24 for all censuses and countries. Overestimates are visually evident through the U-shape of the estimates when grouping by census round. One exception is that Peru and Ecuador do not show this characteristic. The U-shape of the estimates (made by using the declarations from the 15- to 24-year-old women group) represents erratic values when compared with the rest, which are more likely to be ordered in a smooth line. These erratic values are disregarded as input to the linear regression models that will be run to summarize the gap among each spatial group and at the national level by country. These coefficients are summarized in Table D.2 in Annex D: Infant mortality coverage.

Figure 6.10 Infant Mortality estimates by indirect methods on census data by spatial group and census round, 2000-2010.



Source: Census data of 1990, 2000 and 2010

I use both the URRs and the linearly modeled gap in census data by groups of cities compared to the national level to determine coverage in IMR. Adjusted IMR is presented in Figure 6.11. Unadjusted estimates from the registered data invert and/or widen the gaps among the groups of cities, especially for those countries with the highest URR. This means that before correcting the estimates, either the gaps between the spatial groups were smaller or the main-and-large-cities group had the highest IMR, if not both. However, after correcting the estimates for under-coverage, in most cases the main-and-large-cities groups have the lowest IMR, showing that differences without correcting the data were mostly driven by more deficient registry outside the main cities.

In Ecuador and Mexico, while indirect estimates indicate that towns-and-rural-areas groups have the highest IMR, registered data indicates the main-and-large-cities group as the highest. This shows that differences in IMR are highly biased by differential in under-coverage. The order of the IMR levels by spatial group in Colombia, Brazil and Peru are the same, regardless of the data used for their estimates. However, when using the indirect method, gaps by spatial group are much wider than those seen using registered data. For countries like Venezuela and Chile, who have the smallest URRs at the national level, differences are seen only for the town-and-rural-areas group.

Similarly, when combining both ratios, Chile has complete coverage of infant mortality in all groups of cities and at the national level. In contrast, Peru and Ecuador have the lowest proportion of registration. Figure 6.12 summarizes the percentage of coverage by spatial group that was applied in order to correct the IMR estimates (Chile is excluded from this graph since it is considered it has complete coverage of infant deaths). It is clear that, at spatial-group level, it is in the main-and-large-cities group where the coverage is higher and the town-and-rural areas have the lowest for all countries. Colombia is the only country that breaks the pattern and for which medium-sized-and-small-cities group seems to have the worst coverage. Another exception is Venezuela, where under-coverage is almost entirely concentrated in the towns and rural areas.

In general, there is not much variation in coverage over time. Variation is seen through the dispersion of the proportion of coverage represented in the size of the boxplot. In all the cases, dispersion here is a synonym for improvements in the coverage of registered data due to the fact that no country has shown any diminishing coverage. Superbly, Brazil and Mexico show important improvements in the coverage at all levels during this period. The towns and rural areas in Venezuela also show increases in their coverage.

In summary, these first coverage estimates follow the same patterns seen in the quality assessment: there are undoubtedly different levels of strength in the vital statistics systems among countries, but there are also differentials in the scope of the systems according to the spatial group. This scope seems to be related to the size of the city: the biggest cities have the highest coverage and vice versa.

Figure 6.11 Infant mortality unadjusted and adjusted estimates by spatial group and sex

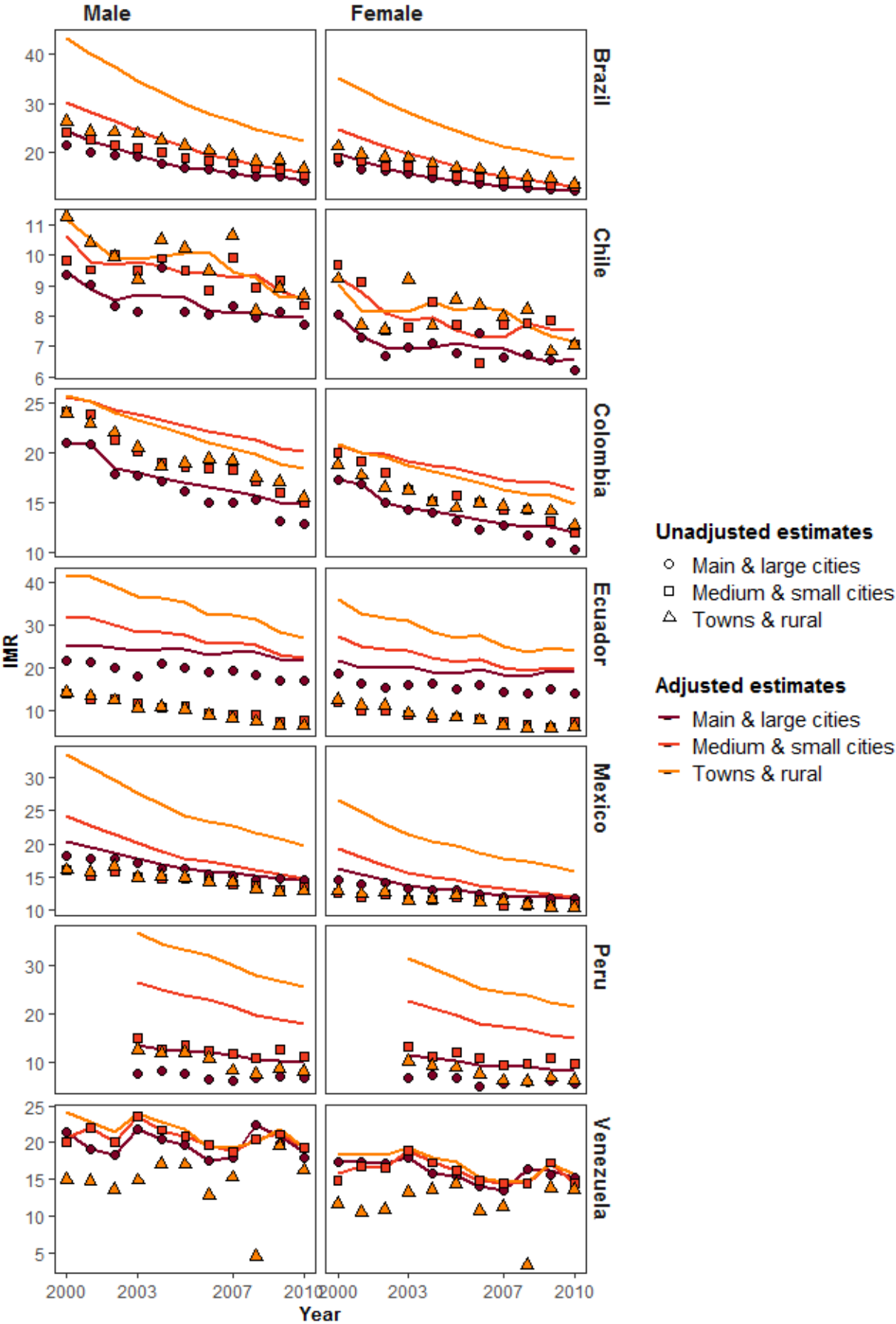
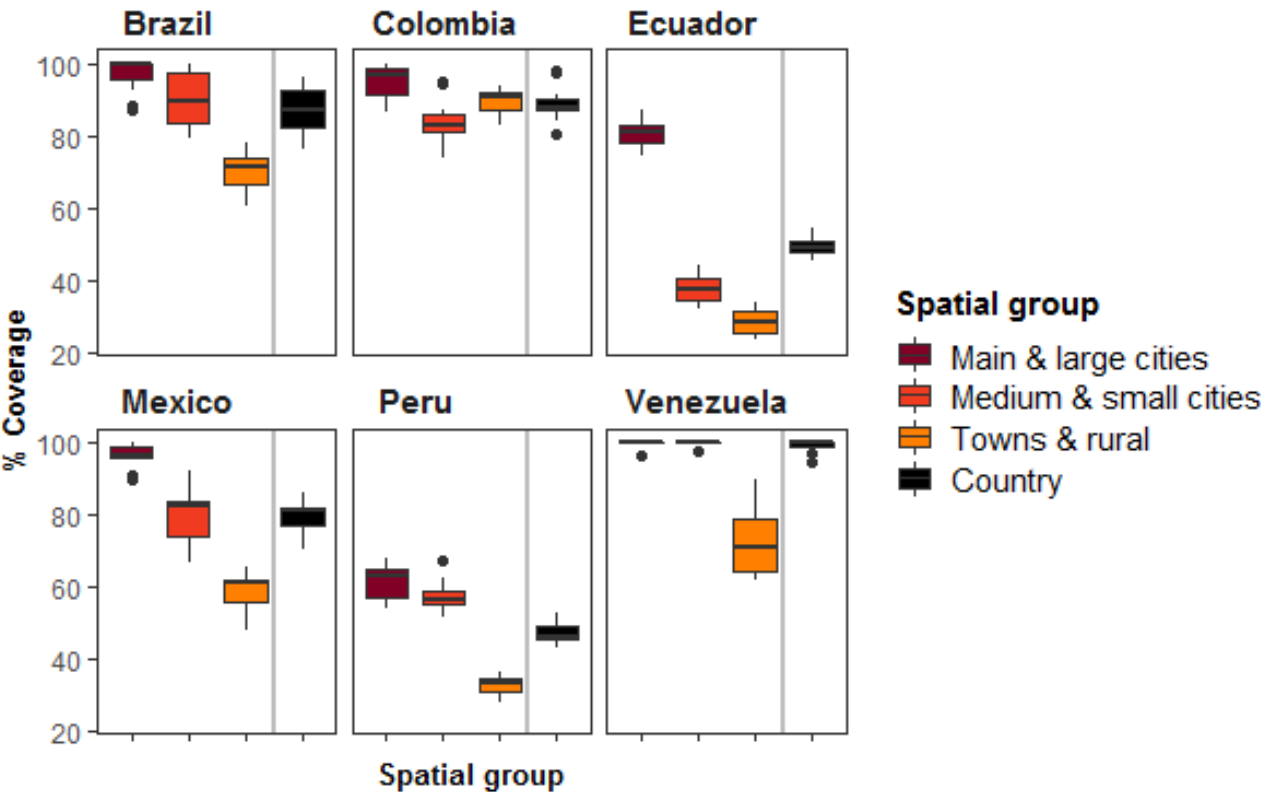




Figure 6.12 Percentage of coverage in registered data for IMR



Source: Table D.3 Percentage of coverage of registered IMR by sex and spatial group in Annex.

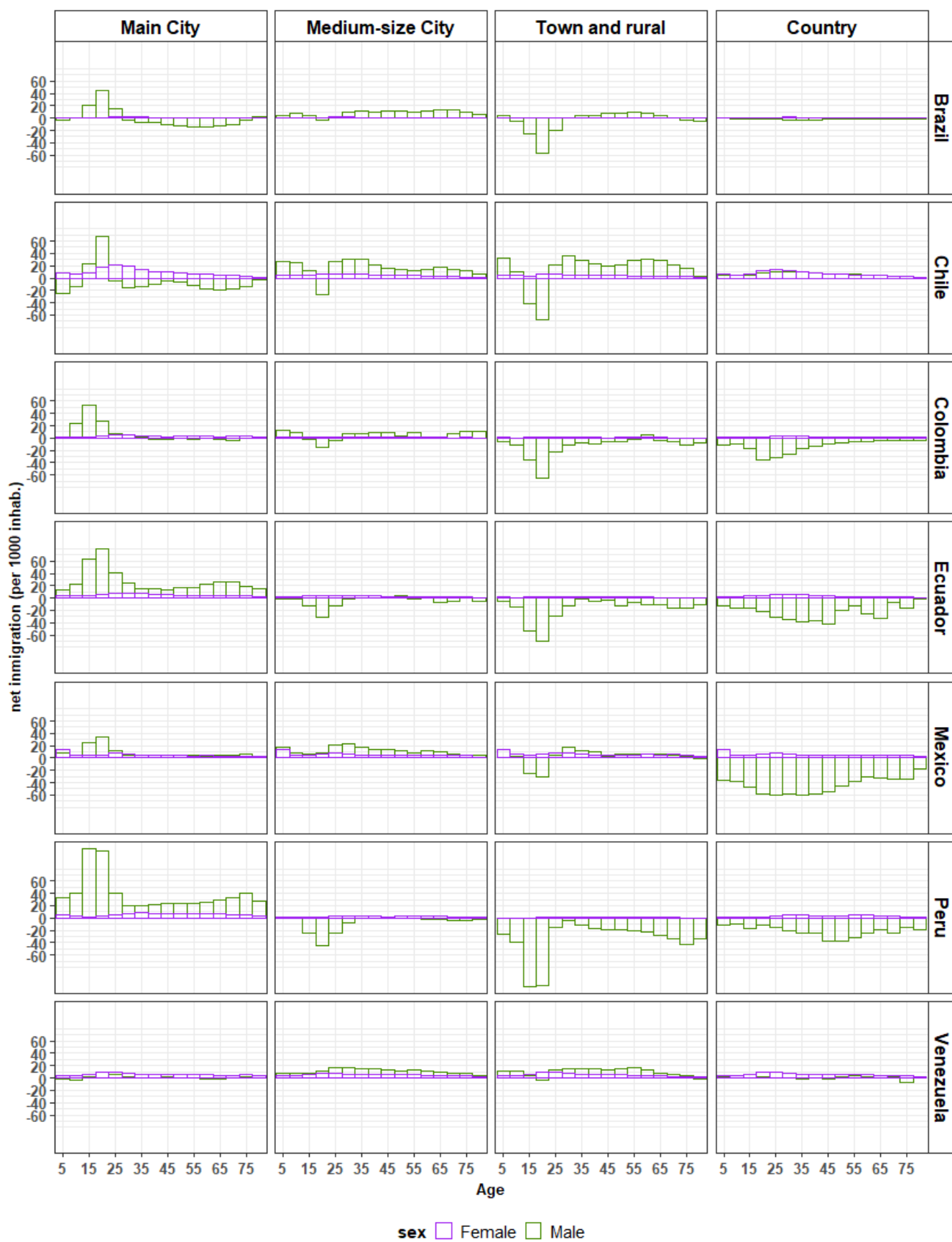
**6.3.5 Adult mortality coverage in registered data**

For estimating the coverage of adult mortality, two important previous steps are taken: 1) assessing the census data; and 2) estimating migration on the final population used by the indirect method for mortality estimation. The aim of evaluating census data is related to assessing age and sex preferences. The results obtained from census data evaluation (see Annex A: Assessment of census data, for details) highlights the general adequacy of their use. For indirect estimation methods of adult mortality, information on population up to age 70 is reliable with the necessary inclusion of migration.

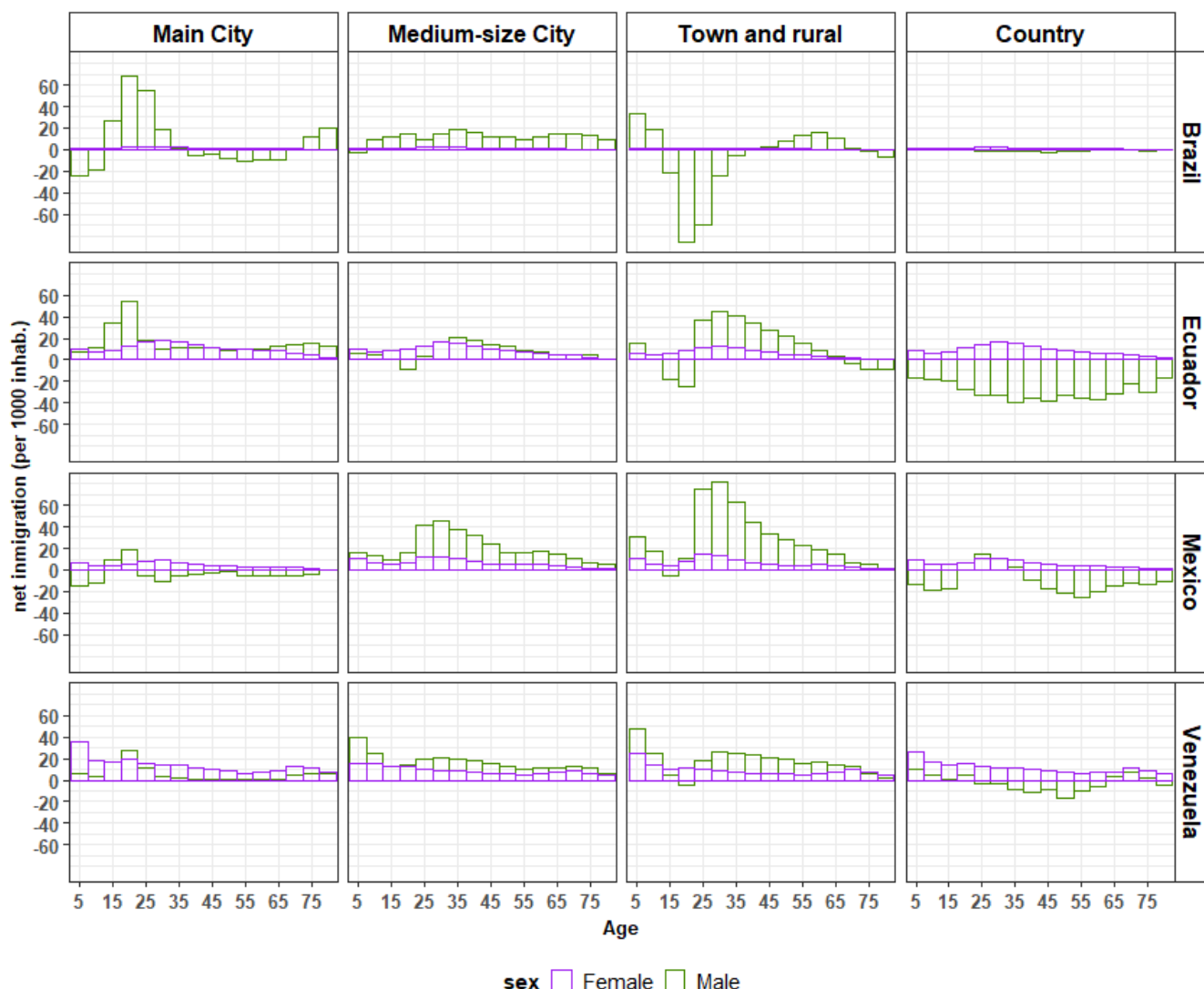
Regarding migration estimates: as said before, domestic and international migration structures are estimated separately. The results are shown in Annex B: migration estimates (Figures B.4 to B.6). In Figure 6.13 are displayed total net migration counts by spatial groups, sex and countries for the inter-census periods 1990-2000 and 2000-2010. Logically, net migration at the country level refers to international migration, while the spatial-group level refers to both domestic and international. It is important to keep in mind at this point that international emigration could only be included at the country level because there is no information of the spatial group from which emigrants left. This means the counts shown here are biased to over-estimated under-coverage. In countries without significant international emigration flows during the inter-census period, this bias will not have an impact. In contrast, countries like Ecuador and Mexico are more sensitive to the bias.

Figure 6.13 Net migration by sex and spatial group

Period 1990-2000



Period 2000-2010



Source: Census rounds in each country, IPUMS microdata and DESA migration estimates.

Net migration counts from both inter-census periods are included in the death distribution methods. All estimates are calculated with the R package DDM, Death Distribution Method developed by Riffe et al. (2016)<sup>14</sup>. In this sense, Table 6.5 shows all coverage estimates made by the two methods (General Growth Balance (GGB) and the Synthetic Extinct Generation (SEG)), and their combination (GGBSEG). For all methods, the averages of the deaths are considered to better approximations than their sums for the whole inter-census period<sup>15</sup>.

The obtained results come with graphic diagnostics that may help understand the efficiency of the methods, according to the assessment of data quality and compliance with the assumptions they involve (Queiroz and O. T. Sawyer 2012). Annex E includes graphics corresponding to male and female death completeness (*Figure E.1 GGB-SEG age-pattern of coverage estimates with census data by sex, groups of cities, country and inter-census period*).

<sup>14</sup> All default settings have been kept for age group and life expectancy in the open age group (80 years old, in this case). Similarly, the program chose by default the age range that minimizes the mean squared error.

<sup>15</sup> Because of availability, a false inter-census average is constructed for Peru by considering only average for the year in the middle of the 2003-2004 period.

Table 6.5 Percentage of coverage of adult mortality with census data by census round, sex and spatial groups.

Country	sex	Spatial group	1990's - 2000's				2000's - 2010's			
			delta	ggb	seg	ggbseg	delta	ggb	seg	ggbseg
BRA	Male	Main & Large	1,03	93	83	91	1,00	102	103	95
		Medium & small	1,00	100	95	96	0,95	101	112	89
		Town & Rural	0,98	102	101	93	1,01	103	90	75
		Country	1,01	99	91	94	0,99	100	101	88
	Female	Main & Large	1,00	87	84	85	0,99	103	104	92
		Medium & small	1,00	99	93	95	0,96	100	113	90
		Town & Rural	0,99	96	94	91	1,04	100	77	76
		Country	1,01	100	89	94	0,99	100	98	89
CHI	Male	Main & Large	1,02	100	90	99				
		Medium & small	0,94	99	113	94				
		Town & Rural	0,95	100	112	94				
		Country	0,98	102	107	98				
	Female	Main & Large	1,04	100	85	99				
		Medium & small	0,96	100	108	95				
		Town & Rural	0,97	100	108	95				
		Country	1,00	100	99	97				
COL	Male	Main & Large	0,93	102	135	98				
		Medium & small	0,93	101	111	92				
		Town & Rural	1,10	107	71	96				
		Country	0,99	103	99	95				
	Female	Main & Large	0,87	113	138	94				
		Medium & small	0,89	98	119	88				
		Town & Rural	1,08	102	75	94				
		Country	0,93	100	109	91				
ECU	Male	Main & Large	0,92	239	189	124	0,97	61	81	70
		Medium & small	1,17	284	119	255	0,99	67	73	68
		Town & Rural	0,97	131	127	108	0,98	72	81	72
		Country	1,03	241	132	142	1,02	73	65	71
	Female	Main & Large	0,91	264	201	122	0,98	63	76	68
		Medium & small	1,24	392	132	404	1,00	66	65	65
		Town & Rural	1,05	182	123	156	1,02	77	64	70
		Country	1,20	391	142	288	1,03	69	54	65
MEX	Male	Main & Large	1,00	106	106	105	1,00	116	108	109
		Medium & small	0,96	105	110	99	0,94	102	119	94
		Town & Rural	0,98	100	102	95	0,93	98	120	91
		Country	1,03	109	99	107	0,97	103	104	97
	Female	Main & Large	0,99	108	111	107	1,01	121	110	115
		Medium & small	0,99	113	112	108	0,97	106	110	100
		Town & Rural	1,04	114	97	112	0,97	103	106	97
		Country	1,06	116	95	118	1,02	113	103	109
PER	Male	Main & Large	1,02	116	100	108				
		Medium & small	0,97	119	112	105				
		Town & Rural	1,09	98	70	94				
		Country	1,10	100	72	97				
	Female	Main & Large	1,06	59	41	51				
		Medium & small	1,12	62	34	52				
		Town & Rural	1,09	93	71	88				
		Country	1,11	98	71	95				
VEN	Male	Main & Large					1,00	99	98	96
		Medium & small					0,95	98	111	91
		Town & Rural					0,92	73	111	77
		Country					0,99	100	98	94
	Female	Main & Large					1,02	98	87	94
		Medium & small					0,98	100	101	91
		Town & Rural					0,95	70	95	74
		Country					1,02	101	85	94

Source: Output DDM R package on census, migration and death count data for each country.

Graphs come from  $N_{x+5} / \hat{N}_{x+5}$  ratios derived from the combination of the SEG method and the differential omission coefficient (delta) obtained by GGB method. Combining these methods, as has been pointed out by the literature, turns out to give the most linear and stable ratios possible with the available input data.

Broadly, the results obtained from GGBSEG at the national level seem to be the closest to those recently calculated by scholars using different methods and which are displayed in Section 5.2.2 Death registration, in Chapter 5. A comparison of life expectancy estimates with adjusted rates and international estimates at the national level are displayed in Figure 6.14. Furthermore, adult mortality coverage estimates confirm the levels seen when evaluating the registered data coverage of infant mortality: the main-and-large-cities group has higher coverage for most of the countries, in contrast to the towns-and-rural-areas group, which has the lowest coverage.

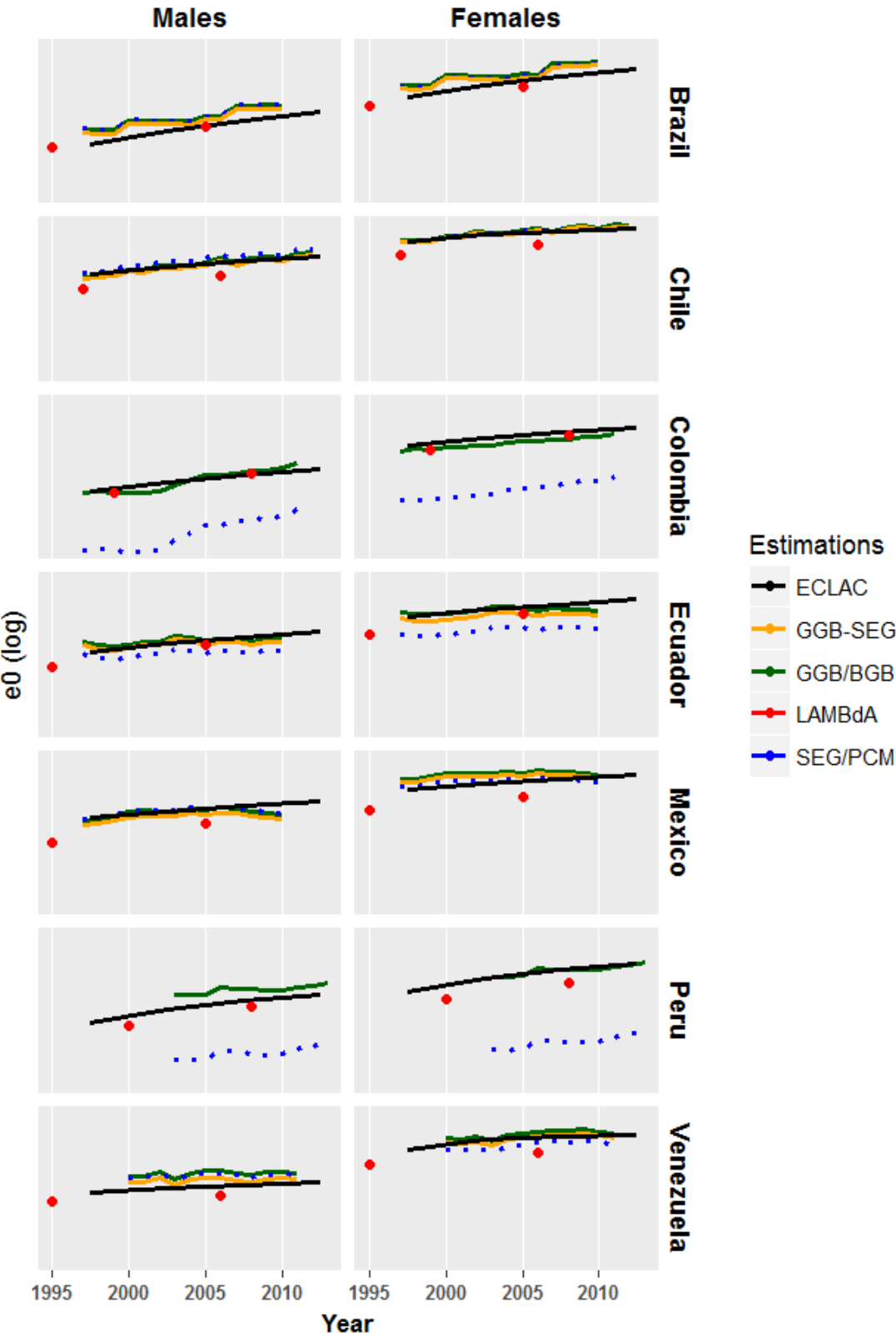
However, some specific concerns arise, above all, regarding the Colombian and Peruvian results. In Peru, there are remarkable sex differentials in the coverage. These do not seem to be in accordance with any known bias practice in the registered data. Then, they must be interpreted as misestimates. For its part, Colombian coverage estimates are considerably higher than expected, according to a previous analysis at the national level. What is more, its estimates break the hierarchical relationship between coverage and spatial group that is shown by other countries.

One obvious issue in these two countries is the long length of their inter-census period: 13 years for Colombia and 15 years for Peru. This is a period in which changes in mortality and migration trends could be happening. One way to deal with this is applying the same death distribution methods, but in their one-census variant, without relaxing the stability assumption for the most recent census data. The results of a rehearsal practiced on the 2000 census rounds in both countries are in Table E.2 in Annex E. The two DDM applied without relaxing the stability assumption are the Brass Growth Balance (BGB), which is equivalent to the GGB, and the Preston and Coale method (PCM), which is equivalent to SEG. This time, the estimates made with the BGB method at the national level are closer to those previously displayed in Section 1.2 for both countries, specifically when comparing them with previous coverage estimates in Table 6.5. However, estimates with the BGB method do not seem to have the linear adjustment necessary when applying these methods (Annex E shows once again the graphic diagnosis of the BGB method that was used on the data in *Figure E.3*).

Ecuadorian and Mexican coverage estimates for the period 1990–2000 are misled exaggerations of death over-registration. On the one hand, Ecuadorian population is significantly lower than the other countries under study. Additionally, an intense internal and international inter-census migration net flow occurred in the period mentioned before. Thus, real changes in population due to migration, together with the worsening quality of the 2000s population census data (as reflected in the total omission and misreported age) are more likely to explain the results obtained. The same situation arises in 1990–2000 Mexican coverage estimates: over-registration of death for all spatial groups and at the national level for this period is more likely to be led by missing migration data (return migration, seasonal labor commuters conjointly with Central America transmigration).

Figure 6.14 shows the life expectancy estimates made by correcting the proportion of coverage in reported death counts and compared with estimates made by both the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the Latin American Mortality Database (LAMBdA).

Figure 6.14 Comparison of life expectancy at birth with adjusted estimates using census data



Notes: ECLAC: United Nations Economic Commission for Latin America and the Caribbean; LAMBdA (Latin American Mortality Database); GGB-SEG: estimate made by combining GGB (Census omission differential) and SEG; GGB/BGB: combining the General Growth Balance method used on data from two censuses and BGB on data from one; SEG/PCM: Synthetic Extinct Generation on data from two censuses and the Preston and Coale Method on data from one census.

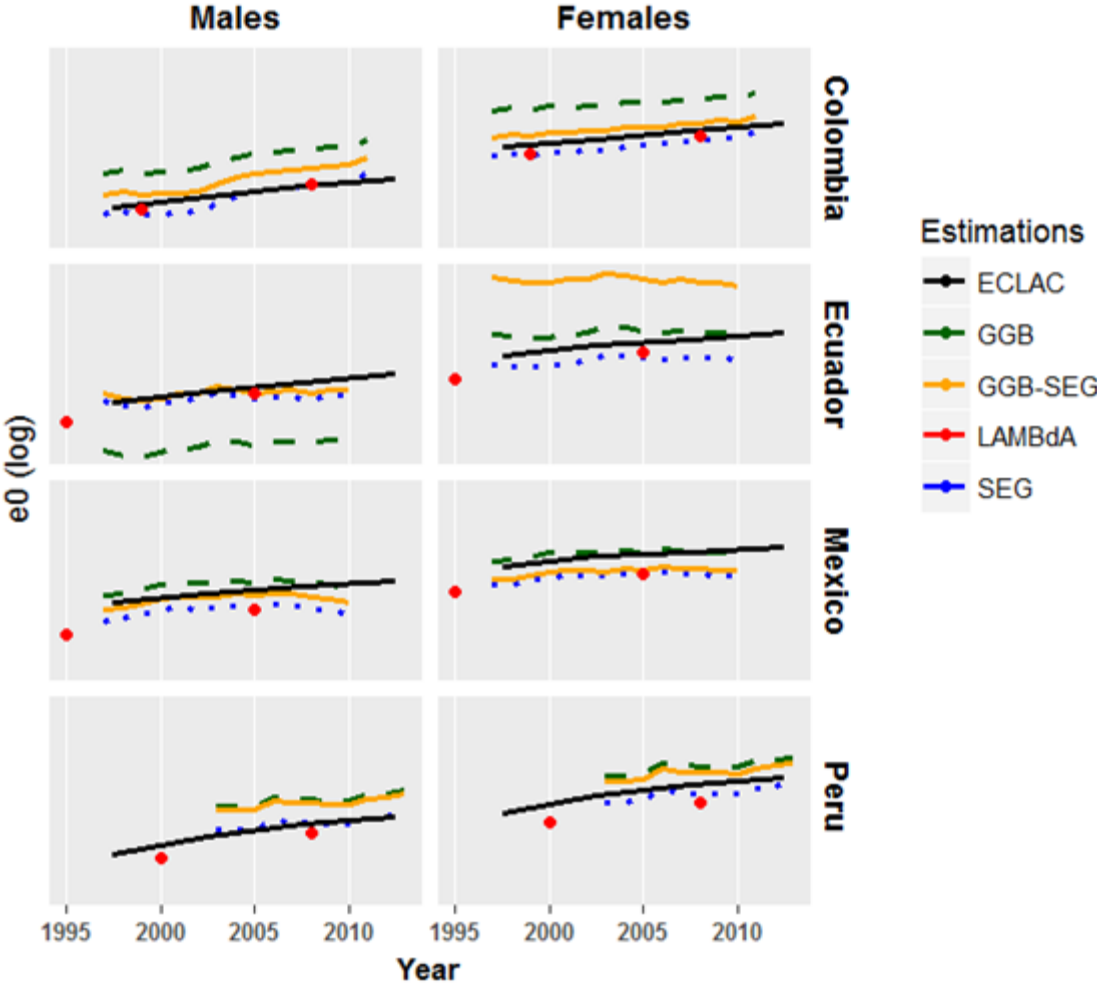
Adjustments have been done only considering under coverage of the inter-census period 2000-2010 for Venezuela, Brazil, Ecuador and Mexico, and 1990-2000 for Peru and Colombia. Regarding the adjusted life expectancy at birth estimate made using the GGB-SEG method while considering census data, it seems to be in general the one closer to the estimates made by ECLAC and LAMBdA. However, some issues regarding the effect of the quality in population counts are still unresolved. Indeed, in the four countries mentioned before (Colombia, Mexico, Peru and Ecuador), fundamental problems arise when the error(s) in more than one of the components of the equation (population counts, migration flows, death data) are unknown or they have non-acceptable data quality. As stated, the net migratory balance of a country and census omission constitutes the greatest challenges to indirect estimates, both individually as well as in terms of disentangling their combined effects.

The relevance of the methods could be associated more with "variations" in the quality of the information provided rather than the dynamics of the demographic phenomena. To try to isolate the effects of defective population counts from death coverage assessment, one way is to consider the population estimates of the National Institute of Statistics.

Considering the uncertainty in the under-coverage estimates found in Colombia and Peru due to the long length of their inter-census period, and Ecuador and Mexico, migration flows, mid-year population estimates are taken to replace the population count from censuses. Then, instead of comparing two census counts, two mid-year population estimates are used to evaluate the coverage of the registered deaths. In this case, the populations at mid-year 2000 and mid-year 2010 are considered to be the initial and final population counts for the DDM. Migration net counts are also included in these populations and an average of death counts is introduced as input into instead of additions to the DDM in order to determine coverage in adult mortality. A graphical comparison of results obtained at the national level in Figure 6.15 show the estimates from the GGB-SEG, GGB and SEG methods using population estimates. Table E.4 in Annex E provides the proportions of coverage calculated with all methods using population estimates.

The SEG method is ideal for population estimation because population estimates are adjusted population counts; this means that they do not suffer from data collection process errors. The SEG method applied to population estimates gives a national level life expectancy at birth that is more similar to those previously made by ECLAC and LAMBdA than to those obtained using census data. Similarly, linearity is better accomplished for all countries when SEG is used in population estimates (Figure E.5 in Annex E provides the estimate of death completeness using the SEG method ratios:  $N_{x+5}/\hat{N}_{x+5}$ ). One exception is Ecuador, which breaks this pattern. The  $N_{x+5}/\hat{N}_{x+5}$  ratios in Ecuador are less dispersed in the 2000 census data which is nevertheless questionable in terms of data quality, especially age misreporting. That is why this research has decided to adopt population estimates as a more pertinent alternative for estimating under-coverage in registered death in Colombia, Ecuador, Mexico and Peru.

Figure 6.15 Comparison of life expectancy at birth between with adjusted estimates using population estimations

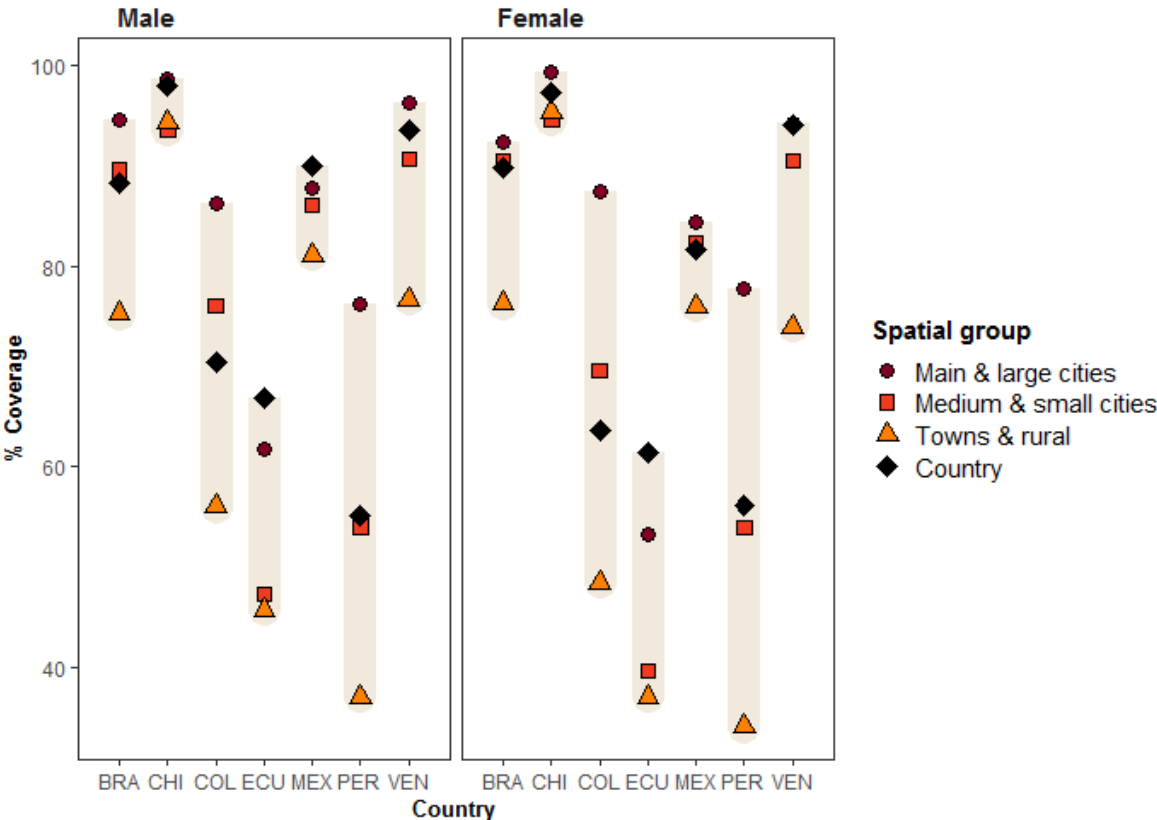


Notes: ECLAC: United Nations Economic Commission for Latin America and the Caribbean; LAMBdA: Latin American Mortality Database; GGB: General Growth Balance; SEG: Synthetic extinct generation; GGB-SEG: combination of both the GGB and SEG methods.

Final coverage estimates at the national and spatial group levels are presented in Figure 6.16. Brazil, Chile and Venezuela are the countries with higher coverage while Peru and Ecuador have the lowest. For all seven selected countries, coverage in adult mortality in the main-and-large-cities group is higher than in other groups. In countries such as Colombia, Ecuador, Peru and Venezuela, differences in coverage by spatial group are wider than in the rest of the countries. In general, proportions of adult mortality coverage turn out to be similar to under-coverage estimates for infant mortality.



Figure 6.16 Proportion of coverage in adult mortality by sex, city-size group and country



Estimates in Annex E, Table E.4.

In summary regarding adult mortality coverage: by having acceptable data in terms of content, it was possible to assess the sensitivity of the methods in different scenarios of underreporting/under-enumeration of the inputs used. All quality indicators measuring levels of age and sex misreporting verify acceptable accuracy of the sources used in the methods for estimating coverage. No additional correction was required beyond the proportional distribution of unknown cases.

Thus, the most relevant method for estimating coverage when the under-enumeration differential is isolated from the population data is the Synthetic Extinct Generations method proposed by Bennett and Horiuchi (1981), which has also been indicated by Palloni and Aguirre-Pinto. SEG is the method that produces fewer errors in the different scenarios found in Latin America and the Caribbean for the period 1950-2000 (Palloni and Pinto-Aguirre 2011). For this reason, a combination of GGB-SEG is used to determine registered death coverage using census data in Brazil, Chile and Venezuela; while SEG is applied to Colombian, Ecuadorian, Mexican and Peruvian population estimates.

Observing sex differentials, the results obtained by Jasper and Orellana (1994) are also confirmed. In their review of data coverage and quality during the period 1960-1985, the scholars detected a better coverage of male cases over females. The reason was the concentration of death by external causes — which is easier to identify and diagnose — in males at younger ages (Jasper-fajier and Orellana 1994). In results obtained by this study, the sex differential in coverage is perceptible even at the national level in countries known by their high concentration of external causes of death.

## 6.4 General data arrangements

Different data sources have to be used in this work to ensure a proper evaluation of the quality of registered mortality data in the seven selected countries. As has been said in previous sections, describing in detail all quality and coverage related issues relies on the assumption that intra/inter-country differences in mortality levels could indeed be hiding quality and coverage differentials. The seven countries selected for the analysis have differences not only in the developmental level of their national vital statistics systems but also in the scope and quality in terms of geographical areas.

Thus, to summarize the quality of the mortality data used, two separate considerations have to be made. The first is in regard to the data's general characteristics ascribed to the strength of the vital registration system itself: its capacity to produce and provide quality data. Second, the specific quality is evident at the subnational level, due to different scopes of the national system. Both are ultimately considered to evaluate the necessary arrangements for offering data that is good enough for future comparative analyses.

### 6.4.1 Vital statistics system strength

It is possible to summarize into precise aspects all the characteristics of the vital statistics systems in the seven countries during the period of analysis, as well as their coherence with other demographic sources. Evidently, the evaluation is focused on the registered death data as needed in the framework of this analysis: databases containing age, sex, MIAD of residence, and underlying cause of death for every single death that occurred during the period 2000 to 2010. In particular, four broad characteristics are important:

1. *Accessibility* refers to the ease with which data can be obtained. This includes how easily the information is accessed as well as the format and availability of the current data (Cameron 2005).
2. *Smoothness* of the data refers to predominantly seamless patterns in the counts, without unjustified leaps.
3. *Timeliness* refers to the delay between the reference point and the date the data becomes available.
4. *Long-standing time series* of the ICD-10 period Refers to the period in which the ICD-10 is implemented in each country vs. the available registered death counts.

All characteristics are summarized in Table 6.6 for each country. Countries present different obstacles. Those of Chile and Mexico, for example, are more related to data accessibility, whereas Colombia and Ecuador fail to produce smooth data. Among all of them, Brazil seems to have the strongest vital statistics system in terms of public availability and acceptable delays. Meanwhile, Venezuela and Peru are the weakest due to the lack of accountability for Venezuelan data and the short-standing time series in Peru.

Furthermore, evaluation and correction measures rely on methods that normally contrast different data sources. Similarly, rate construction itself involves one numerator (death) and denominator (person-years lived). In this sense, not only mortality data must be overviewed but its relationship with other data sources. Brazil Mexico and Ecuador have all the necessary input to produce and assess mortality rates according to the specificities of this research.

However, at this point, it is important to remark broadly on the problem faced during the data assessment and future data correction for some countries:

-In Chile, the quality and coverage of registered data is higher than other demographic data produced in the country until 2012 (currently, the last census available). Thus, the strategy of estimate mortality rates through indirect methods and using them in comparisons is not efficient. The superior quality of registered data does not imply lack of coverage or quality errors in the Chilean mortality counts, but rather the non-pertinence of using indirect estimation methods. The assumptions of the indirect methods could introduce a wider bias than the expected proportion of under-coverage. Direct methods of evaluating registered deaths are imperative for incorporating the most recent census data<sup>16</sup>.

*Table 6.6 General data available in the seven countries*

Country	Accessibility	Smoothness	Timeliness	Time coverage of ICD-10 implementation/availability
<b>Brazil</b>	Free Online	Smooth data	2 years delay	1997/1997
<b>Chile</b>	On request at the national statistical institute	Smooth data	2 years delay	1997/1997
<b>Colombia</b>	Free Online	Several leaps through the period concentrated geographically in 2003 and 2007 counts.	1 years delay	1997/1997
<b>Ecuador</b>	Free Online	Leaps due to changes in the coverage are possible to see between geographical territories in 2006.	2 years delay	1997/1997
<b>Mexico</b>	On request at the health secretary	Smooth data	2 years delay	1998/1998
<b>Peru</b>	On request at the health secretary	Leaps in 2007 and 2008 because of increasing mortality due to late registration.	3 years delay	1999/2003
<b>Venezuela</b>	At National Statistics Institute's offices	Smooth data	5 years delay	1996/2000

-In Peru and Colombia, major gaps between censuses in both countries deter the proper monitoring of changes in the quality and coverage of the registered data by means of indirect inter-census methods for adult mortality. Even when great efforts have been made to produce information through demographic surveys; they lack representation at the spatial-group level and it is not possible to use them as replacements for census data. Other strategies are needed to evaluate registered data during this period. Incorporating future population counts from the 2010 censuses or later would indeed be helpful in disentangling this issue.

-For its part, Venezuela's coverage and late registration patterns in registered births have changed dramatically during the period, with uncertainties being introduced into the infant mortality estimates. The disrupted patterns are exclusively due to administrative and legal changes in the official registration offices (they were moved from the MIAD civil authority offices to hospitals) and in the institution responsible for producing official statistics.

<sup>16</sup> Results from the 2017 Chilean census were not available at the moment of this research.

In summary, the countries analyzed in this research have different strengths and weaknesses in their vital statistics systems. The improvements must be acknowledged for all of them during the period covered in this assessment, as previous specific indicators have proven. However, in order to achieve a comparative analysis, different strategies should be adapted to each country in order to get levels of reliability that are as similar as possible. Strategies must depend on not only registered-death particularities but also on the quality of complementary data involved in the estimation of mortality rates.

#### 6.4.2 Spatial group quality assessment

The methodology for evaluating data quality is always twofold: First, which dimensions of data quality should be the primary focus? And, second, what information is required for that assessment. Previous sections of this chapter are focused on specific indicators to measure different aspects of what could be considered data quality. However, specificity may distract from the overall aspects of the data. The use of Principal Component Analysis (PCA) together with Hierarchical Cluster Analysis (HCA) turns out to be helpful in summarizing all these aspects under assessment, thus providing a synthetic view of the level of trustworthiness expected in the data. Here, both analyses permit, first, reducing indicators into broad dimensions that are linearly uncorrelated and, second, classifying the data by looking for future proper correction measures.

The use of PCA allows synthesizing dimensions that could be behind the specific indicators employed to measure data quality. PCA is an exploratory statistical method for reducing  $p$  variables measured on  $n$  individuals while considering all possible linear relationships between them. It transforms a large number of correlated variables into a few uncorrelated principal components. In this case,  $n$  is equal to each population treated independently. Then, registered deaths of sex  $s$  belonging to a spatial group  $g$  in a country  $c$  constitute one independent population group. In total, 56 independent populations<sup>17</sup> are submitted for study (More technical details of PCA are given in the section 7.4.2)

Besides PCA, HCA is also applied. The aim is to classify the 56 populations based on a set of variables (displayed above) into a number of different groups, such that the ones similar in terms of overall data quality are placed in the same group. Both analyses are carried out with the statistical program SPAD while considering continuous variables to be the average of the quality indicators for each country described in previous sections of this chapter. Variables are standardized in order to avoid misleading results due to the different scale on the variables selected:

1. *Information Completeness*: Proportion of cases with unknown information for each sub-population (sex, age, MIAD of residence).
2. *Age misreporting*:
  - Age heaping: Myers index for total digit preference in registered deaths
  - Age exaggeration: ratio at age 90 in registered deaths

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<sup>17</sup> Total registered deaths in each country are considered as independent populations, but they are only included as illustrative cases in the PCA analysis. Some quality indicators of the total registered deaths in each country may gather different results than by adding a specific subpopulation's results. A clear example is the proportion of unknown cases. At the country level, they are counted instead of cases with unknown age and sex, while those without a MIAD of residency information cannot be included in the geographical division.

3. *Quality of causes of death declaration*: Proportion of ill-defined causes of death

4. *Under-registration*:

- Proportion of under-coverage in adult registered deaths
- Proportion of under-coverage in infant mortality data (births and deaths together)

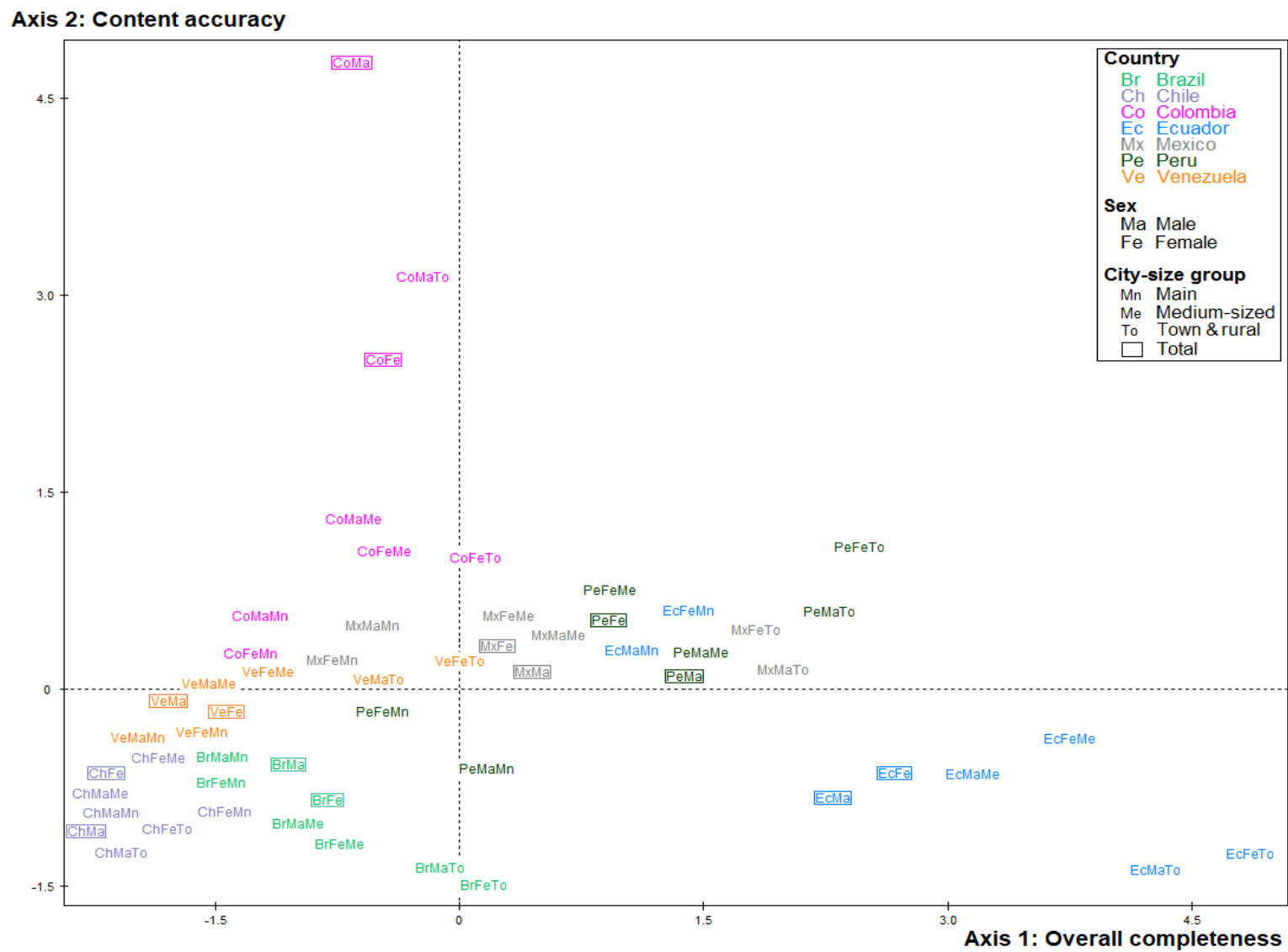
PCA results are shown as a principal component subspace scatterplot in Figure 6.17 (see Annex F, Table F.1 Statistical coefficients of the principal component analysis of registered death quality). The first two axes explain 70 percent of the variance (eigenvalues Axis 1= 3.1, equivalent to 50 percent; eigenvalues Axis 2= 1.2, equivalent to 20 percent). A third axis with eigenvalues of 0.7 that indicate 12.6 percent of the variance is disregarded, and this decision is based on considering that this third axis correlates with specific cases where there is missing or ill-defined information on underlying cause of death. This dimension could also be summarized by Axis 1 (see Table F.1 for statistical coefficients). Then, the evaluation of data quality is summarized in two broad dimensions: *overall completeness* (Axis 1) and *content inaccuracy* (Axis 2).

*Overall incompleteness* refers not only to coverage but to the complete information in all the variables under study, such as age, sex and MIAD of residence. Axis 2, named *content inaccuracy*, refers to issues related to properly stating the variable. In this case, the adequate definition of cause of death, age exaggeration and digit preference are the variable along the axis. In this way, all populations are placed within four quadrants that represent the combination of the two dimensions in continuous scales. The top right side of the graph indicates the overall completeness, whereas the bottom left represents incompleteness. Thus, the bottom part of the graph denotes lower proportions of inaccurate content, while the top represents accuracy.

For analytical purposes, Figure 6.17 displays all population groups using three illustrative variables: sex, city-size group and country. This could just as easily follow a spatial pattern. The first obvious aspect is that the particularities involving data quality are more homogeneous between Chilean, Brazilian and Venezuelan subpopulation groups than among the rest. The three countries were chosen for having the highest proportions of urban population in this analysis.

Despite country dissimilarities, a group's proximity to the axis maintains a hierarchical direction when one notes the spatial group. There is a clear path in which the main-and-large-cities are better positioned in relation to the positive aspect of Axis 1 and the negative aspect of Axis 2, particularly when compared with the rest of the spatial groups in the same country, thus indicating better overall data quality. In this sense, the Mexican and Venezuelan groups of cities are situated closer to the positive side of the overall completeness axis. In contrast, Colombian and Brazilian groups of cities are more driven by differences in their content accuracy; while Ecuadorian and Peruvian groups of cities combine both dimensions. One exception is Chile, which breaks the pattern by not having geographical hierarchy in regard to either of the axes. Indeed, none of the active variables introduce significant differences in Chilean subpopulation groups.

Figure 6.17 Two-dimensional principal component subspace on data quality indicators



In general, sex does not seem to play any important role in discriminating completeness or content inaccuracy, although some small distances are found between sexes, according to the country. For example, in Venezuela and Ecuador, male deaths are slightly more influence on the overall completeness's positive axis; and in Brazil, this is the case for both axes. Prominently, Mexican female registered deaths are always closer to the positive sides of both axes, even when they stay in the same quadrant.

The HCA's results split all subpopulations into three groups<sup>18</sup>. The illustrative variables of the groups are exhibited in Table 6.7 (see Table F.2 in the annexes for statistical coefficients). Additionally, Figure 6.18 summarizes the three-group distribution of the variables utilized for the analysis. These three groups are given names related to the overall data quality on the populations they contain. Therefore, I have: 1) the accurate data group, with 28 subpopulations; 2) the acceptable data group, with 22 subpopulations; and 3) the deficient data group, with six subpopulations.

Table 6.7 Cluster characteristics

clusters	Population	Countries	Spatial group	Sex
<b>Group 1: Accurate data</b>	28 (50%)	6 Brazil	11 Main & large cities	14 Male
		8 Chile	8 Medium-sized & small cities	14 Female
		4 Colombia	3 Town & rural areas	
		2 Mexico	6 Country	
		1 Peru		
<b>Group 2: Acceptable data</b>	22 (39%)	7 Venezuela		
		2 Brazil	3 Main & large cities	11 Male
		4 Colombia	4 Medium-sized & small cities	11 Female
		2 Ecuador	9 Town & rural areas	
		6 Mexico	6 Country	
<b>Group 3: Deficient data</b>	6 (11%)	7 Peru		
		1 Venezuela		
		6 Ecuador	2 Medium-sized & small cities	3 Male
		2 Town & rural areas	3 Female	
		2 Country		

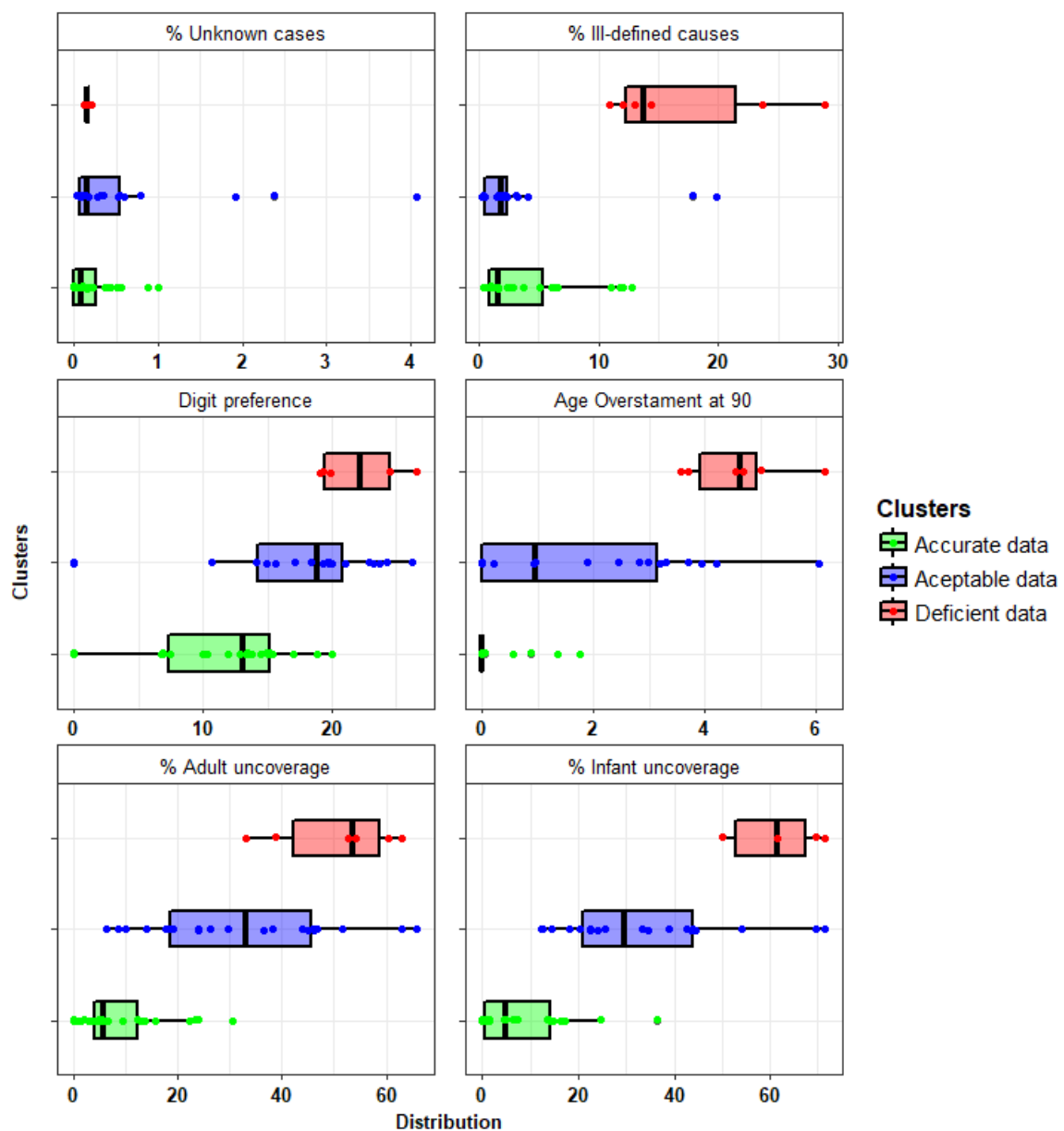
- Group 1, the accurate-data group: This represents 50 percent of all populations. Chile is the only country for which all populations are counted within this group. It contains all the non-town-and-rural groups of Brazil and Venezuela, and only the main-and-large-cities groups of Mexico and Peru. In fact, eleven of the twenty-eight populations pertain to the main-and-large-cities group independently of the country, and only three of the town-and-rural groups are in this group. Their proportion of under-registration is under 20 percent, and there is no

<sup>18</sup> Statistical analysis suggests splitting into four groups. The fourth group would contain total death counts in Colombia and male death data for small-cities-and-rural. The division is driven mostly by the proportion of unknown information on the deceased's MIAD of residency, which is higher than in other countries but does not exceed 4 percent of the total death counts. Because the aim of using Hierarchical Cluster Analysis (HCA) is to address the reliability level of the estimates produced with this data, I merged this group with the acceptable-data group. Statistical coefficients corresponding to the HCA are presented with the automatic classification into 4 groups (see Table X6 in annexes for statistical coefficients).

significant age overstatement or heaping. Nevertheless, a small proportion of ill-defined causes of death exist. This proportion does not exceed the expected existence of death without a defined cause.

- Group 2, the acceptable-data group: This contains most small cities and rural areas of all countries and, unusually, the Ecuadorian and Peruvian main-and-large-cities groups. This group represents 39 percent of all subpopulation groups and contains almost all the subpopulation groups of Mexico and Peru. Compared to the first group, this group has a lower proportion of ill-defined causes of death but higher levels of all the variables related to overall completeness. In addition to the proportion of under-registration, they have the biggest percentage of cases with unknown information.

Figure 6.18 Clusters for the distribution of data-quality variables





- Group 3, the deficient-data group: This contains Ecuadorian medium-sized and small cities, towns and rural areas. This group has the biggest problem with coverage, and it is among the highest in terms of lack of accuracy in all information content, especially age overstatement. It represents only 11 percent of the subpopulation groups. Higher levels of under-registered mortality data could in fact be related to high levels of under-registered international emigration. The impact from lacking accurate international migration data in all seven countries is heightened in Ecuadorian case due, first, to the impossibility of disentangling the impact of high international emigration flows for the period from the proportion of under-registered deaths at the spatial-group level.

These three groups give an idea of both the reliability and comparability of the estimates that are possible when using the registered death data in the seven selected countries. In general, all data seem to be susceptible to improvements. However, in order to keep them comparable, the accurate-data group is subjected to unnecessary precautions, e.g., aggregation of lower limits in the last open-ended age group. In this sense, estimates derived from the deficient-data group must be cautiously analyzed when making old-age population estimates. The next section of this chapter summarizes each of the main arrangements needed and their specificities.

## 6.5 Achieving comparability in the data

A set of six main arrangements could be deduced after the assessment made on the registered death data. They are mainly geared towards overcoming issues that affect comparability in further estimates. For each arrangement, an important remark is made to summarize either exceptional cases or the most problematic subpopulations requiring their application, among others.

<i>Arrangement</i>	<i>Important remarks</i>
1) To adjust rates by the proportion of adult and infant mortality coverage	One exception: not for Chile. Chilean registered data proved to have better quality than census data. Results obtained using indirect methods could indeed be more affected by the sensibility of the method's assumptions than by the assessment of the data. However, some remaining problems in registered births affecting infant mortality estimates should be solved. The application of smoothing techniques in the estimations will address this problem, specifically moving average.
2) To aggregate into five-year age group.	In order to correct for digit preference, it is necessary to aggregate the data into five-year groups to produce mortality rates instead of applying a smoothing technique. This strategy is mostly due to high levels of digit preference in Mexico, especially in the town-and-rural-areas group.

<p>3) To distribute proportionally unknown cases (age, sex and MIAD of residence).</p>	<p>In most of the countries, the proportion of unknown cases is relatively low even in the town-and-rural-areas group. Nevertheless, Colombia is the most affected by unknown cases. Missing information is mostly concentrated in the MIAD of residence (1 percent to 4 percent).</p>
<p>4) To distribute proportionally ill-defined causes of death into well-defined ones</p>	<p>Brazil has significantly reduced the proportion of ill-defined causes of death during the period of analysis in all their subpopulation groups, above all, in the Brazilian town-and-rural-areas group. Similarly, the town-and-rural-areas group in Chile also has significantly reduced its proportion of ill-defined causes of death. This reduction could be due to improvements in defining all causes of death or may in fact be related only to one specific cause. Either way, causes-of-death quality is going to be more accurate at the end of the period in comparison with the beginning.</p>
<p>5) To limit the open age interval at 80 years</p>	<p>Mexico and Peru have the highest age exaggeration after 80 years old, even more so in the towns and the medium-sized city groups. Following a detailed comparative analysis, it is more advisable to use indexes under that age group.</p>
<p>6) Reduce selected countries to six</p>	<p>Ecuador must be left out of the analysis. Its multiples problems regarding coverage and the difficulty to estimate under-coverage in registered death counts through indirect methods due to the impact of international emigration at subnational level.</p>

**6.6 Conclusions**

Inter/intra-regional analysis always raises the question of whether territorial division is pertinent. Demographic studies commonly use political-administrative units while assuming differences in local policies or the ability of specific regions to incorporate the benefits of new technologies and social programs. Here, another strategy is implemented, with more relevance given to capturing the gaps in demographic phenomena that are introduced by the direct association between Latin American development and urbanization. This strategy analyzes groups of cities according to their size. This decision implies making great efforts to keep geographical areas comparable in terms of urbanization while also following these territories through a vast number of demographic databases.

In this chapter, all possible aspects of the demographic data have been addressed, from the historical development of the demographic data up to the specific scope of the national vital statistics system in each spatial group. Independently of the recent improvements on the vital statistics system in each country, some authors since the nineties have already shown, on the

one hand, the positive relationship between the demographic transition and urbanization, and, on the other, a direct association between the coverage/quality of registered data and the levels of mortality/fertility. Countries with the lowest mortality and fertility levels have: 1) the best overall coverage/quality data; 2) the fewest coverage differentials by age group, sex, geographical unit or any other variable; and 3) the most complete information (Jasper-fajer and Orellana 1994; ECLAC 2014). In this sense, it is not surprising that, among the seven countries, Chile is the one with the best quality/coverage in their vital statistics registration system.

What is more, the relationship is not only seen at the whole-country level but also within the countries. It is in the main and biggest cities where data quality is better. Then, when grouping cities by their sizes, it seems to be clear that there is already a relationship between urbanization and the under/development of overall data quality. The continuous reference to the quality and comparability of these groups is the key to evaluating the results obtained by this research.

The assessment of the demographic data in the seven selected countries allows foreseeing that spatial analysis of spatially unadjusted data could lead to wrong conclusions, which is driven more by the geographical differentials in the vital statistics system coverage than by demographic phenomena. For example, something that could be initially interpreted as an urban penalty on infant mortality in countries like Ecuador and Mexico is actually higher under-coverage in medium-sized-and-small-cities and in towns and rural areas in comparison to lower under-coverage in main-and-large cities. Thus, considering geographical differentials in the quality/coverage of data may open ways to a better understanding of the health transition at the national level.

Despite the errors in declaration and under-registration found in registered deaths, the arrangements considered in the chapter to come guarantee reliable estimates. One exception to this is the Ecuadorian subpopulation groups identified as the deficient-data group. Ecuador is going to be left out future analysis because of representing high risk of falling into miss-estimations.

## 7. METHODS AND ANALYSIS

This chapter describes the methods used to assess properly whether Latin America has an urban (dis)advantage in mortality that equally affects all ages and sexes. Keeping in mind the quality assessment results, Ecuador is excluded from the following mortality analysis. Likewise, due to their low quality in declared causes of death, Peru is excluded from the cause-of-death analysis (results shown in Chapter 9 and 10). With the purpose of pursuing the most accurate comparisons possible, death and population counts are grouped into the following: under one year of age; one to four years old; and from there into five-year age groups up to an open-ended age group of 80 years and more.

This chapter is divided into five sections. The first presents the basic indicators used in mortality analysis, along with different criteria regarding their estimation. In this section, I briefly define age-specific death rates, standardized death rates, and death-to-population ratios. Throughout the second section, I review the analyzed indicators from the annual life tables for the subpopulations. The third section summarizes the decomposition methods for determining the age components of the life expectancy differential at birth among the subpopulations, specifically by means of two methods: the stepwise replacement, with its extension the algorithm of contour replacement method. The fourth section addresses cause-of-death grouping in this research according to etiological similarities and their amenability. The last section focuses on two classification analyses used to summarize the subpopulations' patterns: Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA).

### 7.1 Mortality rates and ratios

#### 7.1.1 Age-specific death rates

Age-specific death rate (ADR) is a ratio of occurrence to exposure indicating the mortality risk of a population at a specific age and time. These two features—occurrence and exposure—account for: the number of deaths occurring within some defined time period given the number of persons in a population; and the length of the time frame in which exposure is counted, known as the number of person-years lived (Preston, Heuveline et al. 2001). In this analysis, ADRs refer to annual ratios, and they summarize the estimated number of deaths ( ${}_n\hat{D}_x$ ), defined as the observed and adjusted numbers of deaths. The exposure of the person-years lived is the estimated number of persons alive at mid-year in  $x$  age group,  ${}_n\hat{N}_x$ . ADRs are the basic inputs for all estimates needed in the analysis, and they are expressed as  ${}_nM_x$  mortality rates for age group  $x$  and  $x+n$ , with  $n$  being the length of the age group interval in each subpopulation  $\beta$  (the combination of sex, group of cities, and country) in time  $t$ :

$${}_nM_x^{t,\beta} = \frac{{}_n\hat{D}_x^{t,\beta}}{{}_n\hat{N}_x^{t,\beta}} \quad (7.1)$$

All death rates are adjusted according to the level of under-coverage for infants and adults, as determined in Chapter 6. This allows obtaining the estimated number of deaths at age  $x$  and  $x+n$ . Each year is adjusted individually, as the under-coverage correction factor ( $CI_x^{t,\beta}$ ) is an annual estimate for each subpopulation  $\beta$ , for infant mortality, whereas adult mortality in a single inter-census correction factor.

$${}_n\widehat{D}_x^{t,\beta} = {}_nD_x^{t,\beta} * CI_x^{t,\beta} \quad (7.2)$$

Subpopulation death rates are divided by using a proportional cause-of-death distribution ratio in order to get specific cause-of-death rates ( ${}_nR_{x,s}^{t,\beta}$ ). The ratio used to calculate the specific proportional distribution for cause of death involves evenly redistributing ill-defined causes of death into well-known causes of death:

$${}_nR_{x,s}^{t,\beta} = \frac{{}_nD_{x,s}^{t,\beta}}{{}_nD_x^{t,\beta} - {}_nD_{x,u}^{t,\beta}} \quad (7.3)$$

where  ${}_nD_{x,s}^{t,\beta}$  is the observed number of deaths in subpopulation  $\beta$  due to specific cause  $s$  at age  $x$  in time  $t$ ;  ${}_nD_x^{t,\beta}$  is the total observed number of deaths at the same age and time; and  ${}_nD_{x,u}^{t,\beta}$  is the total observed number of deaths by ill-defined causes. Then, the specific cause-of-death rate is:

$${}_nM_{x,s}^{t,\beta} = {}_nR_{x,s}^{t,\beta} * {}_nM_x^{t,\beta} \quad (7.4)$$

### 7.1.2 Standardized cause-of-death rates (SDR)

Because rates are occurrence to exposure ratios and mortality varies according to age, the occurrence of a specific cause of death is linked to the age distribution of the population. In this research, the subpopulation's number of persons alive at mid-year in  $x$  age group is set as the time of the exposure. Furthermore, since subpopulations differ in their sizes and distributions by age and sex, summary measures are not released of the population structure component, this variability introduces unwanted effects in terms of the comparability. To eliminate this effect, the subpopulation death rates by specific causes are directly standardized.

Standardized cause-of-death rates are constructed as the sum of the product of the specific cause-of-death mortality rate of a subpopulation  $\beta$  in time  $t$  ( ${}_nM_{x,s}^{t,\beta}$ ) and the standard population ( $P$ ). Expected deaths are obtained according to the  $\beta$  subpopulation's observed level of mortality if its population structure is the same as the standard population.

$$SDR_s^{t,\beta} = \sum {}_nM_{x,s}^{t,\beta} * P \quad (7.5)$$

The process of choosing a standard population is not conceptually justified and is normally arbitrary. However, standard populations will overweight events occurring across overrepresented ages (Ahmad, Boschi-Pinto et al. 2001). Hence, rather than selecting a standard current age-structure of some population(s), this research adopts the World Health Organization's (WHO) standard population based on the average world age-structure. This standard population removes the effects that historical events such as wars and famine have on population age composition, and it allows for comparing populations with different structures.

### 7.1.3 Deaths-to-population proportional ratios

A national mortality pattern that is evenly spread across the territory would be indicative of non-bias toward a geographical area. “Evenly-spread mortality” means death counts are as proportionally distributed as the population. Because subpopulations may have variations in their distribution by age and sex, and due to mortality depending on both of these features, an evenly-spread mortality distribution implies an equal proportional distribution of death counts and population—by age and sex—in each spatial group when accounting for their national contributions. In order to check for any bias arising from urbanization, a ratio of the distribution of death counts to the distribution of population counts by sex and age is calculated for each subpopulation. A subpopulation’s deaths-to-population proportional ratio  $DPR^{t,\beta}$  at time  $t$  is the quotient of the proportion of the subpopulation’s death  ${}_nD_x^{t,\beta}$  at age  $x$  and  $x+n$  ( ${}_nD_x^{t,c}$ ), to the proportion of subpopulation’s size  ${}_nN_x^{t,\beta}$  at age  $x$  and  $x+n$  ( ${}_nN_x^{t,c}$ ):

$$DPR^{t,\beta} = \frac{{}_nDR_x^{t,\beta}}{{}_nNR_x^{t,\beta}} \quad (7.6)$$

where,

$${}_nDR_x^{t,\beta} = \frac{{}_nD_x^{t,\beta} *}{{}_nD_x^{t,c}} \quad (7.7)$$

and,

$${}_nNR_x^{t,\beta} = \frac{{}_nN_x^{t,\beta} *}{{}_nN_x^{t,c}} \quad (7.8)$$

## 7.2 Building life tables

Annual abridged period life tables are built for each subpopulation. Life tables, in their classical form, contain age-related functions pertaining to a single decrement process, which in this case is death. When building period life tables, I assume that the demographic experiences of several cohorts can be summarized in a given period similarly to the experiences of the groups throughout their lives—specifically in terms of their fertility, mortality, and migration behaviors, which are measured by the age-specific rates observed at one point in time (Vallin and Caselli 2006). This artificial construct is often referred to as either a *hypothetical*, *fictitious* or *synthetic* cohort. In order to build period life tables, the age-specific risk of dying is estimated from the hypothetical cohort age-specific rates. As explained in the previous chapter, not only is the subpopulation data quality heterogeneous among the selected countries, but so is the available data’s level of detail. One solution is to aggregate death and population counts in order to build abridged life tables.

Life table functions are arithmetically related due to their complementary nature, e.g. the number of deaths at a certain age ( ${}_nd_x$ ) is extrapolated from the number of survivors at the exact age  $x$  ( $l_x$ ) minus the number of survivors at exact age  $x+n$  ( $l_{x+n}$ ). The average person-years lived in an age interval ( ${}_na_x$ ) is of great importance for calculating the time of exposure in all functions. In a period life table setting, I apply the  ${}_na_x$  in the interval  $x$  to  $x+n$  to the observed mortality rates  ${}_nM_x$  in order to obtain the probability of dying  ${}_nq_x$  in the age interval. Then, the probability of dying is estimated by:

$${}_nq_x = \frac{{}_n * {}_nM_x}{1 + ({}_n - {}_na_x) * {}_nM_x} \quad (7.9)$$

The  ${}_n a_x$  estimates depend on the age, meaning that the value  ${}_n a_x$  is an empirical function of the mortality level itself. A low mortality level in the under one year of age population concentrates deaths more heavily concentrated among the youngest babies because prenatal and perinatal deaths are greater than postnatal. Coale and Demeny (1983) summarized the strong relationships between  ${}_1 a_0$ ,  ${}_4 a_1$ , and  ${}_1 q_0$ . This research applies this approach to estimate  ${}_1 a_0$  and  ${}_4 a_1$ . The obtained values pertain to the range that Coale and Demeny assigned to Infant mortality rates (IMR) that are below 107 per 1,000 live births, as all subpopulations in this study show IMR levels lower than this benchmark. In table 7.1 are summarized the values proposed by Coale and Demeny and used in this research for producing  ${}_1 a_0$  and  ${}_4 a_1$ .

Table 7.1 Values of  ${}_1 a_0$  and  ${}_4 a_1$  for use below 5

Values	Male	Female
${}_1 a_0$	$0.045 + 2.684 * {}_1 m_0$	$0.053 + 2.800 * {}_1 m_0$
${}_4 a_1$	$1.651 - 2.816 * {}_1 m_0$	$1.522 - 1.518 * {}_1 m_0$

On their side, the values of  ${}_n a_x$  for 5-to-79 age intervals are calculated using a rule of thumb. Deaths are assumed to be evenly distributed within the age intervals; then,  ${}_n a_x = n/2$  (Preston, Heuveline et al. 2001). Finally, the average number of person-years lived in the open-ended age interval (80 years and over) is calculated as the inverse value of the age-specific mortality rate, which makes  ${}_{\infty} a_{80}$  equal to  ${}_{\infty} e_{80}$  (Land, Yang et al. 2005). This research applies all the life table functions for a comparative analysis of subpopulation mortality levels, using the key synthetic indexes life expectancy at birth, the temporary risk of dying, and lifespan disparity.

**7.2.1 Life expectancy at birth**

Life expectancy is the most frequently-used sub-product of life tables. It refers to the average number of additional years that a survivor at age  $x$  will still live, and it is calculated as a ratio of the number of person-years lived to the number of survivors at that age (Preston, Heuveline et al. 2001). Here, I focus on analyzing life expectancy at birth, its trends, changes, and differentials among subpopulations and countries. Life expectancy at birth ( $e_0^0$ ) is the sum of all person-years lived by the hypothetical cohort divided by the total number of members of the cohort. In other words, life expectancy at birth is the average age at death of a hypothetical cohort.

Life expectancy at birth is suitable as a synthetic index when comparing the mortality levels of several subpopulations, because it summarizes the average number of years a newborn is expected to live in each subpopulation if their mortality patterns remain as they are in the period of analysis. As a synthetic index, its changes can be easily followed in a long-term analysis. Analytical approaches taking in this research to understanding the inter-subpopulation difference and their evolutions over time are explained below, in Section 7.3 of this chapter.

### 7.2.2 Risk of dying

Risk of dying between age  $x$  and  $x+n$  is computed as the probability of dying while restricting exposure-occurrence to a specific age range. This means that survival from previous ages is an implicit condition for the computation. In this case, I use the risk of dying at younger adult ages (defined as the age interval 15 to 45 years ( ${}_{30}q_{15}$ )) and at older adult ages (between 45 to 75 years ( ${}_{30}q_{45}$ )). The risk of dying in the age interval  $x$  to  $x+n$  is expressed as:

$${}_nq_x = \frac{{}_nd_x}{l_x} = 1 - \frac{l_{x+n}}{l_x} \quad (7.10)$$

The criteria consider selecting age-intervals risk of dying are based on the expected age-interval changes in mortality set by the health transition, because the mortality decline occurs along with changes in age-of-death patterns. Throughout the earliest stage, improvements occur mostly among children as infectious diseases decline, followed by improved young adult mortality as a consequence of reductions in circulatory diseases, and lastly by improved older adult mortality. Additionally, splitting adult mortality into two intervals is possible to keep track on the epidemic of violence recorded in several Latin American countries, as it mostly affects young men. Following the age-intervals, it is possible to disentangle changes in adult mortality resulting from these two different processes.

### 7.2.3 Lifespan disparity

The age distribution of deaths indicates the concentration of deaths at a specific age. Throughout mortality decline, increased life expectancy occurs in tandem with reductions in the differences among individual ages at death, as has been recorded in most developed countries. An initial reduction in the distribution of age at death is due to the progress achieved by reducing premature deaths, which leads to a mortality compression and reducing mortality disparities; whereas continuous progress in reducing deaths at older ages, lead to once again increases variations in lifespans (Vaupel, Zhang et al. 2011).

The goal is to examine changes in the concentration of death at a specific age while looking for differentials in life span disparity between sexes and across subpopulations. Several indicators are used to measure lifespan disparity in a population (e.g. the Gini coefficient, life years lost, and variance in age of death, among others). However, the high correlation among these suggests consistency in their results (van Raalte and Caswell 2013). Here, the evolution of the dispersion in mortality is calculated using the standard deviation of death distribution and its changes. The advantage of this over other indicators is that the standard deviation of age of death distribution is comparable to life expectancy, since both are expressed in years, making easier its interpretation. The standard deviation of the age at death distribution ( $\sigma$ ) is defined as:

$$\sigma = \sqrt{\int_a^\omega (x - e_a)^2 f(x) dx} \quad (7.11)$$

where  $f(x)$ ,  $e_a^0$  and  $\omega$  denote, respectively, the age at death density function, life expectancy at age  $a$ , and the open-aged interval (80+). According to the literature review, infant mortality



reduction continues to be one of the main drivers of increasing life expectancy in some Latin American subpopulations. Reason why the standard deviation of the age at death distribution is estimated by 1) considering all ages, and 2) without taking into account the under one year of age population. Likewise, mortality compression and variations in age of death are also analyzed by isolating the changes in infant mortality.

### **7.3 Life expectancy at birth decomposition**

As stated before, life expectancy at birth is one of the most suitable synthetic indexes for carrying out comparative mortality analysis. Even more, decomposing differences in life expectancy at birth allows knowing which dimension contributes to its changes over time and which is responsible for differences between two populations. The most common dimension considered in the decomposition is age, but it can also be cause of death or any other covariates. Because life expectancy is a non-linear function of death rates, its decomposition procedures are not straightforward (Preston et al. 2001). This is mostly due to the interdependence of changes among age groups, as fractions of changes that are attributable to single age groups are linked to other groups.

There are two main approaches to decomposing the differences in life expectancy at birth: a continuous approach, initially proposed by Pollard (1982); and a discrete approach, developed by Arriaga (1984), Andreev (1982), and Pressat (1985). The continuous approaches deal with the interdependence of changes in age by means of a minor approximation (Pollard 1982; Pollard 1988). This models the total change between two life expectancies through the numerical integration of partial derivatives of the index function with respect to the corresponding age-specific rates (Horiuchi, Wilmoth et al. 2008). On the other hand, the discrete approach makes the contribution of a given age to a change in life expectancy equal to the difference between life expectancies (Vallin and Caselli 2006).

Mathematical demographers have extensively developed both approaches. Here, I focus on following the discrete approach. In his initial proposal, Arriaga identified two components in the contributions from changing age-specific death rates: the direct effects, seen as the impact on life expectancy from changing death rates at each age; and the indirect effects, which refer to the impact on subsequent ages from the extra life years lived by the survivors (Arriaga 1984). Andreev et al. (2002) combined Arriaga's approach with Das Gupta's idea that the total change in the dependent index may be a sum of the effects from sequentially replacing the age-specific rates (Das Gupta 1991; Das Gupta 1994). This allows developing a stepwise replacement method and extending it to the algorithm of contour replacement method. I use these two methods to decompose differences in life expectancy at birth among subpopulations, their changes over time, and by specific causes of death. When studying causes-of-death patterns and their changes while considering urban–rural differences, decomposition methods allow identifying the impact of “urban bias” on the distribution of resources in the health outcomes of subpopulations inside the country, as they associate differences in life expectancy at birth to age-specific contributions and specific causes of death.

#### **7.3.1 The stepwise replacement decomposition method**

When the aggregate measure is a dependent function or a function of factors, the general decomposition problem estimates additive contributions of differences between factors to the

overall differences between aggregate measures. Because life expectancy at birth is a function of the age-specific death rate vector, the stepwise decomposition alters the rates one age at a time, and then recalculates the index function of life expectancy by replacing the elements from one vector of age-specific mortality rates,  $M_x^a$ , with the respective elements of another vector,  $M_x^b$  (Andreev, Shkolnikov et al. 2002).

The transition from life expectancy at birth  $e_0^a$  to  $e_0^b$  corresponds to a transformation of vector  $M_x^a$  into vector  $M_x^b$ . Such a transformation can be performed with a *stepwise replacement* of each age interval from younger to older ages. This means that all age-specific components can be computed by a stepwise replacement of age-specific death rates of  $e_0^a$  with the corresponding age-specific death rates of  $e_0^b$ , progressing from age 0 to the last age  $\omega$  (Shkolnikov and Andreev 2010). In this way, the method's formulae remains consistent with the earlier formulae developed in the discrete approach of Arriaga, Andreev and Pressat (Shkolnikov, Valkonen et al. 2001).

The transition of  $e_0^a$  to  $e_0^b$  ( $\delta_{ab}^i$ ) is often not exactly the same as the transition of  $e_0^b$  to  $e_0^a$  ( $\delta_{ba}^i$ ) in absolute values (Andreev, Shkolnikov et al. 2002), because decomposing the differences between life expectancies depends on the permutation of the vectors being compared. Previous methods developed by Andreev (1982) and Pressat (1985) solved this problem by averaging both transitions to obtain symmetrical components. Then, the age-specific component ( $\delta_{ab}^i$ ) of the difference from  $e_0^a$  to  $e_0^b$  should be complemented by estimating:

$$\delta_{ab} = \sum_{i=1}^n \frac{1}{2} (\delta_{ba}^i - \delta_{ab}^i) \quad (7.12)$$

In the life table notation, the difference is:

$$\delta_x = \frac{1}{2} \sum_{x=0}^{\omega} \{ [l_x^b (e_x^b - e_x^a) - l_{x+1}^b (e_{x+1}^b - e_{x+1}^a)] - [l_x^a (e_x^a - e_x^b) - l_{x+1}^a (e_{x+1}^a - e_{x+1}^b)] \} \quad (7.13)$$

where,  $l_x$  corresponds to survivors and  $e_x$  to life expectancy at age  $x$ . In addition, the age component could be split according to additional dimensions such as causes of death and subpopulations, among others. Such a decomposition can be accomplished using the same general algorithm for replacing age-group-specific death rates and the age-specific population weights of groups. In practical terms, the algorithm estimates the effects of replacing each elementary cell of one matrix with the respective cell of another matrix.

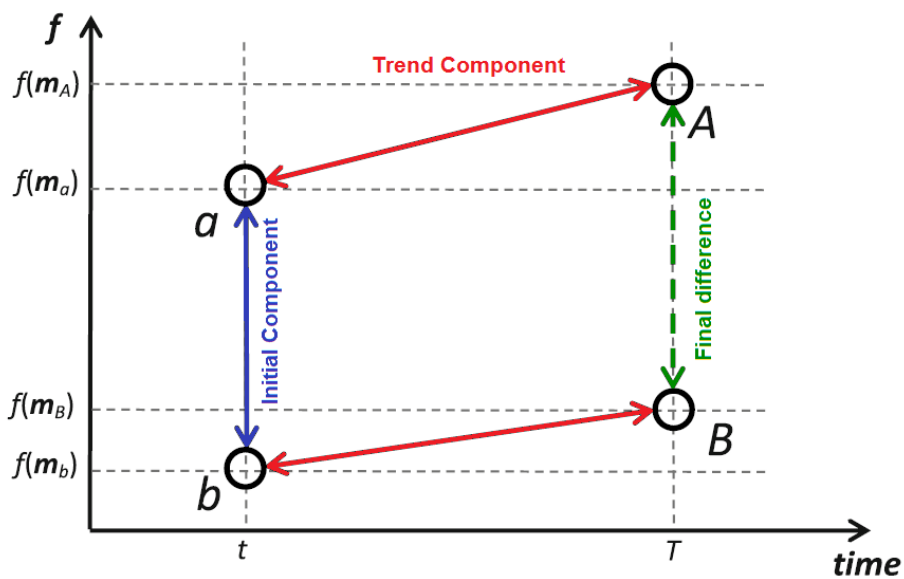
The stepwise replacement method is applied in this research using the R package *DemoDecomp*, developed by Riffe (2018). I compare age-specific contributions to differences in life expectancy at birth among the subpopulations in each country, as well as the evolution of their changes over time. All differences are shown in years, which allows for accurately determining the subpopulations' (dis)advantages in mortality. The results obtained for the total-death contributions to these differences are provided in next chapters.

### 7.3.2 Algorithm of contour replacement decomposition method

The algorithm of contour replacement decomposition method is an extension of the stepwise replacement method. It takes the initial differences in the event-rates of the aggregated

measure and the differences in trends and splits them into additive components. This maintains the discrete approach and, as does the previous decomposition method, it allows for an inter-population contribution to the difference in life expectancy at birth, by age-specific covariate or by any other, such as causes of death. In addition, the method splits the total difference in the contributions, which are due to the initial conditions among life expectancies and to changes in the life expectancies over time (Jdanov and Shkolnikov 2014). The method incorporates three decompositions: at the initial time between the two populations (initial component); and the two decompositions of their changes (trend component) between the initial and final time (final difference) of the two life expectancies being compared.

Figure 7.1 Cross-sectional differences and longitudinal changes in an aggregate demographic measure of two populations



Source: Jdanov et al. (2017).

Once again, because life expectancy is a nonlinear aggregate function of age-specific death rates, “its decomposition is nonsymmetrical and nontransitive with respect to populations and years” (Horiuchi, Wilmoth et al. 2008), this ensures that the age components of the decomposition of the final difference cannot be obtained by summation of the other two (Jdanov, Shkolnikov et al. 2017). The challenge face by this decomposition method is that, when decomposing the difference in life expectancy at birth between populations A and B at final time  $T$  ( $\Delta_{AB}$ ), the sum of the initial difference ( $\Delta_{ab|AB}^i$ ) at every age between populations  $a$  and  $b$  at initial time  $t$  and the trend ( $\delta_{ab|AB}^i$ ) component is equal to the total age-specific component ( $\Delta_{AB}$ ):

$$\Delta_{AB} = \sum_{i=1}^n (\text{Initial}^i + \text{Trend}^i) = \sum_{i=1}^n (\Delta_{ab|AB}^i + \delta_{ab|AB}^i) \quad (7.14)$$

Decomposing the between-population difference in life expectancy at birth  $\Delta_{ab}$  at time  $t$  and the within-population temporal changes  $\delta_{aA}$  or  $\delta_{bB}$ , are calculated in the same way as the stepwise replacement method. In fact, formula 7.10 is applied in both decompositions. Then:

$$\Delta_{ab} = \sum_{i=1}^n \frac{1}{2} (\Delta_{ba}^i - \Delta_{ab}^i) \quad (7.15)$$

and

$$\delta_{aA} = \sum_{i=1}^n \frac{1}{2} (\delta_{Aa}^i - \delta_{aA}^i) \quad (7.16)$$

Next, it is necessary to decompose the difference between life expectancies that are conditioned by their past differences and their temporal e independent changes. Instead of directly replacing  $M_b$  with  $M_a$ , as the conventional stepwise replacement algorithm does, this method considers transitions throughout the original population, starting from the youngest age (Jdanov, Shkolnikov et al. 2017). Then, the age component of the trend of each population is:

$$\delta_{Aa|AB}^i = \frac{1}{2} [\delta_{Aa|B}^i - \delta_{aA|A}^i] \quad (7.17)$$

and,

$$\delta_{Bb|AB}^i = \frac{1}{2} [\delta_{Bb|B}^i - \delta_{bB|A}^i] \quad (7.18)$$

Thus, the age component of the overall trend contribution is:

$$Trend^i = \delta_{Aa|AB}^i - \delta_{Bb|AB}^i \quad (7.19)$$

While, the age component of the initial difference is:

$$Initial^i = \Delta_{ab|AB}^i = \frac{1}{2} [\Delta_{ab|B}^i - \Delta_{ba|A}^i] \quad (7.20)$$

The contour replacement decomposition method and its algorithm are (so far) the only way to estimate differences in life expectancy by dividing the effects of age-specific trends in a given period while controlling for initial differences in age-specific mortality levels. It analyzes whether current differences in life expectancy at birth are due to the catching-up process of lagging subpopulations or to persistent (dis)advantages by quantifying the effects of past mortality conditions and temporal changes within each age component (Jdanov, Shkolnikov et al. 2017).

#### 7.4 Cause of death classification

The aim of studying causes of death is to identify pathologies whose patterns may be the main drivers of mortality changes in a given population. Several groupings have been suggested by research that analyzes mortality throughout history. Here, I focus on two general classifications of the reported *underlying causes of death*. The first is related to the most common causes of death found in the region, while the second distinguishes amenable mortality as the effectiveness of health policies.

**7.4.1 Main-causes grouping**

Eleven groups of causes of deaths are constructed according to their cluster in the 10th revision of the International Classification of Diseases (ICD-10). This cause-of-death list is commonly used in health statistics by the World Health Organization (WHO) and in many countries. It describes the relative importance of different conditions such as cancer, heart disease, stroke, and diabetes. Causes of death and their ICD-10 classification code are shown in Table 7.2. Because of the high prevalence of violence-related death in Latin America, *homicides and violent death with undetermined intention* is a single category apart from other external causes of death. The last group summarizes causes not included in the previous group and it covers specific yet less present causes named *others*.

*Table 7.2 Cause-of-death group*

Causes of death group	ICD 10
Neoplasms	C00-D48
Circulatory diseases (cardiovascular, stroke)	I00-I99
Respiratory Diseases	J00-J98
Digestive Diseases	K00-K92
Diabetes	E10-E14
Infectious Diseases	A00-B99
Other external causes (including traffic accidents, injuries and suicide)	V01-X84
Homicides and other violent causes with undetermined intention	X85-Y36
Maternal	O00-O99
Perinatal	P00-P99
Ill-defined	R00-R99
Others	

**7.4.2 Amenability**

The rapidly changing mortality in developing countries has occurred greatly and in parallel with extending the scope of health care systems. Nowadays, the contribution of health care may play a rather more important role than in the mortality decline prior to the mid-twentieth century in industrialized countries. The terms “avoidable mortality” and/or “mortality amenable to medical/health care” indicates the importance played by public health interventions in the changes in mortality patterns, as they imply that deaths from certain

causes should not occur in the presence of timely and effective medical care. With the term “medical care”, researchers refer not just to medical intervention per se but to any policies leading to prevention, cure and care. This includes *“the application of all relevant medical knowledge [...], the services of all medical and allied health personnel, institutions and laboratories, the resources of governmental, voluntary, and social agencies, and the cooperative responsibility of the individual himself”* (Rutstein, Berenberg et al. 1976). This term was first implemented by Rutstein and has been used by several researchers for grouping specific causes of death to evaluate and compare the efficiency of health systems (Nolte and McKee 2003).

Since Rutstein’s initial proposal, several have attempted using his approach for international comparative analysis and specific cause-of-death analysis around the world. Because identifiable effective interventions of health care providers are linked to a set of contextual conditions such as available technology and health service structure, among others, amenable mortality varies among countries, regions, and even timeframes. These attempts have produced different lists of causes of death and health conditions that could be indeed defined as avoidable or amenable. Likewise, several indicators have been considered in order to illustrate the different components of health care provision – whether they are primary, secondary, or specialized interventions – as well as to assess the outcome of health services.

Among the most known and used definition of amenable causes is the one made by Mackenbach et al. (1988), together with their cause-of-death listing base on medical care innovation. These authors proposed 13 conditions / groups of conditions that could be amenable due to medical intervention for populations aged 0 to 75. They define medical care as *“the application of biomedical knowledge through a personal service system”* (Mackenbach, Kunst et al. 1988). Among the diseases and conditions considered amenable are diabetes mellitus, appendicitis, some maternal causes, tuberculosis, septicemia, diphtheria, cerebrovascular diseases, nephritis and some types of neoplasms, such as lip, skin, kidney and testis. Their studies on the regional variation in mortality decline in the Netherlands between 1969 and 1984 showed that amenable mortality declined by 4.5% per year compared with all-causes mortality at 1.6%. The decline was faster in areas with higher increases in average income and/or educational level. This list has been updated and adapted to different contexts, even by Mackenbach himself when in the year 2000 he added three new amenable conditions (ischemic heart disease, rectal cancer, and hip fracture). He did this to study amenable cause-of-death contributions to life expectancy at birth in the Netherlands, which were a result of medical advances during the nineties (Mackenbach 2000).

In analyzing Latin American causes of death, the term avoidable death was first used by Erika Taucher (1978). She split Chilean deaths from 1955 to 1975 into five categories, according to the actions that could have the greatest influence on their reduction or pressure: 1) deaths preventable by vaccine or preventive treatment; 2) deaths preventable by diagnosis and early medical treatment; 3) deaths preventable by environmental sanitation measures; 4) deaths preventable by applying a set of combined measures; and 5) deaths hardly preventable today (Taucher 1978). Her results highlighted that the most important relative groups of deaths at the moment were avoidable by applying a set of combined measures; while avoidable deaths due to medical prevention or early treatment constituted a minority of the total deaths. These results depended on the timeframe of the study, when most causes of death were identified as circulatory diseases and neoplasm.

In 2001, Tobias and Jackson refined “avoidable mortality” to study mortality trends in New Zealand. Instead of classifying each condition as entirely “avoidable” by either primary or

secondary or tertiary prevention, they used an “expert consensus” method to partition relative weights reflecting the scale of the potential preventability of the cause, placing them within three categories (Tobias and Jackson 2001). A disease or condition could be avoidable for one or a combination of their avoidable categories, depending on the relative weight assigned. Their categories were redefined as:

- 1) Primary prevention or preventing the condition from developing. This group includes conditions related to infectious diseases, anemia, easily detectable neoplasms, car accidents, injuries due to malfunction of public equipment, and suicides, among others.
- 2) Secondary prevention. This means early detection and intervention to delay progression of disease or recurrence of events. Conditions such as diabetes, pregnancy-related complications, and curable neoplasm are in this group.
- 3) Tertiary prevention. This refers to reducing case-fatality by means of medical or surgical treatment, such as cases of appendicitis, congenital conditions, and benign cancers.

This approach is suitable for the study of urban bias, because Tobias and Jackson intended to go beyond the “traditional” concept of avoidable mortality and to mainly measure the theoretical scope for further population health gain (Nolte and McKee 2003). With this classification, it is possible to differentiate not only the health outcomes of health care resource distribution in the countries, but also the pattern of age and sex in which avoidable death occurs.

For this analysis, I take Tobias and Jackson’s initial proposal and link causes of death to the category in which the authors had assigned the higher proportional weight of potential preventability. Regarding causes of death in which the proportional weight does not clearly lead to one specific group but equally divides the intervention, these are classified in a category called “combined”. In addition, I add conditions to the primary avoidable mortality; these are all classified in the ICD-10 as arthropod-borne viral fevers, protozoan diseases, and viral infections. I add these because these conditions regularly affect the countries under study. A summary of the classification following Tobias and Jackson’s initial proposal is shown in Table 7.3.

Tobias and Jackson’s cause-of-death classification is based on the 8<sup>th</sup> and 9<sup>th</sup> revisions of the International Classification of Diseases (ICD). This research is adapted to the 10<sup>th</sup> revision. The detailed classification of both the 9<sup>th</sup> and 10<sup>th</sup> revisions is displayed in Annex G, Table G.1. Once again, considering the high prevalence of violence-related deaths, I have isolated *homicides and violent deaths with undetermined intention*.

Table 7.3 Amenable cause-of-death classification by Tobias and Jackson\*

Classification	Conditions involved
Primary avoidable mortality (PAM)	34
Secondary avoidable mortality (SAM)	17
Tertiary avoidable mortality (TAM)	19
Combined	11
Additional causes added as PAM	4

\*A detailed cause-of-death classification can be found in Annex G, Table G.1, together with the amenable cause-of-death classification by Tobias and Jackson (detailed), and Table G.2 details the primary avoidable mortality (PAM) added to Tobias and Jackson’s classification.

## 7.5 Classification analysis

This research has considered a large number of indexes and their features by sex, age, countries, and their subpopulations. A subpopulation's detailed description allows understanding specific processes and their interactions. However, broad generalizations are needed in order to better distinguish specificities. Classification analysis allows identifying similarities within a set of sub-populations. Classification is based on pattern recognition and results in the assignment of some output value to given input values. The output value involves grouping data into categories based on some measure of inherent similarity or distance.

In this research, two statistical analyses are used in order to characterize, summarize, and classify patterns in subpopulations that extend beyond their nationhood: Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). They summarize 1) quality assessment of the data, and 2) mortality patterns among subpopulations. These analyses allow reducing possibly correlated indicators into broad dimensions that are linearly uncorrelated.

### 7.5.1 Principal component analysis

Principal component analysis (PCA), proposed by Hotelling (1933), is one of the most familiar methods of multivariate analysis that uses the spectral decomposition of a correlation coefficient, which is also known as covariance matrix (Yanai and Ishii 2010). It is applied when pursuing dimensionality reduction in data, and it uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components (Wallisch 2014).

The PCA method is particularly useful when the variables within the data set are highly correlated. The relationship between the variables is quantified by finding a list of the principal axes in the data, and using those axes to describe the dataset. It is essentially just a coordinate transformation in which data are plotted on a scatterplot and used for translation, rotation, and uniform scaling (Calabrese 2019). PCA rotates the two axes so that the new axes lie along the direction of maximum variation in the data.

The resulting principal components are less than or equal to the number of original variables, and they are expressed in terms of the proportion of the total variance they explain. They correspond to a linear combination of the original variables. PCA assumes that the directions with the largest variances are the most "important". The fraction of variation captured by each principal component is the ratio of its eigenvalue (explained variance) to the sum of all the eigenvalues (total variance). In order to estimate how many components are needed to describe the data, one can determine this by looking at the cumulative explained variance ratio as a function of the number of components.

In this research, the variables submitted to PCA are previously scaled by standardization. This is because the variables considered are measured in different scales (rates, life expectancy, and coverage proportion, among others); otherwise, the obtained PCA outputs would be severely affected. There is no well-accepted, objective way to decide how many principal components are enough. This research takes a threshold of 70 percent of the cumulative explained variance to indicate an acceptable number of principal components.



### **7.5.2 Hierarchical cluster analysis**

To identify similarities among subpopulation patterns, a group is created for the subpopulations that share the largest number of similar characteristics, up to the point that these characteristics make them different from (or unrelated to) the subpopulations in other groups. Hierarchical Cluster Analysis (HCA) is a statistical method for finding relatively homogeneous groups of cases based on dissimilarities or distances between objects (Serra and Tagliaferri 2019). HCA considers distances between the cases in order to place groups within the non-correlated dimensional space previously established by PCA. The result is a hierarchical classification tree.

The hierarchical tree diagram, or dendrogram, is generated in order to show the linkage points resulting from an algorithm. The algorithm can be applied agglomeratively (grouping observations) or divisively (dividing the data set). Several methods have been developed to determine the number of clusters. However, evaluating how sensitive clustering algorithms are to the effects of measurement errors indicates that no method is generally superior to any others (Bergman and Magnusson 2001). This research applies the agglomerative hierarchical cluster analysis using Ward's minimum variance method.

Ward's minimum variance method assumes that clusters are represented by their centroid, and the distance between clusters is measured in terms of increases in the sum of square errors. It attempts to minimize the sum of the squared distances of points from their cluster centroids, which are the most representative values of each cluster. In addition, exclusive clusters are defined starting with each case as a separate cluster, and then the clusters are combined sequentially, thus reducing the number of clusters at each step until only one cluster is left (Roy, Kar et al. 2015).

### **7.6 Conclusion**

This chapter has reviewed the methods applied in this research, provided a brief description of their theoretical bases, and described the decisions taken for their execution. Beyond method assumptions, decisions taken to ensure data quality and comparability also have an impact on the method's performance, e.g. using age-aggregated mortality rates instead of a single age reduces the precision in which age-related changes are estimated. The same situation occurs when the open-ended age interval in period life tables is set at 80 years old, which thus highly summarizes different mortality patterns in several cohorts. Consequently, the estimates of the most advanced populations in the mortality transition are the most affected, due to their higher survival at the oldest ages, as in the Chilean case. Applying decomposition methods leads to an expected over-estimation of the contributions of the open-ended age interval group to life expectancy at birth, and this is related to the number of survivors in this age group.

Regarding cause-of-death grouping, this research considers broad groups in its estimates. However, estimates of more detailed elements are shown when significant, not only in the main document but also throughout the annexes. In this way, it is possible to cover the main trends that drive the changes in mortality within subpopulations, as well as "abnormal" trends in particular subpopulations. Limitations in data and methods must be kept in mind when presenting further results.

## 8. MORTALITY TRENDS AND DIFFERENTIALS

So far, I have explored the historical mortality trends and differentials highlighted by the literature review. In this chapter, I describe the first results of this research with a focus on general mortality trends for the period 2000–2010, with one exception: Peruvian data covers the years 2003–2013. In order to examine the existence of differentials introduced by urbanization in Latin American mortality patterns, I use as key indicators: life expectancy at birth trends and their decomposition by age, sex and spatial group, as well as changes in the risk of dying at a specific age groups and in the dispersion of ages at death. Since continuing privilege is given to the cities – especially the capital cities – in terms of regional development for several dimensions such as education, living standards and poverty during the period considered in this research, lower levels of mortality are expected to be seen in the main-and-large-cities group when compared with the towns-and-rural group. This chapter addresses these issues along with the role of the medium-sized and small cities.

The first of a total of four sections in this chapter reviews the differential in life expectancy among countries for the period of analysis, not just the national mortality trends but the contribution that each spatial group has within the country mortality patterns and their changes during the period of analysis. Additionally, the spatial-group differential is seen through the changes that contributions of different ages make to differences in life expectancy at birth.

The second section is dedicated to exploring specific age differentials in mortality among the spatial groups. Here, I considered infant and adult mortality separately. In order to have a better follow-up on the changes in adult mortality, two age groups are used: 15 to 45 years and 45 to 75 years. These are named, respectively, younger and older adults in order to more easily differentiate them. The third section focuses on examining sex differentials among the spatial groups, and the fourth section is dedicated to brief conclusion.

### 8.1 Country differential

Along with different levels of urbanization, the countries considered in this analysis have different levels of life expectancy at birth. These differences are well perceived at the beginning of the period of our analysis for both sexes, but are not necessarily maintained throughout. Figure 8.1 displays life expectancy at birth by sex and country for the period 2000 to 2013. As the figure shows, Chile (in blue) is the only country in which life expectancy remains in the same position within the hierarchy for the entire period, i.e., it stays in the top position, regardless of sex. Chile is the forerunner of the mortality decline in this group, and it does not seem to have any period of stagnation, which is in contrast to the other countries, such as Mexico and Venezuela.

Chilean and Colombian female life expectancies at birth represent the only countries showing constant increases. On the other side, Brazilian and Colombian male life expectancies stagnate across some periods, while Mexico, Peru and Venezuela experience episodes of decreasing life expectancy. The hierarchy among the countries is not the same for males and females. In Venezuela, for example, female life expectancy at birth remains the second highest during the whole period, while male life expectancy is the third and fourth highest. The same happens

with Brazilian life expectancy: male life expectancy in Brazil lingers in the lowest position for most of the years 2000–2010 while females pass from the fourth to the third position.

Figure 8.1 Life expectancy at birth by sex, 2000–2013

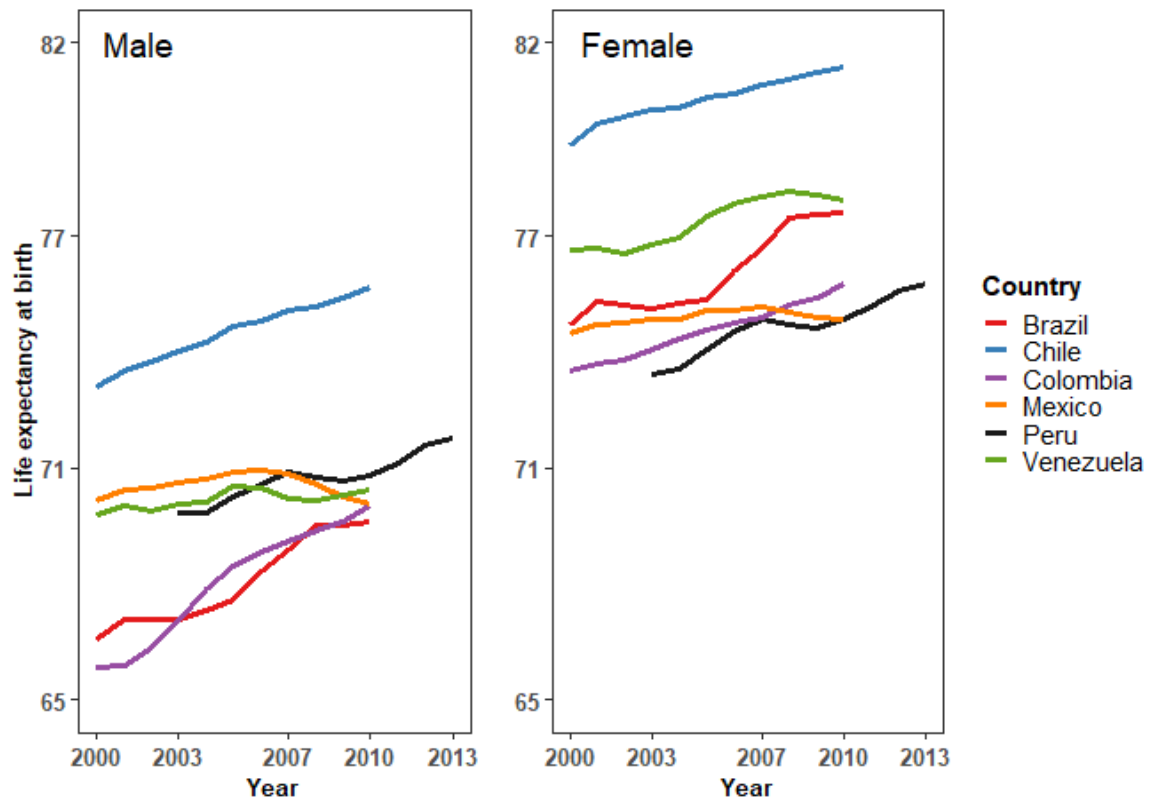


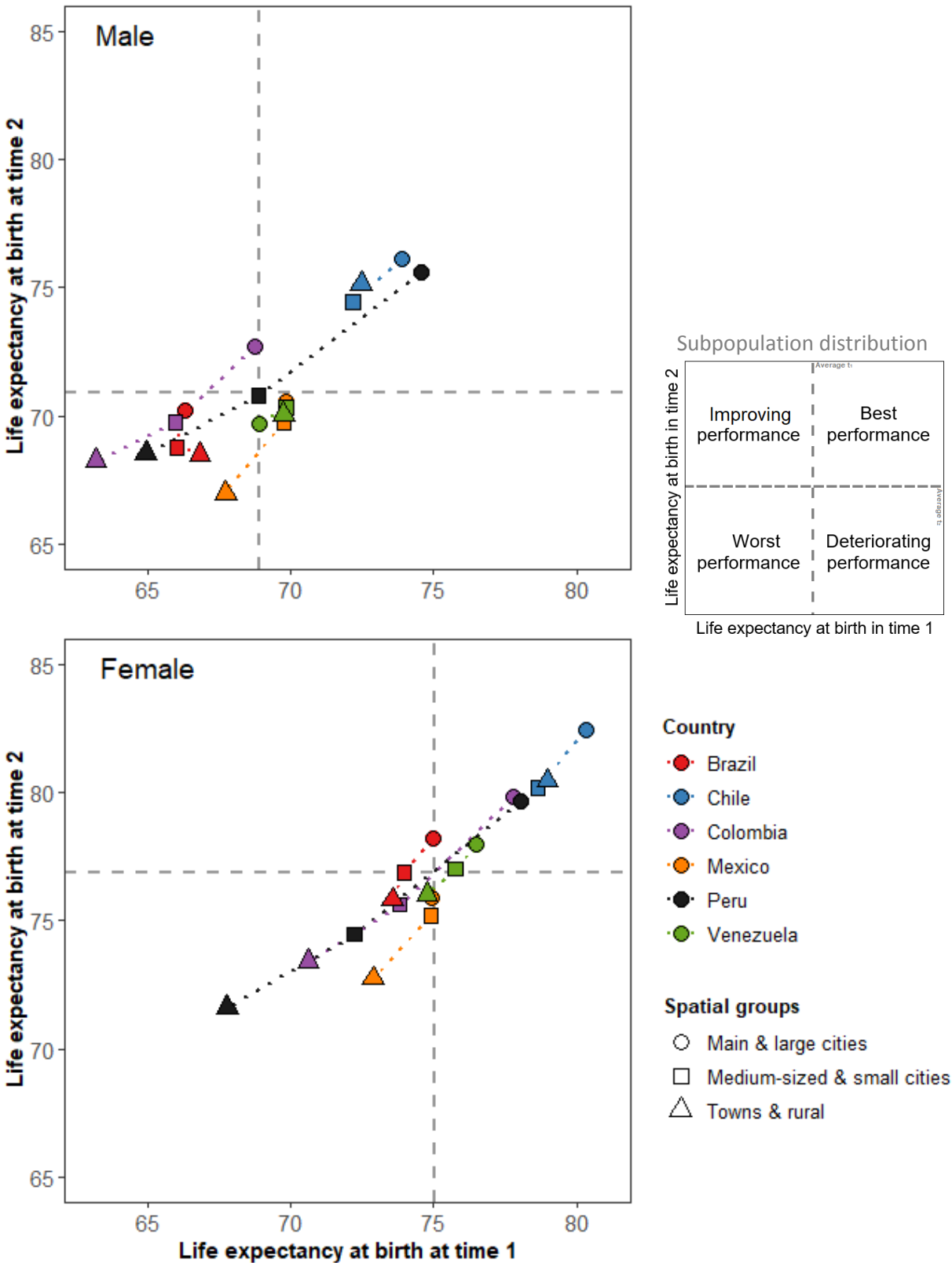
Figure 8.2 illustrates life expectancy at birth by spatial group and sex, with their changes indicated. Here, I use scatter plots to show life expectancy levels in time 1 ( $t_1$ ) on the x-axis vs. life expectancy levels in time 2 ( $t_2$ ) on the y-axis. For comparative reasons,  $t_1$  refers to the year 2000 in all countries (except Peru, whose initial year is 2003); and  $t_2$  refers to the year 2010 (and 2013 in the Peruvian case). Thus, a ten-year period of change is considered for all countries, with the exception of the Peruvian lag. Each estimate in the scatter plot represents a single subpopulation, and each of them are grouped by country (using a color scale), and spatial group (using shapes).

Male and female life expectancies are presented separately, and dashed lines in the plot represent the average life expectancy in the first and last years. Both averages divide the scatter plots into four areas, as this division helps us follow the changes in the subpopulations with respect to the total group. The top right quadrant features subpopulations with the best performance at both times (initial and final) vs. the bottom left quadrant that clusters the worst performance for both times. In the opposite diagonal, the top left quadrant congregates the subpopulation whose life expectancy has gone from being one of the worst to one of the best. In contrast, the bottom right quadrant indicates the subpopulations with a deteriorating relative performance in the group.

The best performance in life expectancy at birth is seen for all subpopulations in Chile. Moreover, the Chilean main-and-large-cities group has the highest life expectancy. Besides having the best performance, it is clear that Chile and Venezuela have the smallest differentials

among their subpopulations in comparison with the other countries in the sample. Only Peruvian and Colombian female life expectancy in the main-and-large-cities group comes close to Chilean life expectancy levels.

Figure 8.2 Life Expectancy at birth in time1 vs. time 2 by sex and spatial group\*



\*Time 1 refers to the year 2000 and time 2 to 2010 – except for Peru, whose period is 2003–2013. Dashed lines represent the average life expectancy for both times 1 and 2

This pattern of highest life expectancy in the main-and-large-cities group is true for all countries, except for males in Brazil at  $t_1$ , and in Venezuela at both times. The fact that the main-and-large-cities group has the highest life expectancy does not mean that all main and large cities are situated in the best performance quadrant. For males, only Chilean and Peruvian main and large cities have achieved the best performance for the period. In contrast, all female life expectancy in the main-and-large-cities group are found in the best performance quadrant, except Mexico's main-and-large-cities group, which has a deteriorating performance below the average of  $t_2$ .

For both sexes, Mexican cities in general have suffered a downgrade in their life expectancy compared to other countries. The same is recorded for Venezuelan males regardless of the area of residency. For their part, Colombian males and Brazilian females living in the main and large cities benefit from the greatest increase in life expectancy when compared with the rest of the subpopulations. The contribution of each spatial group to national life expectancy differs from country to country; so, national patterns tend to be driven by the groups of cities comprising the largest proportions of their populations.

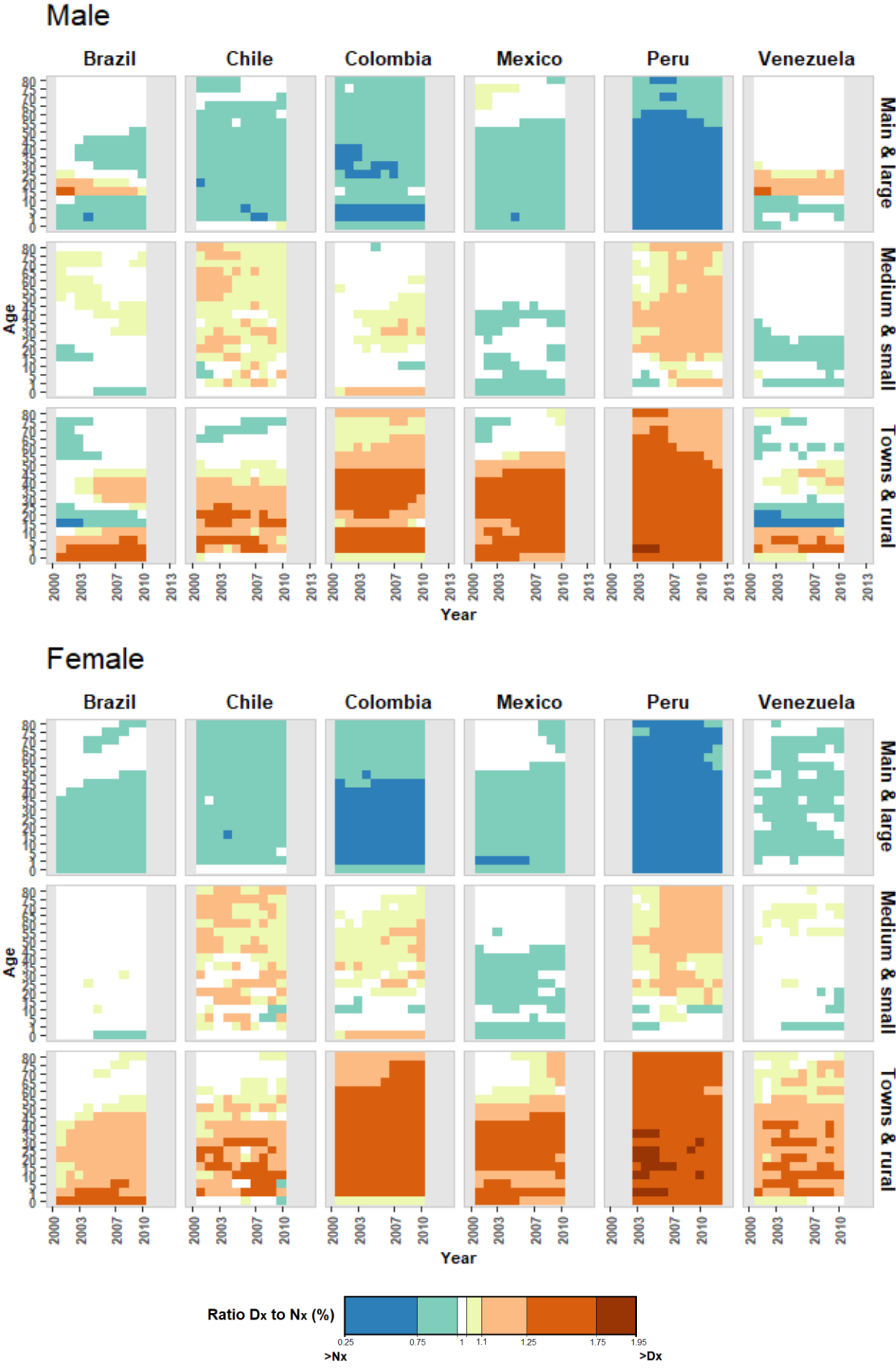
### **8.1.1 Urbanization and mortality distribution**

In addition to life expectancy, the level of urbanization is the other criteria considered in selecting the country under analysis. Chile and Venezuela are examples of the most urbanized countries in the region, while Peru and Colombia are the least urbanized. Likewise, different contributions to the total death and population are expected from the spatial group, e.g., 37 percent of the Peruvian population in the year 2000 lived in the main-and-large-cities group, while this is true for 48 percent of the Venezuelan population. If national mortality patterns were spread evenly across the territory without any bias toward a (dis)advantaged area, death counts would be distributed just as the population is. Then, if the main-and-large-cities group in Peru represents 37 percent of the total Peruvian population in the year 2000, the death counts of this spatial group should equally represent 37 percent of total registered deaths in the country during the same year. Because subpopulations may have variations in their distribution by age and sex, mortality depends on both variables. Thus, it is expected that death counts by age and sex have an equally proportional distribution of the population in each spatial group. In order to check for the existence of bias in a particular sex and/or age when considering the spatial group, a ratio of the distribution of death counts to the distribution of population counts was obtained. Yearly results are presented in Figure 8.3. Differences found in the distribution of death vs. distribution of population by age and sexes are scaled around a central value into seven uneven discrete categories. A value of one tells about the existence of the same proportion for deaths and population (represented by white in the figure); while values above one point out an excess of deaths with respect to the population (colored yellow to red, according to the differences); and values below one indicate under-mortality (colored blue to green).

The results show there is hardly any concordance between the deaths and the population distribution. Countries could be divided into two groups. The first group contains Peru, Colombia and Mexico, whose excess mortality in the towns-and-rural group is persistent,

regardless of age and sex for the entire period. In Peru and Colombia, the excess of death is divided among all subpopulations that are not in the main-and-large-cities group and the medium-sized-and-small cities group for both sexes serves as an intermediate level between the most and least urbanized. In comparison with the other countries, Colombia has a higher concentration of death in the under one-year-old population, and the concentration is even higher in the medium-sized-and-small cities.

Figure 8.3 Concordance between proportion of deaths and proportion of population to the country counts, by sex and age among spatial groups.



In Mexico, the only age group where a large excess of death is not found in the towns-and-rural groups is in the 50-years-and-over age group. For both sexes, the disadvantage of the Mexican areas that are not main-and-large-cities becomes inversed after 50 years old. In the second group, Brazil, Chile and Venezuela display variations in the distribution of death and population, depending on age and sex. Brazil and Venezuela share a more similar pattern, due to an excess of male deaths between 15 and 30 years old in the main-and-large-cities group, and from an advantageous to an even distribution of male death counts at age 50 years and over. Chile is the only countries in the sample showing no differences across spatial groups in the distribution of deaths under one year of age.

The role played by the medium-sized-and-small cities group is not the same in all countries. With the exception of females in Brazil, this group remains at an intermediate level between the main-and-large-cities and towns-and-rural groups. However, they tend to swing closer to one specific group rather than to the other. In this sense, the Chilean, Colombian, and Peruvian medium-sized-and-small-cities groups come out closer to their own towns-and-rural groups than to their main-and-large-cities groups. In Brazil, Mexico and Venezuela, the medium-sized-and-small-cities groups seem to be more like the main-and-large-cities groups.

In order to define these similarities among the cities group, Figure 8.4 (Males) and Figure 8.5 (Females) show the yearly decomposition of life expectancy at birth ( $e_0$ ) using the medium-sized-and-small-cities group as a reference. Age components of changes in life expectancy at birth are determined using the stepwise replacement decomposition method. Differences are presented as positive or negative contributions in years by age group. Years are scaled around zero, which represents no difference from the reference group. In this sense, values between -0.1 and 0.1 (in the lightest colors) indicate that indicate an insignificant contribution of the age group is made to the existing difference in life expectancy at birth in the medium-sized-and-small-cities group. Likewise, positive years indicate an advantage over the reference group (colored green to blue) and negative years indicate a disadvantage (colored yellow to orange).

In general, the age distribution of the difference in life expectancy at birth shows that the advantage held by the main-and-large-cities group in all the countries spreads to all age groups. However, the advantage is higher among the positive contributions made by age groups 45 years and above. It is possible to say that there is an absolute advantage of the main-and-large cities in the following cases: Brazilian and Venezuelan females; Chilean males and females (except for the under-one-year age group); and Colombian males. Exceptions are found in some specific age groups, such as in Chile and Peru, where the contribution of under-one-year age groups to the difference of life expectancy at birth is negative in the main-and-large cities groups. The same happens with older-age life expectancy: the contribution to life expectancy at birth of reaching age 80 and over seems to be negative in the main-and-large cities group in Peru, as well as among females in Chile and Colombia. The term “absolute” refers to the persistent positive contribution of all ages to the differences in life expectancy at birth found between the main-and-large cities and the medium-sized-and-small-cities groups for the entire period of analysis. Brazil and Venezuela show similar trends in the distribution of contributions from all ages to the difference in life expectancy at birth, with these countries being the only ones in which the age groups 15 to 30 contribute negatively to the difference. In contrast, the disadvantage held by the towns-and-rural group in respect to the medium-and-small-cities group does not show an even age contribution.



Figure 8.4 Age contributions (in years) to differences in male  $e_0$  (reference to medium-sized-and-small cities group)

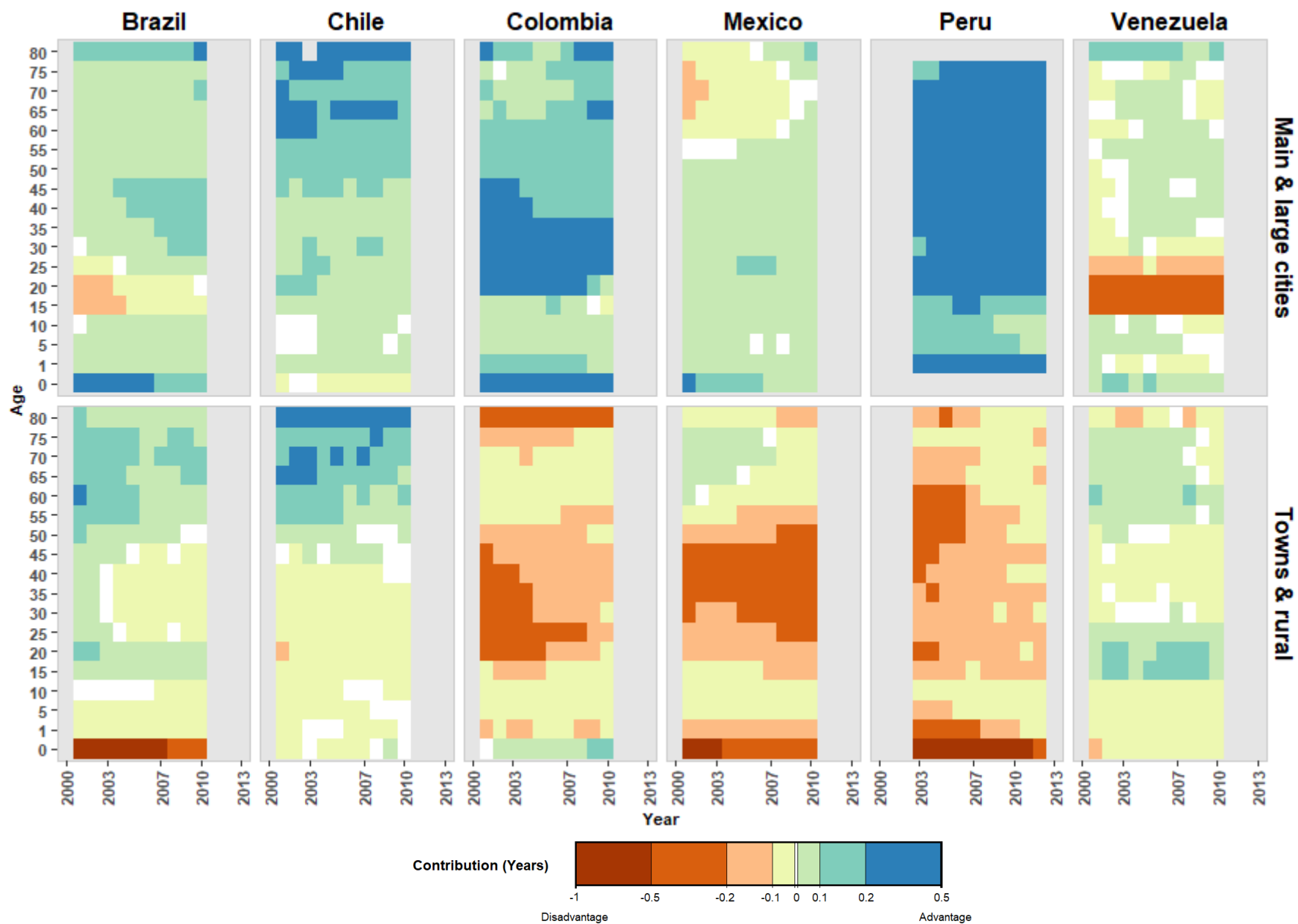
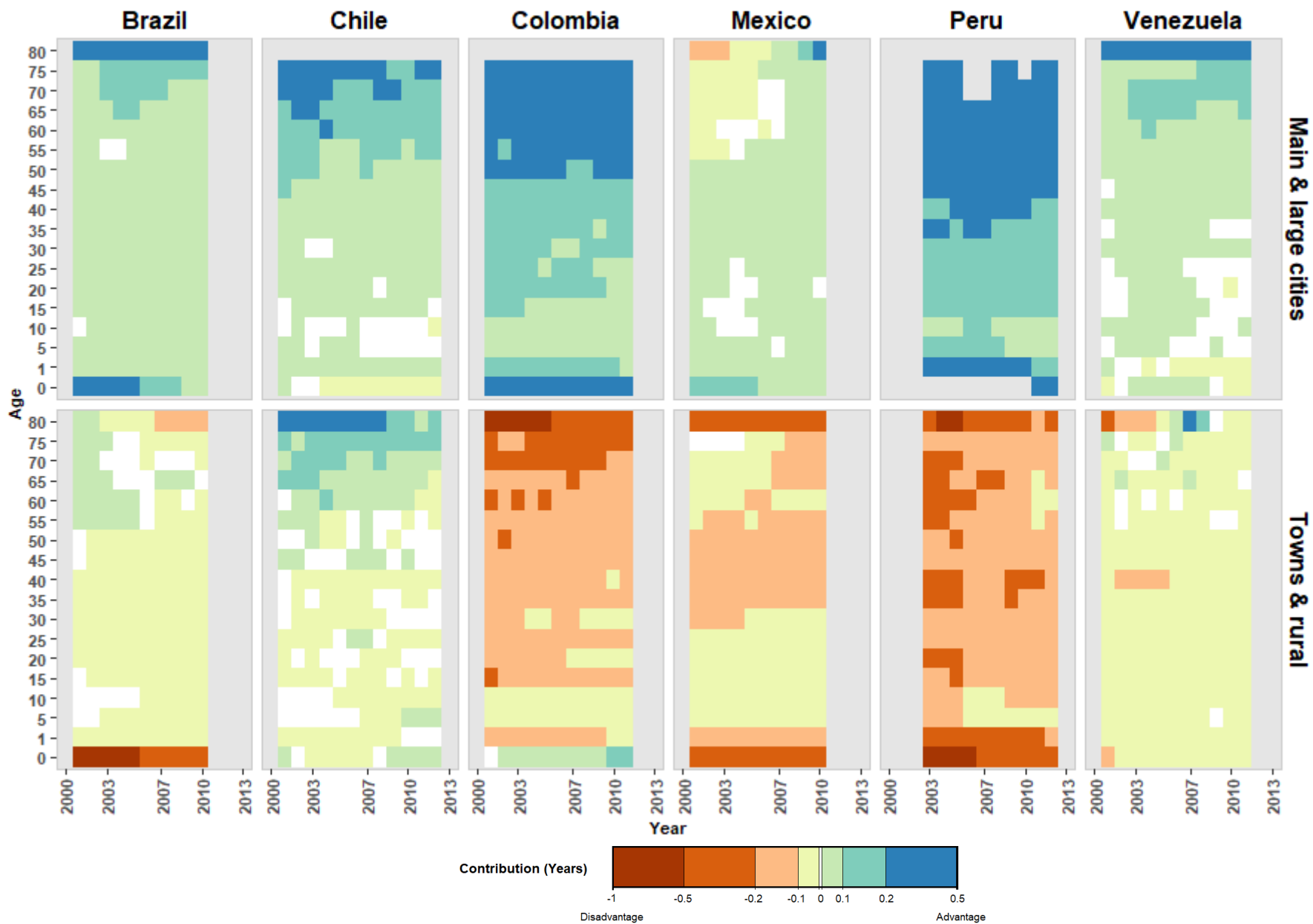


Figure 8.5 Age contributions (in years) to differences in female  $e_0$  (reference to medium-sized-and-small cities groups), 1997–2013.



The results show an “absolute” disadvantage in the towns-and-rural groups in Peru, in Colombia (except for under-one-year age group), and for females in Mexico and Venezuela. For their part, Chile, Brazil and Venezuela (males) display both negative and positive contributions to differences in life expectancy at birth.

The disadvantage of females living in the towns-and-rural-areas group comes mostly from negative contributions from ages 1 to 45 years to life expectancy at birth. This disadvantage remains, regardless the possible existence of positive contributions from any other ages, such as the under-one-year age group or 45 years and over. In the same sense, the advantage of the main-and-large-cities group comes from positive contributions of the 1 to 45 years of age groups, regardless of the negative or positive contributions of any other age group. With the medium-and-small-cities group at an intermediate level in national mortality, it is not a surprise to find that – in most of the countries – it is the main-and-large-cities groups that the difference in life expectancy at birth contains positive contributions from age groups over 45 years; while the towns-and-rural-areas group involves negative contributions of the under-one-year age groups.

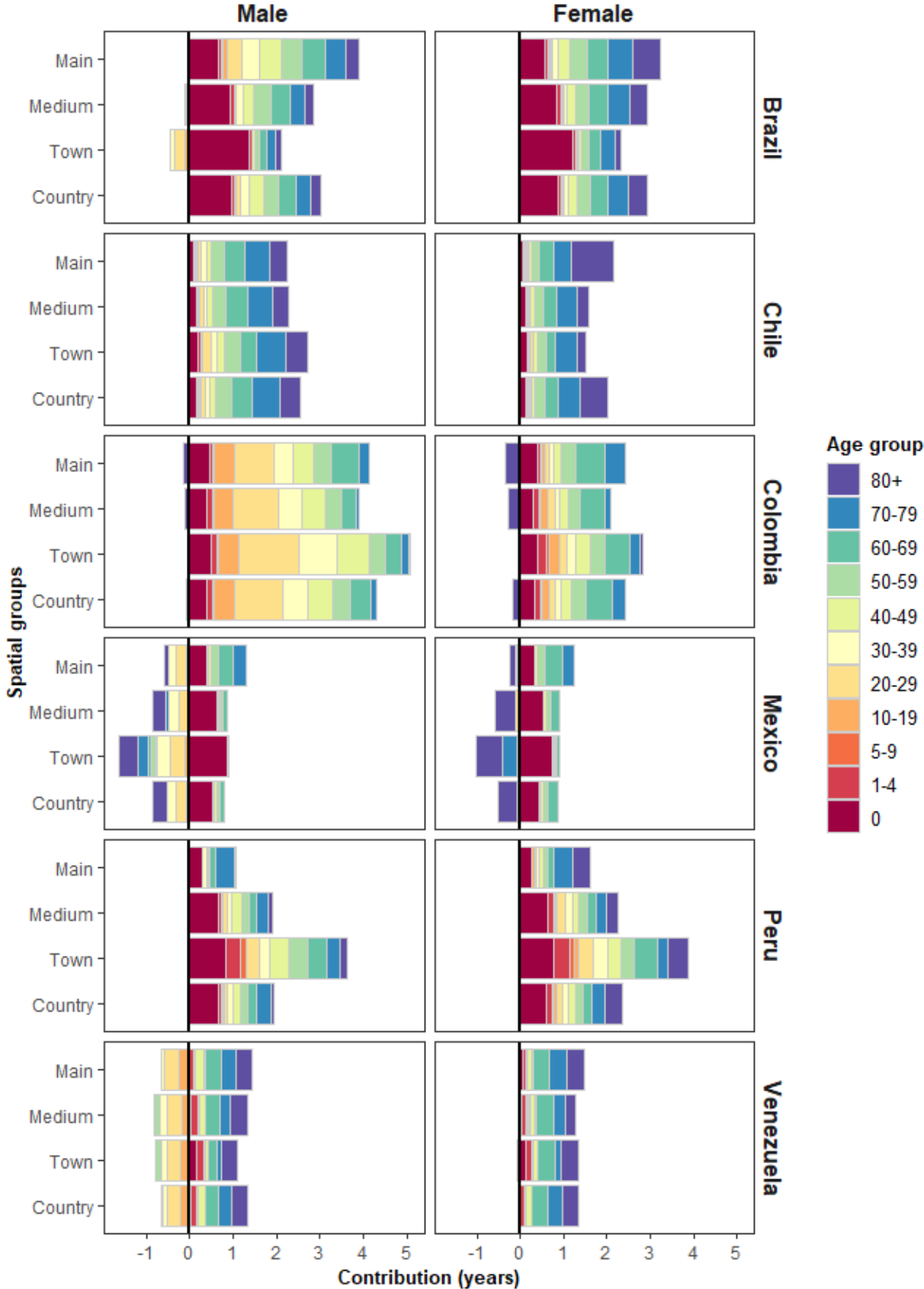
To sum up, it is possible to confirm similarities in the mortality patterns between the main-and-large-cities groups and the medium-sized-and-small-cities groups in countries such as Colombia, Mexico and Peru, which are the least urbanized countries in this sample. In the most urbanized countries (Chile and Venezuela), the similarities in mortality patterns are found between the medium-sized-and-small-cities and towns-and-rural groups. This occurs regardless of the differences in levels achieved in life expectancy and the relative importance of the capital cities in their countries. This means that the advantage may be seen at a dissimilar threshold, depending on the urbanization level of the country. In the most urbanized countries, the main and large cities have the most distinctive mortality patterns; whereas the similarities of less urbanized countries are introduced by the urban-rural opposition, as all the cities are alike while different from the town-and-rural-areas group.

In terms of mortality differentials per country, the most urbanized countries tend to show fewer differences among the spatial groups in all three indicators examined in this section: life expectancy at birth; the death distribution to population-distribution ratio; and contributions to differences in life expectancy at birth. Among them, the remaining importance of infant mortality and the contribution of specific age groups (such as those aged 1 to 45 years) in the non-main-and-large cities groups seem to be the cause of the initial dissimilar life expectancy levels among cities. With the intention of quantifying differences by age during the period, the next section examines the age distribution of gains in life expectancy at birth.

### **8.1.2 Evolution of life expectancy among groups of cities**

After establishing the contributions of groups of cities to national mortality and the differences among these groups, I focused on analyzing gains in life expectancy at birth during the period. For this, I applied the stepwise replacement decomposition method to life expectancy at birth between  $t_1$  (2000, 2003) and  $t_2$  (2010, 2013). This establishes the age group distribution of the total gains by sex in each subpopulation. The idea is to sum up the changes seen previously in Figures 8.1 to 8.4 by putting them all into one figure that allows for a simple comparison between ages and spatial groups. The results are presented in Figure 8.6.

Figure 8.6 Gains (in years) in life expectancy by spatial group and sex\*



\*Period of analysis refers to the years 2000–2010, except for Peru, whose period is 2003–2013.

As shown in Section 8.1, the countries with the greatest gains in life expectancy at birth are those with the lowest at the beginning of the period, i.e.: Brazil, Colombia and Peru. Gains in Peruvian and Colombian life expectancy at birth are larger in the towns-and-rural groups than in any other spatial group for all ages, while the main-and-large cities continue to be the subpopulations that gain more years in life expectancy in Brazil and Mexico for both sexes, and for females in Chile and Venezuela.

When decomposing the contribution to gains in life expectancy at birth by age, the Peruvian towns-and-rural group shows that the highest contributions are made by the under-one-year-old population, as does the 15 and over population in Colombia. In contrast, the gains in life expectancy at birth from the main-and-large-cities group in Brazil are mostly due to the contributions of the 40-years-and-over age groups, for both sexes. The contributions to life expectancy at birth from Brazil's age groups give some clues as to how the groups of cities may fit into the different stages of the health transition. Regardless of the lag in the life expectancy levels, mortality patterns by age show, first, that the main and large cities rapidly decline in adult mortality and, second, that towns and rural areas are behind in the overall mortality decline, with infant mortality remaining high but decreasing. A precise analysis of the causes of death presented in the next chapter will shed some light on these results.

Mexico is the only country with losses in years of life expectancy at birth due to mortality at age 80 and over for both sexes and in all the city groups. Even more, male life expectancy at birth has lost years due to negative contributions from all adult ages in towns and rural areas. Gains in life expectancy at birth come exclusively from decreasing infant mortality in the country and from some small gains in populations aged 50 years and over in all cities.

The medium-sized-and-small-cities group mostly influences gains at the national level, except for Chile and Venezuela, where the national age distribution of gains in life expectancy is more in concordance with the age distribution of gains in the main-and-large-cities group. This is explained by the primacy of the capital over the rest of the cities, such as in Chile, where around 40 percent of the population lives in the capital city of Santiago, and by the higher concentration of populations living in the largest cities, such as in Venezuela.

When there are losses in life expectancy, only two age groups seem to be affected: men aged 20 to 50; and men and women aged 70 and over. Gains are driven by increasing life expectancy at old ages (age 60 and over) in the main and large cities and by infant mortality reduction in towns and rural areas. Mexico is the only country that breaks this pattern. Differences in the risk of dying in specific age intervals are reviewed with more precision in the next section.

## **8.2 Mortality differential by age**

I selected three age intervals to analyze the mortality differentials among the spatial groups. Considering previous results obtained by decomposing life expectancy, I divide infants (less than one year old) and two stages of adult mortality. Despite all efforts, infant mortality stays high in some subpopulations in Latin America, but its continuous decline makes it one of the main drivers in gains in life expectancy. Regarding adult mortality, gains and losses of years in life expectancy appear to be driven by the tandem survival of groups in adult ages, particularly between two different groups: younger adults (15 to 45), and older adults (45 to 75). Thus, three indicators are considered: infant mortality rate (IMR); risk of dying between 15 and 45 ( ${}_{30}Q_{15}$ ); and risk of dying between ages 45 to 75 ( ${}_{30}Q_{45}$ ).

Scatter plots are used to examine changes in the indicators for all subpopulations during the entire period of analysis. Changes between the initial time ( $t_1$ ) and the final time ( $t_2$ ) are plotted on the y-axis while the initial level of the indicator in the initial time ( $t_1$ ) is indicated on the x-axis. In order to achieve better comparability between countries, a ten-year period of analysis is considered for all. Thus,  $t_1$  is set at the year 2000 for all countries but Peru (whose period begins at 2003). Similarly,  $t_2$  corresponds to 2010 for all countries and 2013 to Peru. A thin blue line is added to the scatter plots in order to divide subpopulations whose risk of dying in  $t_2$  is higher than in  $t_1$  (below the blue line) and subpopulations whose risk of dying in  $t_2$  is lower than in  $t_1$  (above the blue line). The farther above the blue line a subpopulation is located, the greater the change in the risk of dying during the period.

Unlike the analysis carried out in Section 8.1 on the subpopulation distribution according to their performance, I focus here on characterizing the subpopulations' catching-up process in the mortality decline. All indicators are evaluated in the same way. First, I describe the general hierarchy among the subpopulation, regardless of the country level, and their proximities at the beginning and end of the period. In order to better visualize the general distribution of the subpopulations, the average of the initial level of the indicator as well as the average of their change is represented by dotted lines. This representation allows dividing the scatter plot into the following four quadrants. 1) The top right quadrant shows subpopulations with the highest mortality at the initial time, but also with the largest reduction in risk during the period. These subpopulations caught up with the initially advantaged subpopulations during the period of analysis and have been named the *updated*. 2) The bottom right quadrant shows the population with the worst performance. These *lagging* subpopulations have the highest mortality at  $t_1$ , but no decrease in time. Conversely, 3) the top left quadrant congregates the *forerunner* subpopulations with the lowest mortality in  $t_1$ , who show a decrease throughout the period under analysis. Finally, 4) the bottom right quadrant contains the *stalled* subpopulations. They have the lowest mortality levels in  $t_1$ , but their gains during the period are considerably small in comparison with others. It is likely they were among the forerunners during periods previous to our analysis, but previous rates of improvement slow down for the period  $t_1$  to  $t_2$ .

A second level of analysis takes into account the perspective of the health transition framework. The idea is to check whether progress in mortality declines indicates convergence or divergence among countries and their subpopulations. In this sense, it might be expected that national mortality levels represent an average of their subpopulation mortality levels. However, the distribution of the national population within the spatial groups is not always even, and the differential between subpopulations mortality levels differs among all countries. Most urbanized countries concentrate the greatest proportion of their population in the main-and-large-cities group, and so the influence of this group over the national pattern is higher than any other spatial groups, and vice versa. Likewise, the role played by the medium-sized-and-small-cities group hardly adheres to an average mortality pattern between the main cities and rural areas, because it tends to be skewed toward one or the other, as said before. Convergence or divergence of the subpopulations may result from convergence or divergence among countries, but it may also come from the similarities in the (dis)advantaged subpopulations that extend beyond their national frameworks. For example, similar behavior among the main-and-large-cities group may be in contrast with the towns-and-rural group independently of their respective country mortality levels.

In addition to the estimates for all subpopulations, estimates at the country level are correspondingly introduced in the figures, as well as a linear regression model to indicate the

existence or not of convergence. The results for infant mortality are presented in Figure 8.7, and those for adult mortality are displayed in Figure 8.8.

### 8.2.1 Infant mortality trends

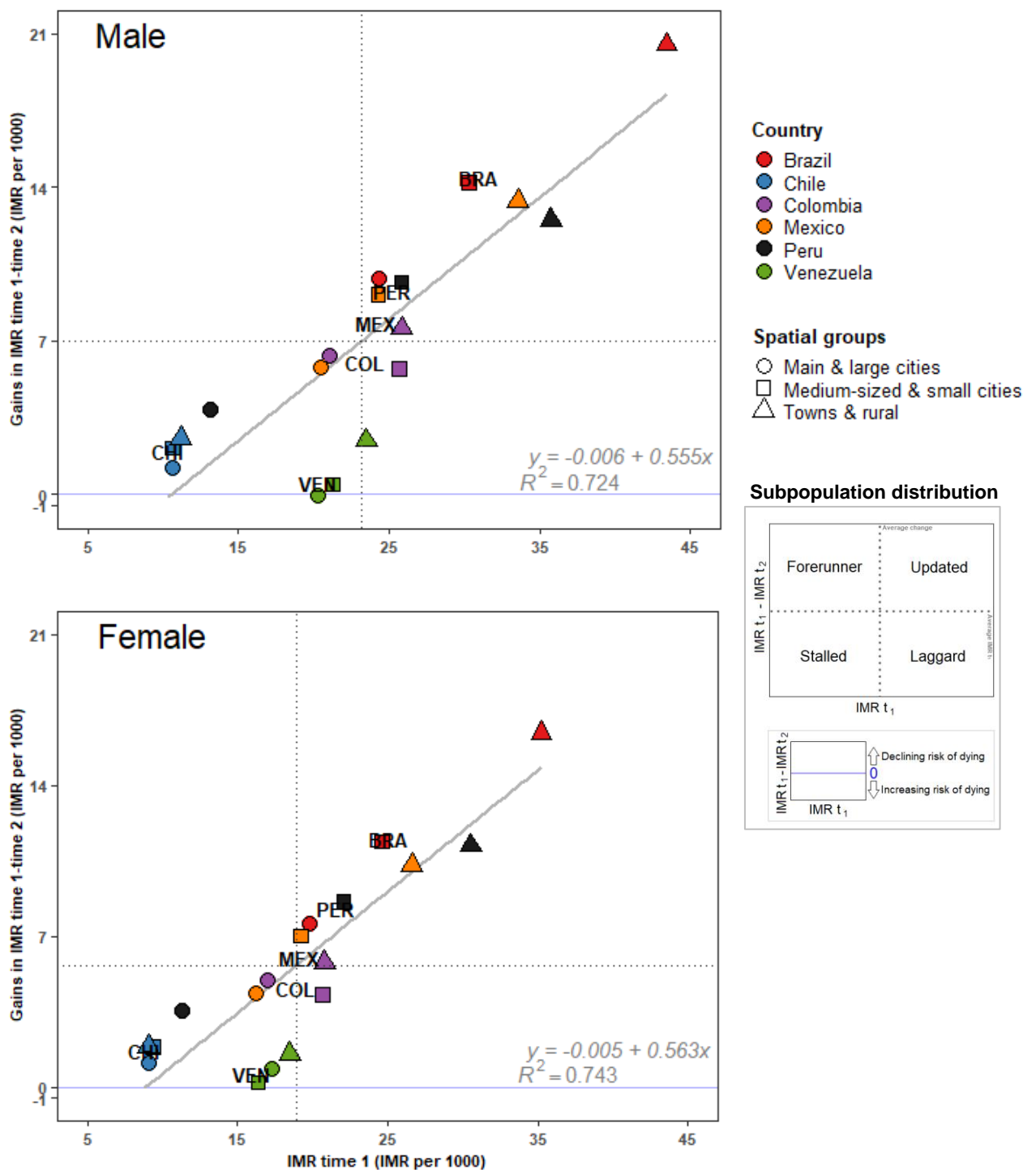
Convergence is seen in infant mortality rates (IMR) at both the country level and for their subpopulations. This means countries with the higher levels of IMR in  $t_1$  have the largest gains as their IMR decreases during the entire period, with Brazil and Peru being good examples of this trend. They have the highest IMR in  $t_1$  and the largest gains between  $t_1$  and  $t_2$ . Chile, on the other hand, has the lowest IMR levels and reports the second smallest gains. In this sense, the infant mortality and life expectancy patterns examined at the beginning of this chapter behave similarly in all subpopulations. The order of IMR for the period could be negatively correlated to urbanization, as the most urban countries have the lowest IMR; thus, the main-and-large-cities groups maintain the lowest IMRs in all countries. Venezuela is the only country in the sample that does not follow the trend. Venezuelan IMR has the smallest reduction in the entire period, although it does not have the lowest IMR at the initial time. Even more, Venezuela is the only country where negative gains in IMR are seen: males living in the main-and-large-cities group record an increase in IMR during the period.

In terms of subpopulations, countries have the same pattern: the most urbanized subpopulations show the lowest IMRs; and subpopulations with the highest IMRs in each country are the ones that decrease the most during the period. The only exception is Colombia, whose IMR for the main-and-large cities group decreases as much as the other two subpopulations, although its IMR at  $t_1$  is much lower. On the other hand, the dispersion of the subpopulations' IMR in each country seems to be positively related to their national levels. Chile and Venezuela, the countries with the lowest IMR, have the smallest differential in their subpopulations' IMR; while Peru and Brazil, the countries with the highest national IMRs, have the largest differentials.

In the performance of IMR, there is no subpopulation that could be considered a forerunner for the period of analysis, as all advantaged subpopulations in the previous period of this research are stalled with minimum gains in IMR. The Colombian medium-sized-and-small cities are the only subpopulation that might be considered as laggard, having the same IMR as towns and rural areas but with less reduction during the period.

Regarding sex differentials, considerably higher mortality in the male population under one year of age has been documented in some populations in Latin America. An analysis made on eight Latin American Countries (Costa Rica, Cuba, Chile, Uruguay, Argentina, Mexico, Guatemala and Venezuela) from 1950 to 1990 showed that women consistently run less risk of dying in childhood than men, and that women's greater gains in life expectancy at birth were the result of greater reductions in mortality at the start of life (Chackiel 1999). This pattern does not seem to be present in our sample for the period of analysis. Sex does not seem to play an important role in IMR, as patterns of change appear to be similar despite the expected slightly higher levels and dispersed distribution recorded for males.

Figure 8.7. Infant mortality rate at time 1 vs. gains in IMR between time 1 and time 2, by spatial group and sex.



\*Time 1 refers to the year 2000 and time 2 to 2010, except for Peru, whose period is 2003–2013. Average IMR in time 1 and average gains in IMR are represented by the dotted line.



### 1.1.1 Adult mortality trends

Two indicators have been chosen to study adult mortality among subpopulations. The first one relates to young mortality and covers the risk of dying between ages 15 to 45 ( ${}_{30}q_{15}$ ). It is displayed in Figure 8.7A by sex. As the sex differential in mortality at this age group is large, and in order to make visible the subpopulation estimates and their changes, I use different scales by sex in Figure 8.7A. The second indicator refers to mortality at older ages: the risk of dying between ages 45 to 75 ( ${}_{30}q_{45}$ ). Older adult mortality is presented in Figure 8.7B by sex.

Countries converge in young adult mortality for both sexes, with the exceptions of Mexico and the male population in Venezuela. The greatest improvements are recorded in Colombia, the country with the highest risk of dying in  $t_1$ ; while Chile, the country with the lowest risk of dying, shows slight reductions during the period. Subpopulations within the countries behave differently: they show a mixed process of convergence and divergence in their risk of dying at young ages, depending on the country. Convergence among subpopulations is clear in all subpopulations in Chile and in the male subpopulations in Colombia and Peru. This convergence is mostly due to towns-and-rural-areas groups catching up with the previously obtained gains of the cities.

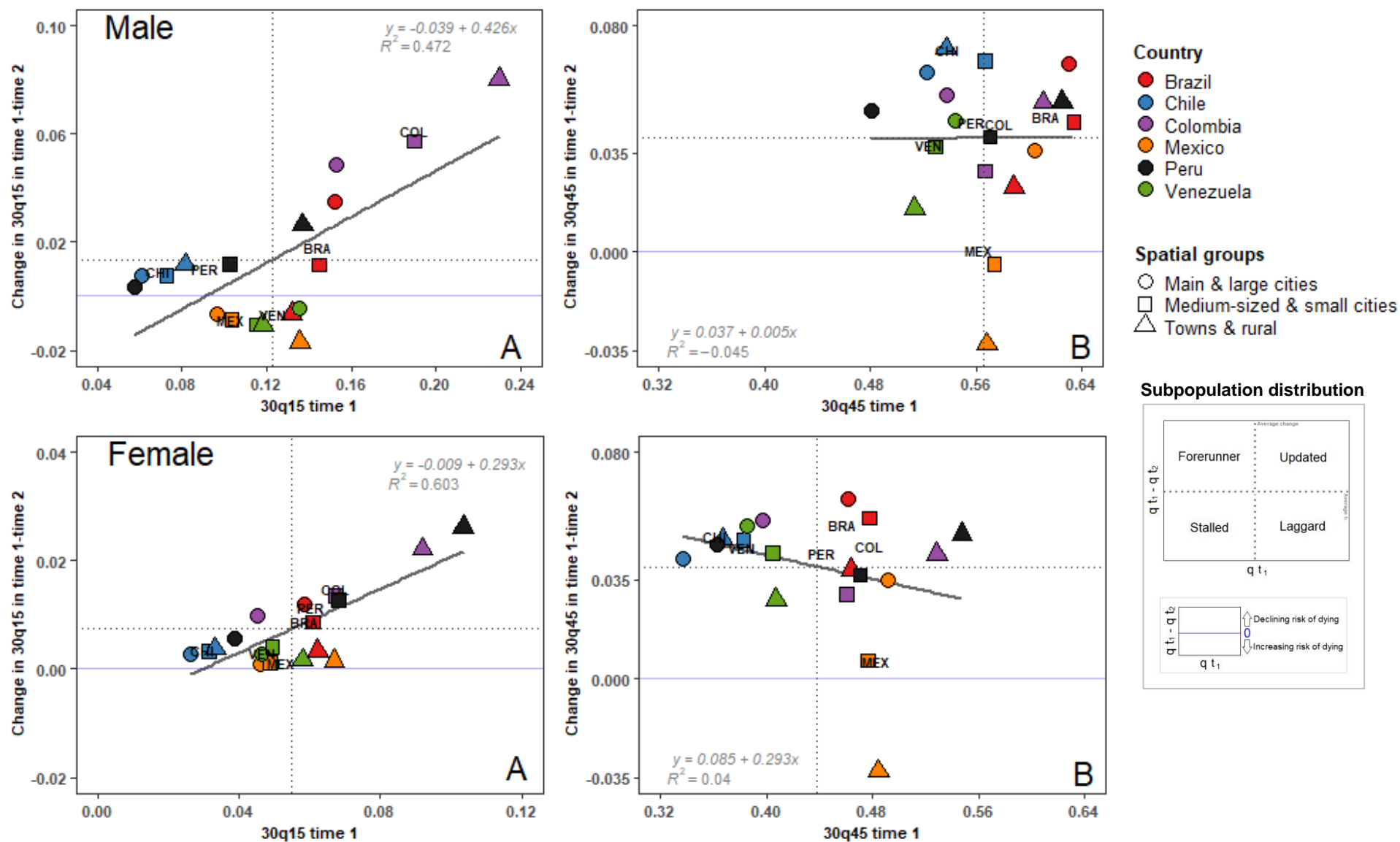
In contrast, divergence is predominant among the subpopulations in Mexico and Venezuela, as well as among females in Brazil. The process of divergence in these subpopulations is driven by a larger reduction in the Brazilian main and large cities, and by the increased risk of dying in the towns and rural areas in Mexico and Venezuela.

The only subpopulation considered to be a forerunner in reducing the risk of dying at young adult ages is Colombian females in the main-and-large-cities group. The main-and-large-cities groups in Chile and Peru, previous forerunners in reducing the risk of dying in this age interval, are stalled in their reduction. The distributions are not only lagging for males in Venezuela and Mexico in all groups of cities and in Brazil's towns-and-rural group, but their risk of dying is increased in this age interval. Focusing on the distribution of the subpopulation's risk of dying at young adult ages ( ${}_{45}q_{15}$ ), I find that the following are catching up with the rest of the subpopulations for both sexes: Colombia; towns and rural areas in Peru; and the main-and-large-cities group in Brazil.

Regarding older adult mortality, countries show divergence in their changes. This divergence is easily perceived in female populations at both the country and subpopulation levels. Brazil and Colombia have consistently higher improvements than countries such as Chile and Venezuela, in which improvements occurred before the period of analysis. These last two countries are the forerunners in older adult mortality. Mexico, for its part, is once again the country with the most deteriorated performance in older adult mortality.

Divergence between female subpopulations is common to all countries, with the exception of Chile, where all non-main-and-large-cities groups are catching up with their initial advantage. For males, when the process is not leading to the divergence of the subpopulations (as in Colombia and Peru), the catching-up process results from the main-and-large-cities groups already holding the highest risk in their respective countries in  $t_1$ , thus obtaining the largest reduction in the risk of dying. This situation concerns males in Brazil, Mexico and Venezuela.

Figure 8.8 Risk of dying between ages 15 to 45 ( $A=_{30q15}$ ) and ages 45 to 75 ( $B=_{30q45}$ ), by groups of cities and sex



Unlike what is perceived in young adult mortality, there is no sex differential in how the subpopulations are distributed in older adult mortality, although, as expected, women usually have lower risks. Almost all female subpopulations aged 45 to 70 living in the main-and-large-cities groups are identified as forerunners in reducing the risk of dying. The only exception to this trend is Brazil, due to its initial higher risk compared to the other main-and-large-cities groups in the sample. However, gains in this group place its probability of dying in  $t_2$  within the range found in the rest of the main-and-large-cities groups in  $t_1$ .

On the other hand, the only towns-and-rural area in the forerunner group is Chilean. Chilean towns and rural areas may be in the process of catching up to the previous advantage. The role of the medium-and-small-cities groups is not an intermediate state, as it was for IMR. In older adult mortality, this spatial group is often seen as less favorable than the towns-and-rural group, as in Brazil and Chile; or the reduction in their risk of dying is less than expected, as in Colombia and Peru.

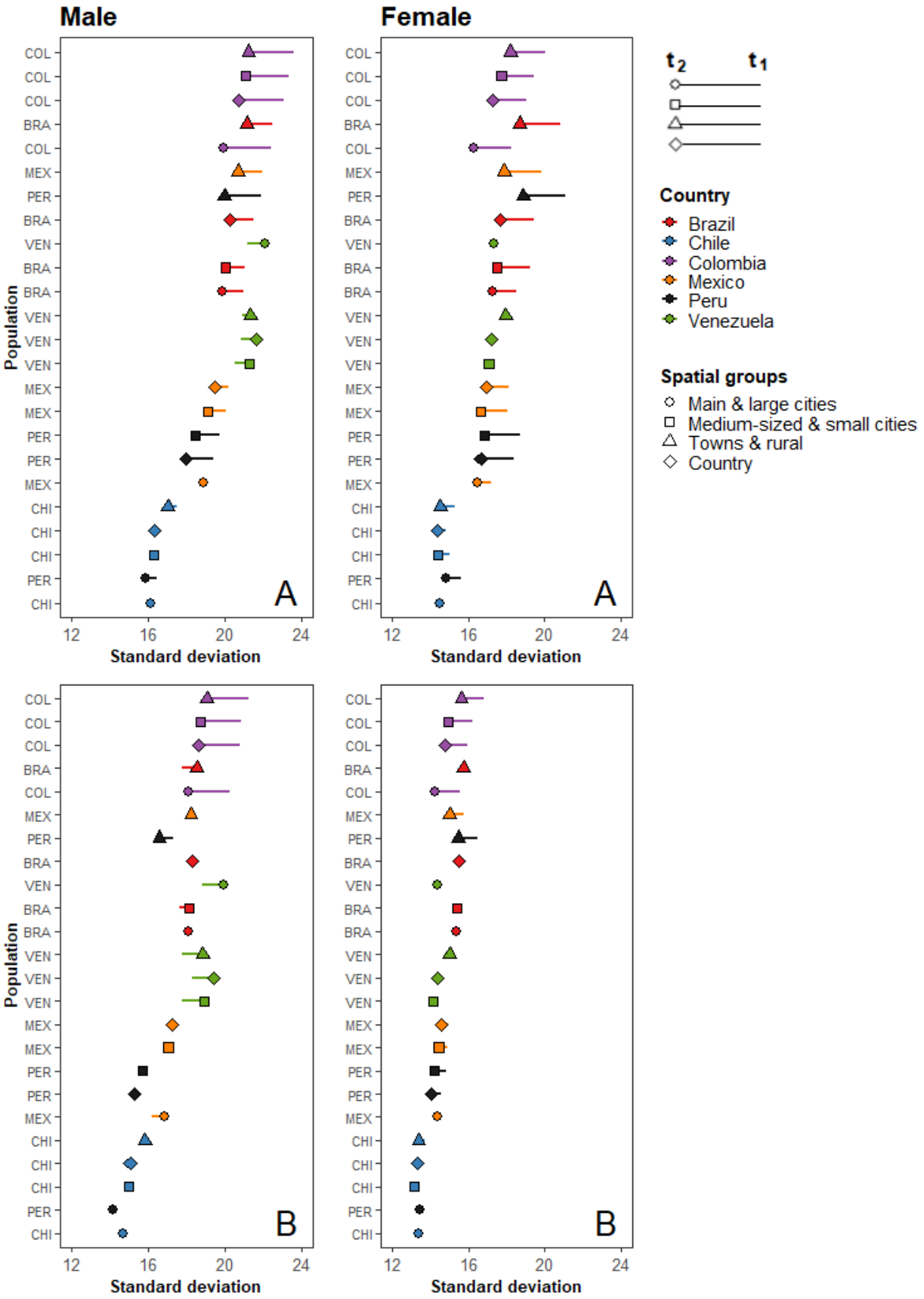
In summary, the best performance in reducing the risk of dying is found in the main-and-large-cities group for all countries. Even in Mexico where the worst performance is recorded in all its subpopulations, the main-and-large-cities group is least affected by the deteriorating trend in adult mortality. The only case in which the main and large cities are losing their advantages over the other groups is when they fail to reduce young adult mortality, as in Mexico and Venezuela. Convergence in subpopulation mortality levels occurs at young ages for all the other countries, while divergence is seen in old ages. Divergence at old ages is due to the greater advantage of the main and large cities. Hardly any improvement exists in old ages outside the main and large cities. The medium-and-small-cities groups are lagging in reducing the risk of dying at old ages and, in some cases, even at young adult ages, such as males in Brazil.

As can be seen, adult mortality does not follow the same pattern of improvement as infant mortality. In fact, subpopulations showing decreasing infant mortality are in parallel with an increasing risk of dying at young adult ages and a declining risk of dying at old adult ages. There is no subpopulation that could be considered a forerunner or laggard for all three indicators, meaning that there is no subpopulation that evenly registers constant improvement or deterioration at all age groups for the period. Chile, the country with the lowest risk of dying in the three age groups chosen here, displays almost no improvements in young adult mortality. On the opposite side, Mexico experiences an increased risk of adult mortality in most of its subpopulations yet still shows improvements in infant mortality. The impact of these trends in the distribution of deaths is examined in the next section. Once again, the idea is to aggregate quantifiable changes in the distribution of deaths into one indicator.

### **8.2.2 Life span dispersion and its evolution among the spatial group**

The age distribution of death is an indication of the concentration of death at a specific age. Here, the evolution of the dispersion in mortality is calculated using changes in the standard deviation of death distribution. Changes are obtained from the difference between the standard deviation at an initial time ( $t_1$ ) and at a final time ( $t_2$ ), and the results are displayed in Figure 8.9.

Figure 8.9 Changes in the dispersion of mortality from time 1 (2000, 2003) to time 2 (2010, 2013), by sex and spatial group.



A = entire population and B the population age 1 year and over. Subpopulations are ordered increasingly according to the ranking of the entire population's standard deviation.

As with previous indicators,  $t_1$  refers to the standard deviation during the year 2000 – and 2003 for Peru – while  $t_2$  refers to the standard deviation in the year 2010 – and 2013 in the Peruvian case. Subpopulations are ordered from the lowest to the highest dispersion in the male age distribution in  $t_1$ . Males and females are presented separately, and two sets of estimates are made: *A* considers the entire population and *B* excludes the population under one year of age. This is because, as said before, infant mortality continues to be high in some subpopulations in Latin America, and changes in life expectancy are driven mostly by its reduction. In fact, most of the changes in the dispersion of death distribution are due to changes in infant mortality. When comparing Figure 8.9A (all populations) and Figure 8.8b (excluding deaths among the under-one-year old population), most of the changes disappear.

The reduction in the standard deviation in Mexico, Peru and Brazil disappears when the under-one-year old population is not considered. It is only in a few countries where it is possible to see changes without the effect of infant mortality, such as in Colombia, where for both sexes the decreasing risk of dying in adult ages is driving changes in the dispersion of mortality. Peru is another country in which the dispersion of the distribution of deaths has a marginal reduction, especially in the towns-and-rural group and among females living in medium-sized and small cities.

Venezuela is the only country in which the change in male standard deviation increases without considering infant mortality. All its male subpopulations show an increasing dispersion driven by the increasing young adult mortality, which is counterbalanced by its mild decrease in infant mortality. A similar phenomenon, but at a lower scale, is seen among Brazilian males living in medium-sized and small cities and in towns and rural areas, as well as among Mexican males in the main and large cities. This last subpopulation goes from stagnation to increasing dispersion when the under-one-year old population is not considered.

Focusing on Figure 8.9B, which analyses changes in the standard deviation without considering deaths among those under one year of age, the Peruvian and Chilean main and large cities are the subpopulations with the lowest standard deviation in  $t_1$ , while Colombian towns and rural areas have the highest. In the cases of Colombia, Venezuela and Chile, all subpopulations in the same country have similar dispersions. In contrast, the mortality dispersion in Brazil and Mexico is similar among the cities, and it is much lower than in towns and rural areas. Lastly, Peruvian dispersion shows an important differential among subpopulations, thus following the same trend in differentials that was seen in the mortality indicators studied previously in this chapter.

To sum up the results on age differential, the dispersion of the death distribution for all ages is redundant in the catching-up process that is seen in the infant mortality rates. Adult mortality does not seem to follow a unique trend: it neither condenses to older adult ages nor it is reduced to a particular age; but, in most cases, the changes combine to cancel each other out. Even Chile, the forerunner of the group in mortality decline, shows increasing older adult mortality during this period, but there is hardly any improvement in young adult ages.

### **8.3 Sex differential in mortality trends**

This chapter has detailed the differentials among age and subpopulations, as well as the combination of both. So far, it has been possible to see some sex differentials in mortality in the trends exhibited by some populations. In this section, I explore the differences between sexes

by means of life expectancy decomposition. Female mortality is used as a reference to determine the age distribution differentials per year in comparison with males in each subpopulation, with every calendar year during the period of analysis included. Some differences are expected between male and female mortality patterns. A female advantage at old ages has been seen in most of the developed countries, as well as a male disadvantage during young adult ages (mortality hump). Both (dis)advantages contribute to the differences found in life expectancy at birth among sex. The method used for decomposing life expectancy in a discrete approach is the stepwise decomposition method. Figure VIII.10 shows the results.

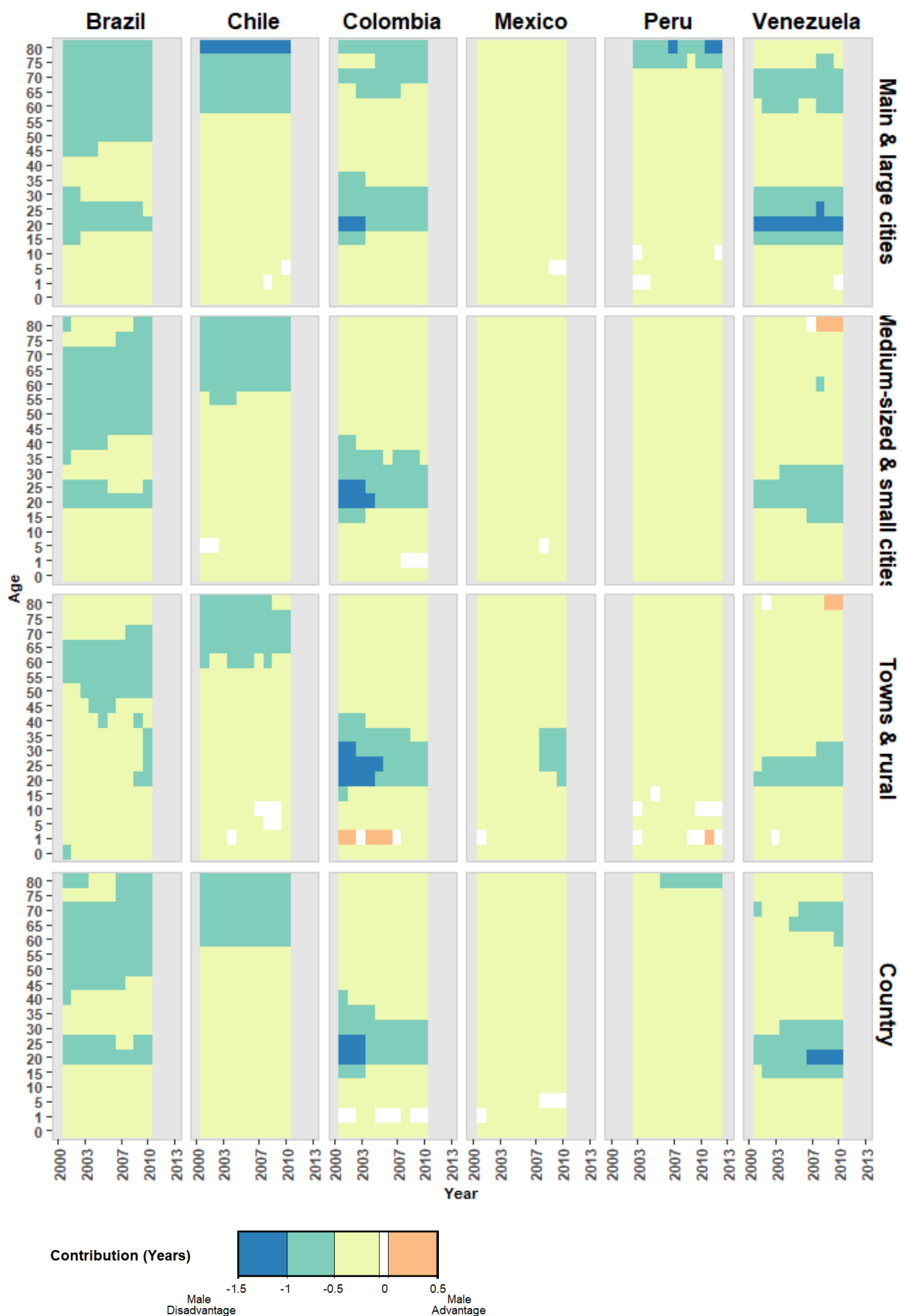
A sex differential among the groups of cities is seen in Venezuela, where the disadvantage of the young male population is stronger in the cities, especially in the main-and-large-cities group. To a lesser extent, its presence is perceived in the towns-and-rural group. The second disadvantage of the male population is seen in ages 60 years and over living in the main-and-large-cities group. In this case, the male disadvantage is exclusively an issue pertaining to the main and large cities.

The same happens in Colombia, where there is a male disadvantage in populations aged 60 years and over, but only in the main and large cities. The difference in Colombia is that the disadvantage of the young male population has spread to all the subpopulations in the country, and it is worsening in the towns and rural areas instead of the main-and-large-cities group, as in the Venezuelan case. Another particularity of Colombia and Venezuela comes from the fact that they are the only countries with a female disadvantage at age interval 1 to 4 years old. In both cases, this occurs in parallel with a period of very high young male over-mortality. In Venezuela, a female disadvantage in recent years is also seen at age 80 and over outside the main-and-large-cities.

In Brazil and Chile, a male disadvantage at old adult ages, even when it is higher in the main-and-large-cities groups, explains the sex differential seen in all the subpopulations, but not in the same age groups. In Brazil, a male disadvantage begins to become evident around 45 years, and it reaches only age 80 years and over in the largest cities. In Chile, in contrast, the male disadvantage starts at around 60 years in all its subpopulations and continues to grow higher at age 80 and over in the main-and-large-cities group.

Mexico, for its part, turns out once again to be an exceptional case. The sex differential in Mexican life expectancy at birth is spread evenly across all ages. This is particularly appealing in the context of increasing the risk of dying at adult ages, as seen in Mexico throughout previous sections of this chapter. An emerging sex differential appears to be starting in young adult ages living in Mexican towns and rural areas at the end of the period of analysis.

Figure 8.10 Age components of life expectancy differences between males and females (in years), by spatial group.



## 8.4 Conclusion

Throughout this chapter, I have examined classical mortality indices (infant mortality, life expectancy, and age of death distribution, among others) and their evolution during the period of analysis. Two broad conclusions can be extracted from their analysis. The first one takes a more technical point of view and is related to how the changes responsible for the mortality differential between subpopulations are occurring separately in younger adult ages (15 to 45), and in older adult ages (45 to 75). Because these two age groups do not follow the same trends in most of the countries, a synthetic indicator of dispersion in the age of death distribution may summarize opposite trends occurring within the mortality structure, as we see in Section 8.2.2 of this chapter. Instead, a categorization of the different trends that are found seems to be a more useful analytical tool for understanding changes in mortality distribution during the first decade of the twenty-first century in Latin America.

The same happens with the correlation between infant mortality and life expectancy at birth. Improvements in Latin American mortality have been driven mostly by a reduction in the risk of infant death. This affirmation is still noticeable in the most disadvantaged subpopulations in our sample. The importance of the reduction in infant mortality must not be viewed only as the main driver in increasing life expectancy, as it also plays a role in balancing the negative impact of the increasing premature death of young adults when comparing synthetic indicators, such as life expectancy at birth among countries.

Second, according with the literature review points out the stagnation in decreasing mortality can be seen in the region after the nineties, even in countries that had previously been engaged in catching up with the advantages of the historical forerunners. Most of these countries had increased their life expectancy at birth in a non-stop fashion from any point in time between the fifties and the seventies. However, periods of stagnation and, in some cases, decreasing life expectancy are repeatedly observed. Considering country comparisons, the literature raises the hypothesis that the impact of violence in young adult mortality is the main cause of the stagnation and setback periods, thus hampering increases in Latin Americans' survival.

Throughout this chapter, I demonstrate that stagnation in increasing life expectancy is mostly due to unsuccessful efforts to reduce mortality in populations aged 45 years and over. Adult mortality reduction is related to urbanization, as shown by the urban gradient. In this sense, this may be one of the reasons why it is in the most urbanized countries where the highest survival is found. A composition effect of the urban/rural population distribution at the national level favors survival after 45 years of age, and this is because increasing survival in old adult populations is occurring in the main and large cities. There is no evidence of increases in older adult survival in the less urbanized areas. The only exception to this is Chile, where towns and rural areas witness increasing survival in male adults in parallel with an excess mortality in young adult mortality.

In addition to being an obstacle to overcome, young adult mortality has acted as an added effect leading to a truncated or failed health transition for some subpopulations. Nevertheless, it is in no sense the only driver of the stagnation in adult mortality decline. The reason behind this stagnation and the lack of rectangularization in the survival curve for most of the subpopulations could be clarified when examining causes of death, which we will see in the next chapter.



## 9. CAUSES OF DEATH DISTRIBUTION AMONG SPATIAL GROUP

Since diseases and causes of death do not always appear by chance but instead correspond to a defined pattern of social organization and structure, cause-of-death analysis provides insight into the level of unequal development among national subpopulations and how strategies to gain access to health could lead to different epidemiological patterns within the same nation. In this regard, Frenk et al. put forth the idea that the coexistence of mixed epidemiological profiles in terms of significant proportions of both communicable and non-communicable causes in the national context. This profile become partially diluted when considering urban/rural divisions, by urban areas concentrating the non-communicable causes of death, whereas rural areas gather the communicable (Frenk, Frejka et al. 1991). In this chapter, I examine the cause-of-death structure in Latin American countries when the urban/rural gradient is considered. As in previous chapters, I look for country and subpopulation differentials according to their urbanization levels.

This chapter is divided into five sections and considers five of the seven initially selected countries (Brazil, Chile, Colombia, Mexico and Venezuela). As mentioned before, selection is based on countries having acceptable cause-of-death data quality. In the first section, I analyze differentials in cause-of-death distribution among countries and spatial groups according to their sizes during the period 2000 to 2010. The aim is to identify the main causes of death driving subpopulation differentials and the general changes in mortality patterns during the period. In this sense, the evolution of standardized cause-of-death rates and modal causes of death by age and sex are examined. Modal cause of death refers to the predominant cause of death by age group and sex. In the second section, differences in life expectancy at birth among spatial groups are decomposed year by year using the stepwise decomposition method. The third section is devoted to the decomposition by age and cause of death of changes in life expectancy at birth during the period for each spatial group.

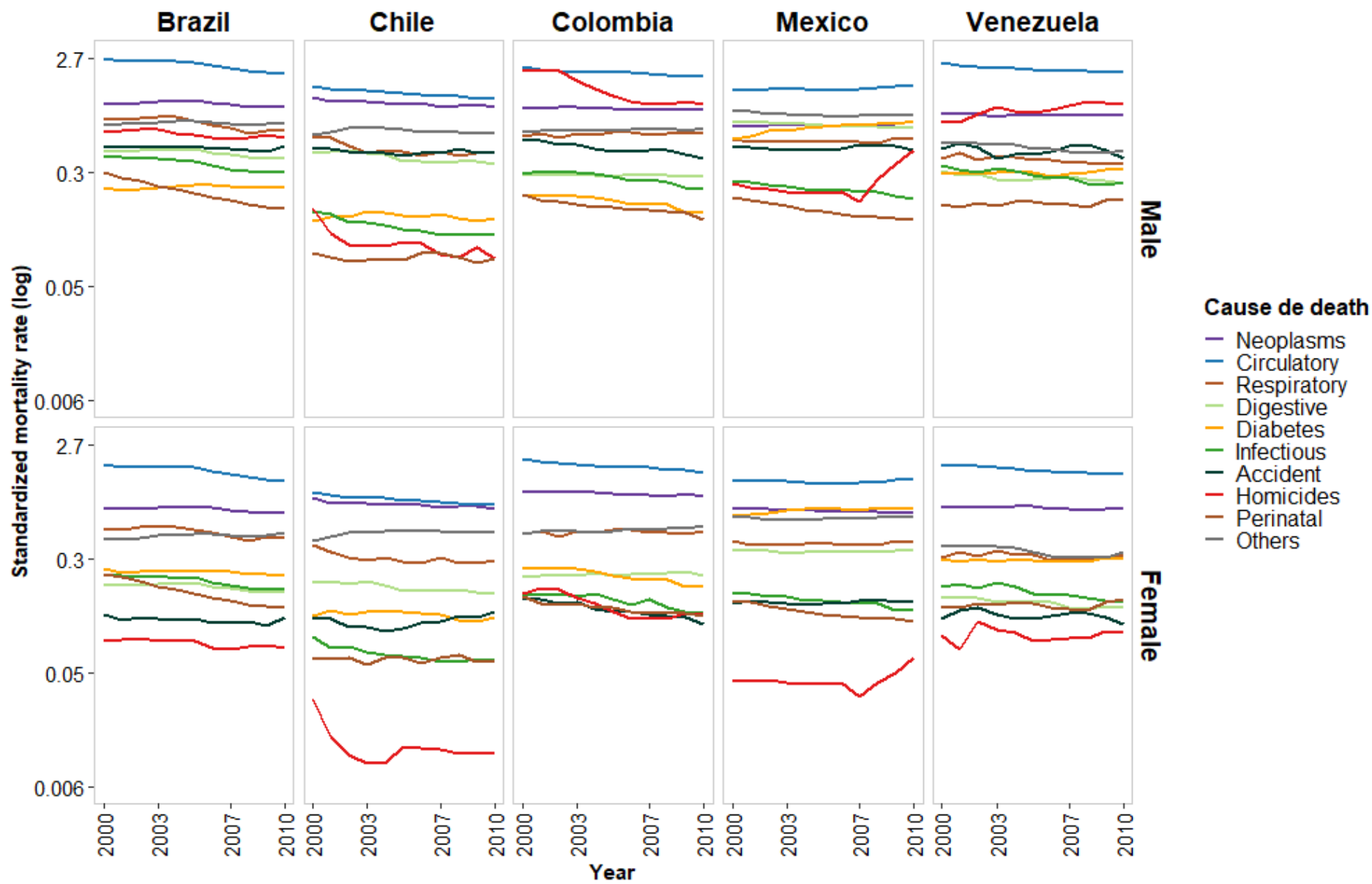
In the fourth section, analysis is carried out considering the amenable character of the cause-of-death distribution. Causes of death are classified according to the level in which effective interventions of health care providers avoid its occurrence if interventions were to have taken place. Amenability classification of causes of death allows keeping track of differentials that public policies may introduce by age, sex, spatial group and country. Finally, the last section is devoted to a brief conclusion on this chapter.

### 9.1 Cause-of-death trends

#### 9.1.1 Causes of death among countries and spatial groups

As seen in the previous chapter, mortality levels and changes in the selected countries are heterogeneous during the period under consideration. In this section, the analysis of the national and spatial-group cause-of-death trends from 2000 to 2010 by sex are carried out using the standardized mortality rates of the ten main-group causes presented in Chapter VII. In Figure 9.1 national trends (in logarithmic scale) are displayed by sex. In the figure, it is clear that circulatory diseases are the first cause of death in all countries, followed by neoplasms, homicides (for males) and respiratory diseases – although at varying levels.

Figure 9.1 Cause-of-death standardized rate by sex and country, 2000–2010.



In Chile, neoplasms mortality rate has reached levels close to those caused by circulatory diseases in both sexes, while the proportional difference is close to twofold in favor of circulatory diseases in the remaining countries. This means that for every two deaths caused by circulatory diseases, approximately one is due to neoplasm. Regardless of the proportion, circulatory disease mortality rates decrease in all countries, while neoplasm rates are rather stable or slightly decrease.

The only exception to this trend is Mexico, where deaths caused by circulatory diseases have been increasing since the mid-2000s for both sexes, and neoplasm has been overtaken as the second main cause of death by diabetes (females) and digestive diseases (males). In addition to Mexico, diabetes only slightly increases in Venezuela for both sexes. For the remaining countries, diabetes remains low and with a decreasing trend.

Regarding both level and trend, homicides constitute the most heterogeneous behavior for all causes of death among these countries. Homicides hardly affect women or Chilean men, and they maintain the highest rates in Colombia and Venezuela. Mexico and Venezuela, once again, are the only countries in which homicide rates are increasing while they have decreased during the period in Brazil and Colombia.

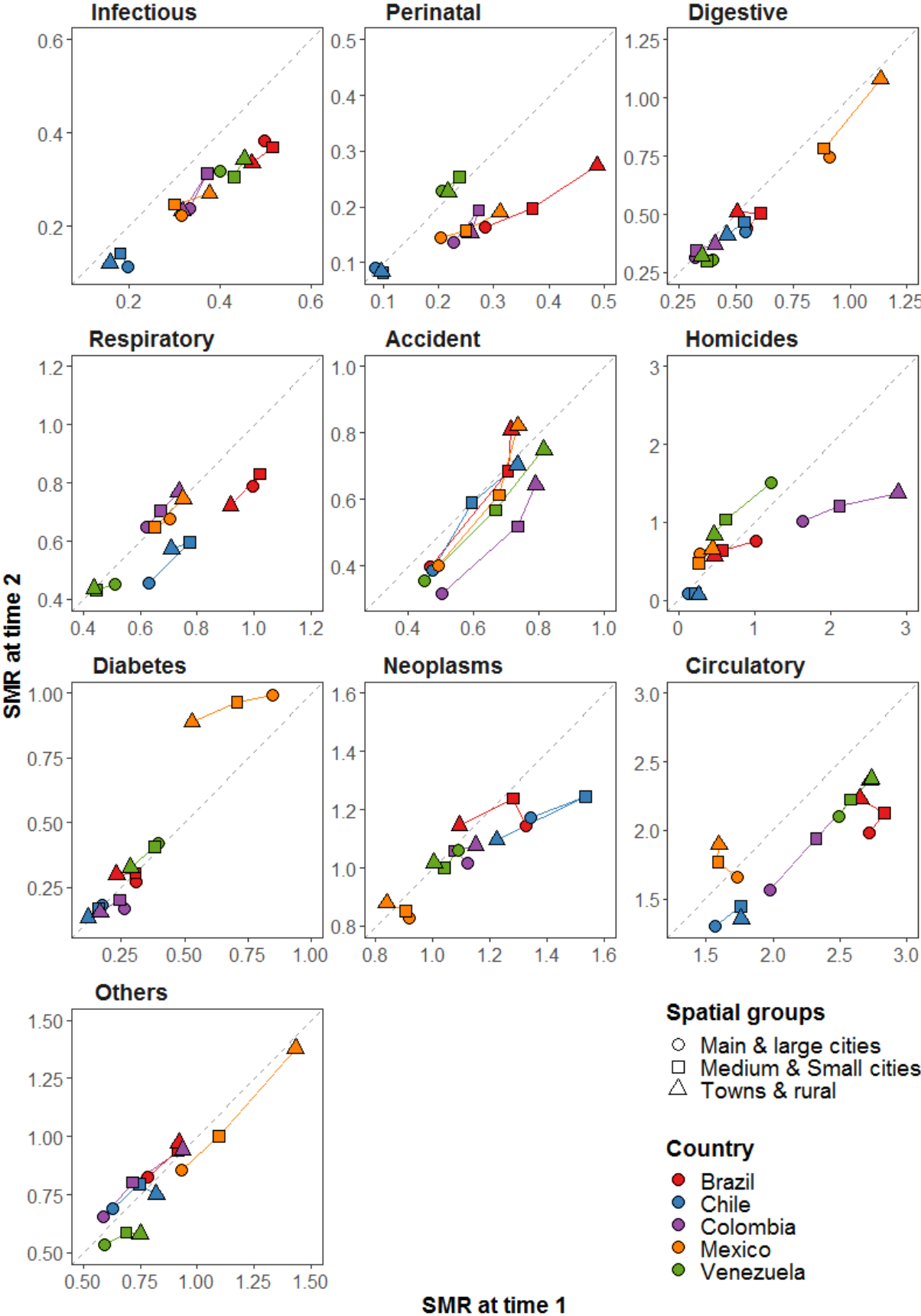
The group referred to as accident comprises deaths caused by traffic accidents and injuries, and it maintains the same sex differential as homicides. However, its trend differs by country. Mortality rates due to accidents remain stable in most countries for males, and it decrease only in Colombia. For females, it is in Chile where increasing rates are notorious at the end of the period.

In general, digestive and infectious diseases along with perinatal conditions follow the same trend in all countries by maintaining already low rates; and they continue to diminish during the period of analysis. Even though respiratory diseases decrease for most of the countries, they still show higher mortality rates than digestive and infectious diseases. It is only in Mexico and Colombia where respiratory disease rates are either stable or increasing during the period.

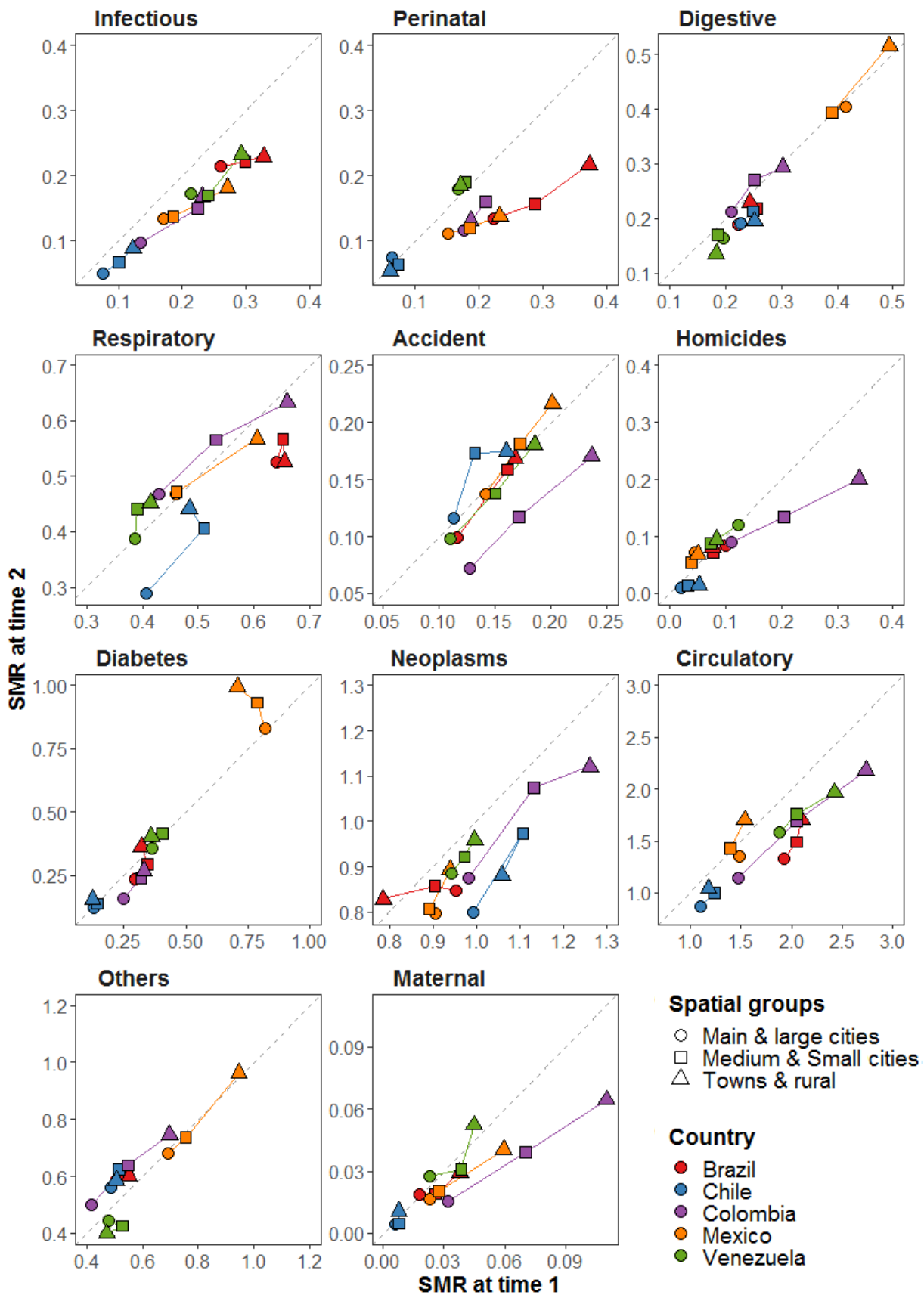
In terms of epidemiological profile, Venezuela, Colombia and Brazil show a cause-of-death structure in which circulatory diseases are predominant and in the process of decreasing. Chile has gone a step farther, with neoplasms increasing in its cause-of-death structure; and Mexico remains behind all countries as it retains a mixed profile in which communicable diseases continue to play an important role, as do circulatory diseases, diabetes and external causes.

In Figure 9.2 for males and 9.3 for females, scatter plots are used to show cause-of-death trends among spatial groups. Standardized rates of specific causes of death in the year 2000 (t1) lie on the x-axis while standardized rates in the year 2010 (t2) lie on the y-axis. A ten-year period of change is considered for all countries, and each estimate on the scatter plot represents a single subpopulation grouped by country (using a color scale), and spatial group (using shapes). The figures have different scales due to the different levels of mortality rates due to specific causes; however, the scaling is even among periods, which is why the diagonal in the figures divides increasing rates (above the dotted line) from decreasing rates (under the dotted line). Mortality associated with maternal conditions has been added to the analysis of female standardized mortality rates in Figure 9.3.

Figure 9.2 Male standardized mortality rates (per 1000 inhabitants) by specific cause of death at time 1 vs. SMR at time 2



**Figure 9.3 Female standardized mortality rates (per 1000 inhabitants) by specific cause of death at time 1 vs. SMR at time 2**



Progress is perceived in all countries when tracking the evolution of infectious and circulatory diseases among subpopulations and that of neoplasms among female subpopulations. Nonetheless, stagnation and increasing mortality are also recorded. Mortality differentials among spatial groups are also variable among countries at the beginning of the period. Differentials among spatial groups are more evident in Mexico and Colombia, where several causes of death seem to drive them. From all causes that explain the spatial differentials in these countries, circulatory diseases and accidents are the ones showing the highest impact on both sexes; whereas neoplasms, respiratory and digestive diseases mostly determine female differentials. In contrast, differentials among spatial groups in Chile and Venezuela are traceable to a few specific conditions. Differentials in Chilean subpopulations are mostly due to accidents and neoplasms for both sexes, and respiratory diseases only for males. In Venezuela, accidents for all sexes and neoplasms and circulatory diseases for females explain the spatial-group differentials. In Brazil, perinatal conditions, accidents (for males) and neoplasms (for females) are the causes of death that constitute differences among subpopulations at the beginning of the period.

At the end of the period, the advantage held by the main-and-large-cities group over the remaining subpopulations in the country is due to differences introduced by accidents, circulatory disease and neoplasms. It is only in Mexico where the main and large cities are still seeing improvements in perinatal conditions, other causes and – to a lesser extent – circulatory diseases. The main-and-large-cities group advantage is harmed only by the increase in diabetes among the male subpopulations in all countries and by that of homicides among males in Venezuela and Brazil.

In general, the lack of progress during the period is mostly due to diabetes spreading to all subpopulations (the worst outcomes being in Mexico) as well as upsurges in external causes (i.e., accidents and homicides) for specific subpopulations in all countries (except for Colombia). Respiratory diseases, neoplasms and perinatal conditions vary their patterns significantly according to each country without having much importance on overall mortality, while digestive diseases remain almost unchanged for Mexico. Finally, an unexpected stagnation in all subpopulations is seen in Venezuela and Chile for perinatal conditions. Stagnation may come from already achieving low mortality levels due to this condition.

Regarding mortality associated with maternal conditions, it is diminishing in the period for all subpopulations, although not in the main and large cities of Venezuela and Brazil, nor in the towns and rural areas of Venezuela and Chile. Maternal mortality adds to spatial differentials among subpopulation in Colombia and Mexico, even at the end of the period of analysis. In the remaining countries, the already low rates at the beginning of the period continue to act in favor of the main-and-large-cities group.

In summary, heterogeneity exists as a result of cause-of-death patterns introducing spatial differentials in these countries. In this sense, Chile and Mexico constitute similar cases while they are dissimilar to Venezuela, Brazil and Colombia, countries that are more alike in their own patterns. The most privileged country in terms of low mortality rates is Chile, where – with the exception of accidents – low rates have steadily fallen over time for a range of causes. On the other hand, the country with the most unfavorable conditions is Mexico,

where circulatory and digestive diseases as well as diabetes are increasing overall, but at an even higher intensity in the towns and rural areas.

### **9.1.2 Modal causes of death**

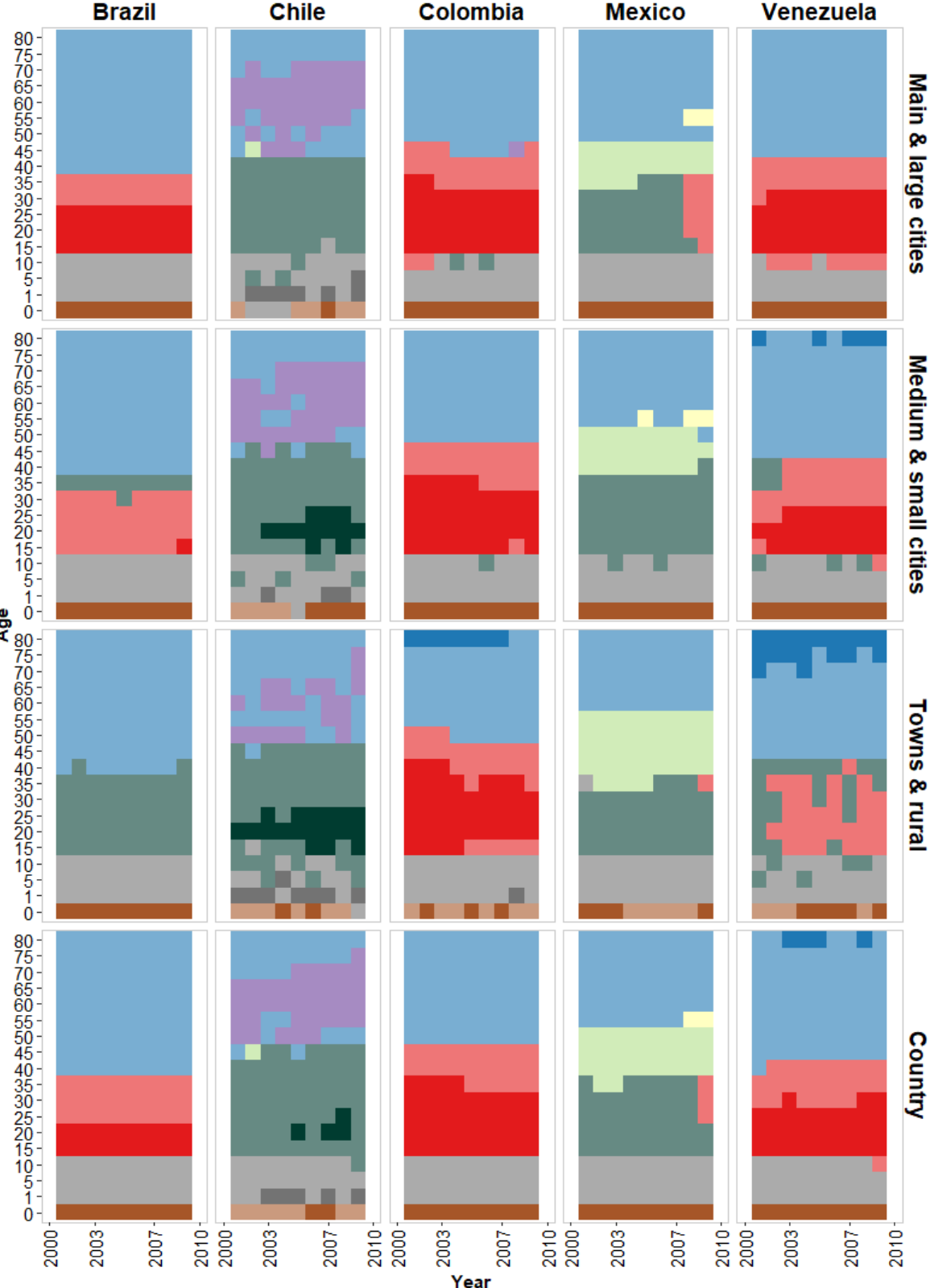
The modal cause of death refers to the predominant cause of death by age group and sex. Here, two aspects are addressed: the predominance itself of the causes, meaning that the cause responsible for the larger proportion of deaths within an age group is identified; and the range in which this cause predominates. In Figure 9.4 for males and Figure 9.5 for females, the level of a cause-of-death predominance is distinguished in less or more than 50 percent of deaths of each age group, sex group, spatial group and country.

Modal cause-of-death figures show that the first necessary distinction is among sexes. Circulatory disease is the identified modal cause-of-death at around 40 years of age and above in male subpopulations in all spatial groups and countries. It is only in Chilean males that neoplasm is the modal cause of death. In addition to circulatory diseases, external causes of death stand out as the modal cause of death for some age groups. Homicide is the main external cause of death affecting young adults in Colombia, Brazil and Venezuela. In Brazil and Venezuela, homicides are mainly urban phenomena, while deaths due to accidents and injuries are recurrent in towns and rural areas. In Colombia, homicides are extended to all subpopulations as the more common cause of death in male populations between 15 and 40 years old. It is only in Mexican male subpopulations that digestive diseases remain as the modal cause in adult mid-ages, around 35 to 55 years; while incipient diabetes emerges in the cities.

For their part, female subpopulations show a more diverse profile, with neoplasms having the same or even more predominance than circulatory disease. In Chile, circulatory diseases are the most common causes of death only in ages 70 years and above; whereas neoplasm is the most common cause of death among the age groups 30 to 70 years, regardless of the spatial group. A higher predominance of neoplasm is recorded for some age groups in the main and large cities, where it represents more than fifty percent of estimated deaths.

Brazil tells a particular story when analyzing its modal causes of death. A cohort effect is noted in all Brazilian females, with neoplasms representing the most common cause of death (populations in the main and large cities dying at 40–49 years old in 2000 to those dying at 50–59 years old in 2010; those in medium-sized and small cities from 30–39 years old in 2000 to 40–49 years old in 2010; and those in towns and rural areas from 30 years old in 2005 to 40 years old in 2010). Their predominance among other causes follows a gradient among spatial groups, and they are largely more predominant during the period of analysis in the main-and-large-cities group while less so in the towns-and-rural-areas group. What is more, Brazil is the only country where infectious diseases still play a role as the most common cause of death for females aged 25 to 30 years old at the beginning of the period in all cities, regardless of their size.

Figure 9.4 Male modal causes of death by age, spatial group and country

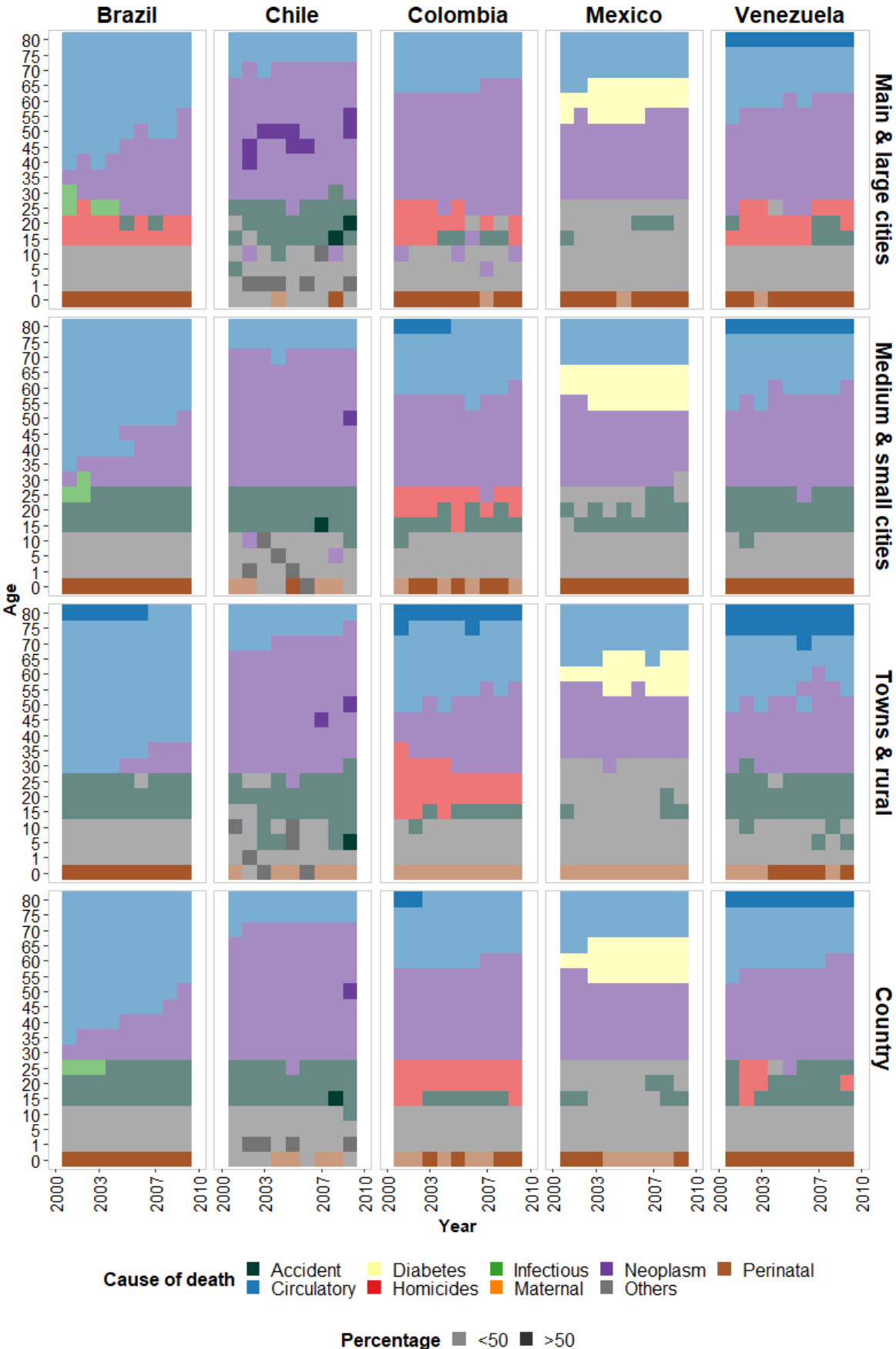


**Cause of death** ■ Accident ■ Diabetes ■ Homicides ■ Others  
 ■ Circulatory ■ Digestive ■ Neoplasm ■ Perinatal

**Percentage** ■ <50 ■ >50



Figure 9.5 Female modal causes of death by age, spatial group and country



Another particular case is – once again – Mexico, where diabetes is the modal cause of death for women aged 55 to 70 years in all subpopulations. Mexico is the only country where diabetes is known as the most common cause of death. Its appearance surpasses the predominance of neoplasms recorded in the other countries. In addition to the particular impact of diabetes, Mexican females have also an unusual pattern regarding external causes of death in comparison with the other countries. Mexican young women living in main and large cities as well as in towns in rural areas are less likely to have an external cause of death as the most predominant. Only young women living in medium-sized and small cities have traffic accidents and injuries as the most common causes of death for some ages and in certain years during the period.

With Mexico as the abovementioned exception, external causes of death are the modal cause of death among female subpopulation at young ages (15 to 30 years) in most subpopulations. Even when their presence spreads less across age groups than in male subpopulations, these causes of death follow the same age and spatial group patterns mentioned for male.

Brazil, Colombia and Venezuela are the only countries in which homicides are the most common causes of death for females aged 15 to 25 years. In Brazil and Venezuela, their predominance is found exclusively in the main and large cities; while in Colombia, they are spread across the whole country. For the 15-to-20-year age groups in all countries, homicides are either acknowledged as the most common causes of death or they have been replaced by accidents (traffic accident and injuries). This is the case for all female subpopulations in Chile and in the non-main and large cities in Brazil and Venezuela. For Chilean females living in towns and rural areas, accidents are spread across younger age groups (age 5 and above in some years), and they are beginning to emerge as the most common cause of death at age ten.

Differences among spatial groups in terms of causes of death indicate that the profiles of the medium-sized and small-cities groups maintain an intermediate state between the main-and-large-cities group and the towns and rural areas, combining the causes of death seen in both groups of cities. The next section presents a decomposition of cause-of-death contributions to spatial group differentials in life expectancy at birth.

## **9.2 Cause-of-death contribution to spatial-group differentials**

As mentioned in previous sections, there are some specific causes on which subpopulation differentials may rely. In order to keep track of spatial-group differentials, cause-of-death groups are reduced to diseases or conditions that have been identified as those that introduce differentials among spatial groups. Thus, the stepwise-replacement method has been used to decompose the contributions of five groups of causes to differences in life expectancy at birth among spatial groups and by country. The age distribution of the difference by each cause of death is estimated considering the medium-sized and small cities group as a reference. The five groups are circulatory diseases, neoplasms, external causes of death, diabetes and a group of causes that continue to be important in the differentials but still maintain considerably low rates in most of the sample countries, which include here digestive, respiratory and infectious diseases. The contributions of the five cause-of-death

groups is presented in the figures included in this section, and the contributions of specific causes of death within each group are included in Annex I.

Differences are presented as positive or negative contributions in years by age group. Years are scaled around zero, which represents no difference from the reference group. In this sense, values between -0.1 and 0.1 (in white) indicate that the cause of death has an insignificant contribution to spatial-group differential. Likewise, positive years indicate an advantage over the reference group (colored green to blue) and negative years indicate a disadvantage (colored in red).

### **9.2.1 Circulatory disease contribution to spatial-group differentials**

In general, the contributions of circulatory diseases are seen in all countries around ages 30 and above. It is also possible to say that circulatory diseases have broadly positive contributions to differences in life expectancy at birth, favoring the main-and-large-cities group, and negative contributions to towns and rural areas in comparison to the medium-sized-and-small-cities group. This is straightforward for females in most of the countries, but less precise for male subpopulations.

For females, a clear gradient of contributions is seen in Brazil, Colombia and Venezuela; the main and large cities do better than medium-sized and small cities, while towns and rural areas have a total disadvantage. Colombia is the extreme case in this group, where the gradient is wider than in any other country. In contrast, Mexico is the only country showing negative contributions to life-expectancy-at-birth differentials, due to circulatory diseases in the main and large cities at the beginning of the period. This negative contribution became positive as a result of improvements among Mexican females living in the main and large cities. Chilean females, for their part, break the gradient pattern, as the medium-sized and small cities are the ones that maintain a disadvantage, which is not so distant from towns and rural areas. One must keep in mind that Chile is also the country with less spatial-group differentials due to circulatory diseases (see Figure 9.3).

For male subpopulations, spatial-group differentials found in life expectancy at birth follow a clear gradient only for Colombia. In the remaining countries – except for Mexico – the advantage of the main and large cities continues; however, the towns-and-rural-areas disadvantage is diffuse. Trends found in circulatory diseases are mostly influenced by the evolution of heart diseases and stroke (see Annex I.1). Stroke contributions (Annex I.2 A and B) are more significant for females, whereas the contributions of heart diseases (Annex I.3 A and B) are traceable in both sexes. In fact, heart diseases are responsible for most of the differences in male life expectancy among the cities group, due to circulatory diseases.

Life expectancy at birth among the medium-sized-and-small-cities group and towns-and-rural-areas group has similar patterns in the absolute age contribution due to circulatory diseases. When compared with medium-sized and small cities, circulatory diseases have positive contributions to the differentials among males living in towns and rural areas around ages 45 to 70 years. At the same time, the contribution reverses below age 45 and at age 70 and over, with negative contributions of circulatory diseases being seen in towns and rural areas.

Figure 9.6 Contributions (in years) of circulatory diseases to differences in male life expectancy at birth among spatial groups (the medium-sized-and-small cities group is used as a reference).

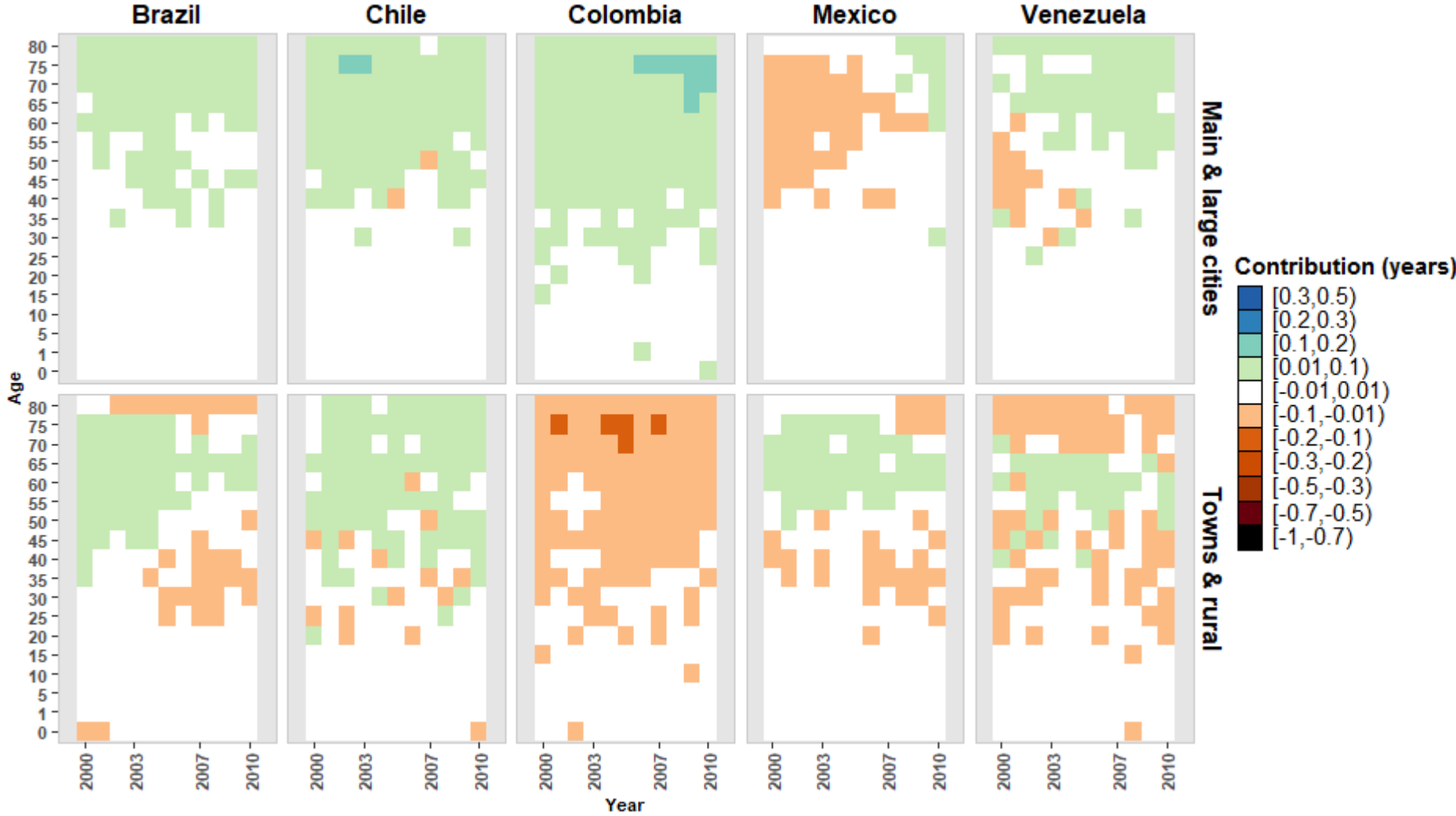
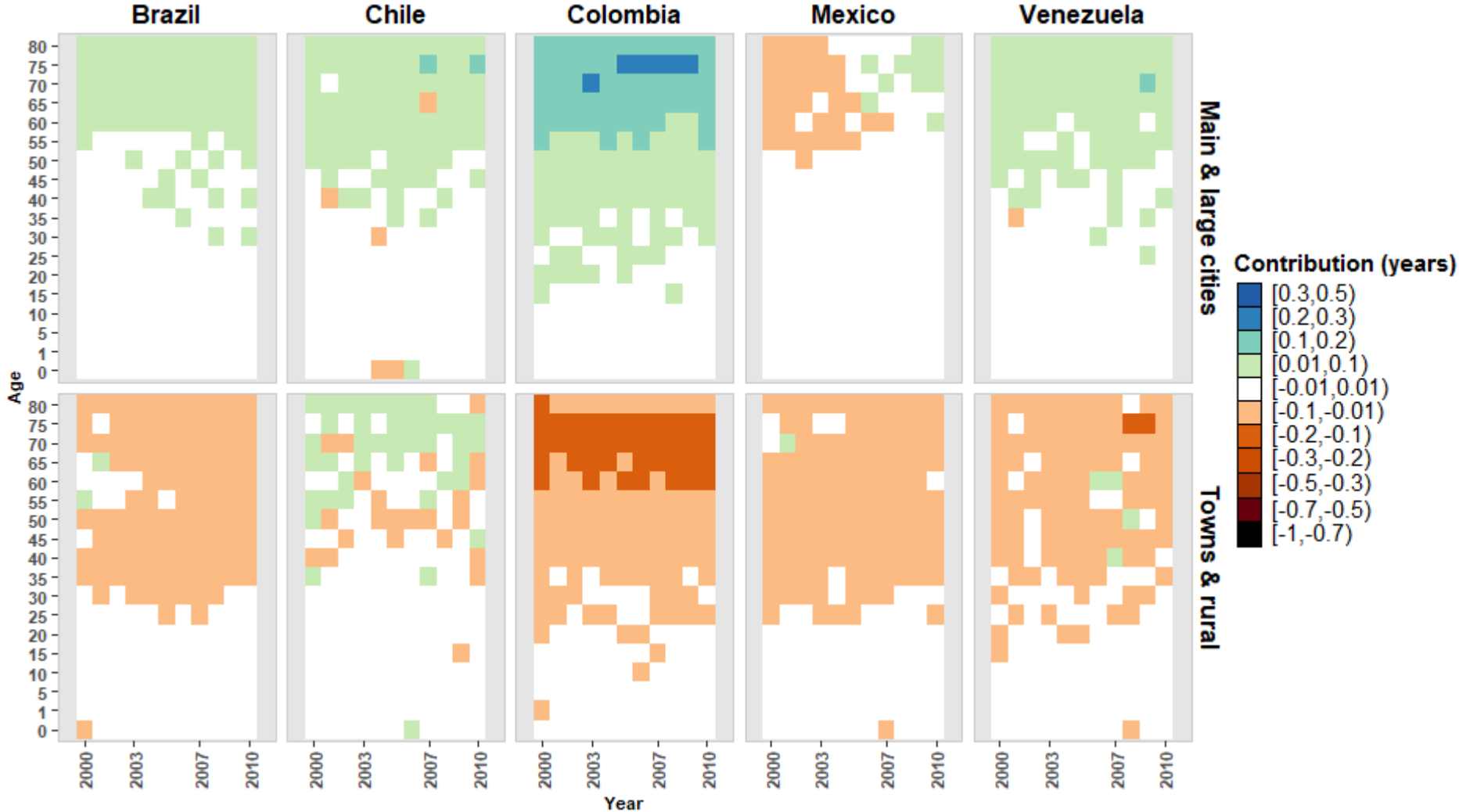


Figure 9.7 Contributions (in years) of circulatory diseases to differences in female life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).



In Chile, contributions to differences in male life expectancy at birth are distributed in a different manner. The disadvantage is found in the Chilean males living in medium-sized and small cities, especially for older adult populations; and no gradient is perceived in Chile regarding the contribution of circulatory diseases. Mexican male subpopulations also have a particular age contribution. Mexican males living in the main and large cities have mostly negative contributions to the difference in life expectancy at birth due to circulatory disease. As mentioned above, Mexico is the only country with increasing circulatory disease trends in most of its subpopulations. Thus, the positive contributions to differentials in life expectancy at birth among males in the main-and-large-cities at the end of the period results not from real improvements in the main and large cities, but from worsening conditions in the rest of the country.

### **9.2.2 Neoplasm contributions to spatial-group differentials**

There is no common (dis)advantage of a particular spatial group when analyzing the age contributions of all neoplasms combined to differences in life expectancy at birth (see Figure 9.8 and 9.9). In male subpopulations, positive and negative contributions at different ages are found in all countries – except for Chile – in both the main-and-large-cities and towns-and-rural-areas groups. It seems that medium-sized and small cities in Brazil, Chile and Mexico are in fact doing worse than their towns-and-rural-areas counterparts.

Mexico shows negative contribution to differentials at age 45 and under in towns and rural areas, as specific cohorts are affected when compared with medium-sized and small cities. In Venezuela, neoplasms have mostly negative contribution to the differentials in male life expectancy at birth in the main and large cities.

For females, it is only in Brazil where neoplasms mark a clear disadvantage for the main and large cities and an advantage for towns and rural areas. In Colombia, positive contributions at all ages are noted in the main and large cities while negative contributions due to neoplasms are seen in towns and rural areas. Chile, for its part, has the worst performance for neoplasms in the medium-sized and small cities. In Venezuela and Colombia, a combination of positive and negative contributions are seen in both groups, although the negative contributions in Venezuela are more common in towns and rural areas, while the positive contributions occur in the main and large cities.

When seen by specific neoplasm, the most common ones are in the respiratory and genital systems for males – except for Chile and Colombia, where neoplasms of the stomach maintain levels that are as high as respiratory and genital system neoplasms in all spatial groups. For females, the most common neoplasms are of the genital system (see Annex I.4).

All these mixed age-contributions to the spatial groups are due to different patterns of specific neoplasms. While, for females, neoplasms of the stomach and genital system act in favor of the main and large cities, breast neoplasms had a negative contribution in all countries (see Annexes I.5 to I.9). The same occurs with male life expectancy, neoplasms of the digestive system have negative contributions in all countries in the main and large cities, while stomach neoplasms have positive contributions.

Figure 9.8 Contributions (in years) of neoplasms to differences in male life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).

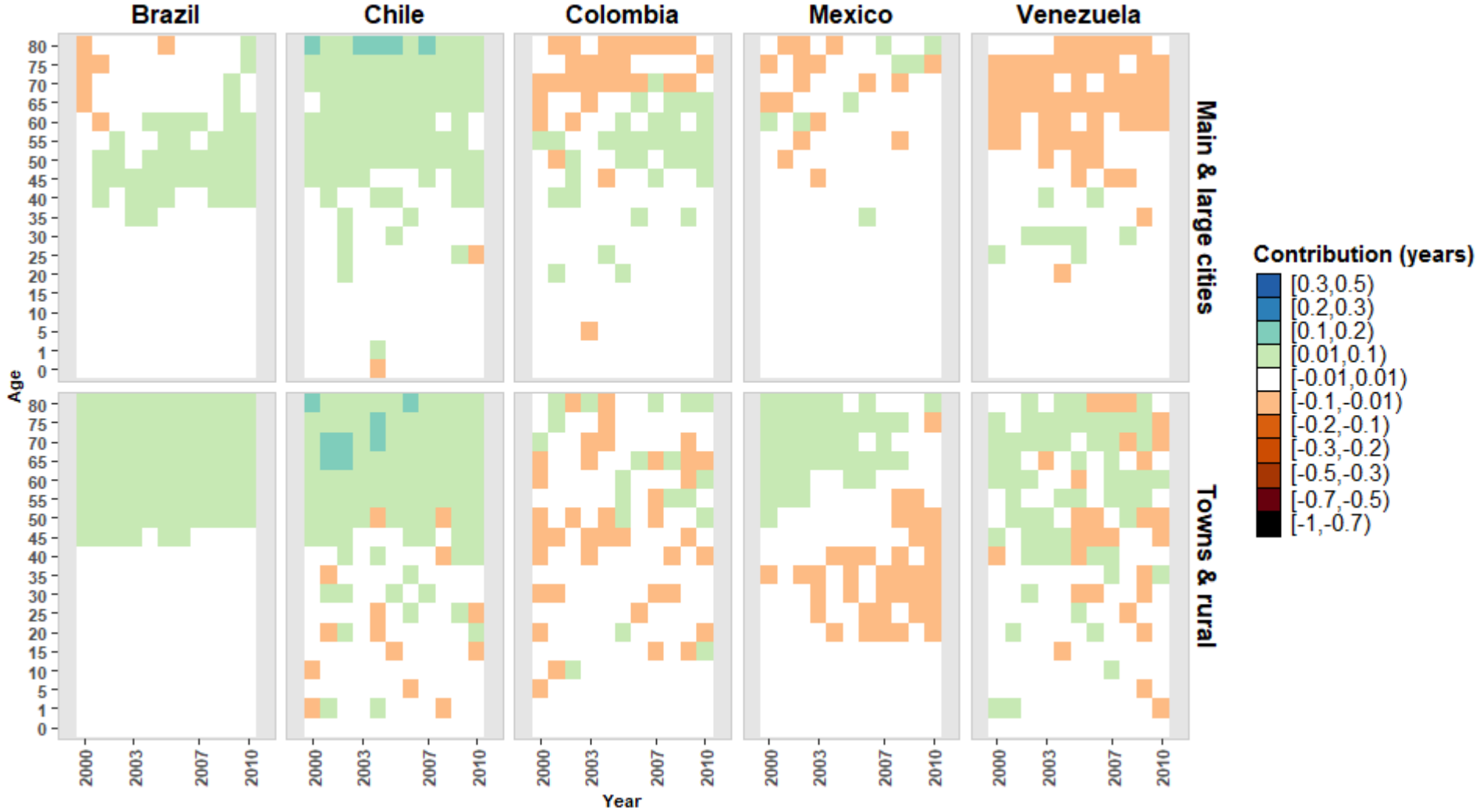
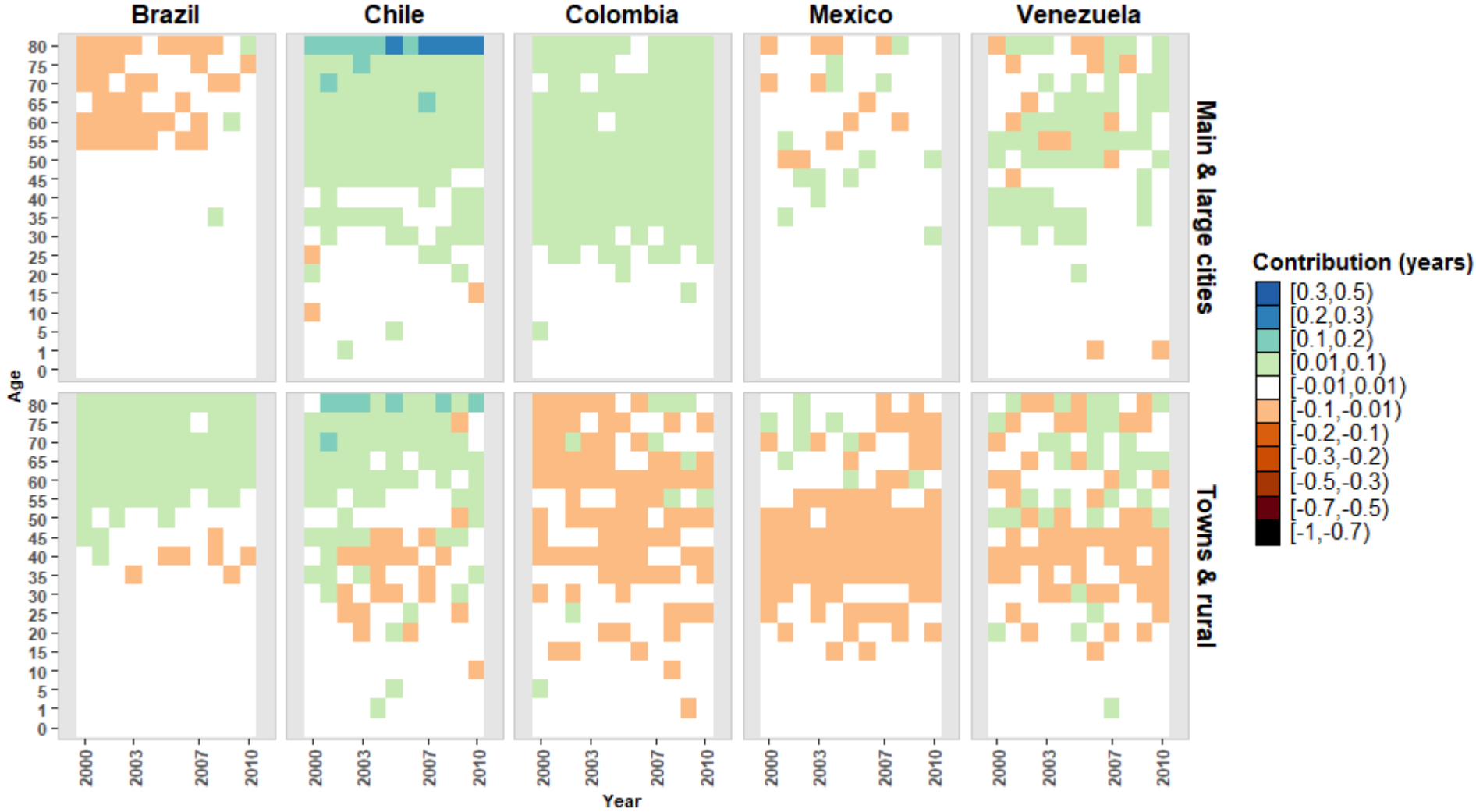


Figure 9.9 Contributions (in years) of neoplasms to differences in female life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).





### 9.2.3 Contribution of external causes to spatial-group differentials

The age contribution of external causes of death to spatial-group differentials in life expectancy at birth is displayed in Figures 9.10 (male) and 9.11 (female). As with neoplasm, the age contribution from external causes of death to the differentials in life expectancy at birth is the result of two opposing patterns combined: one is driven by transport accidents and injuries, which in all countries favor the main and large cities and contribute negatively to the difference in towns and rural areas; and the other is driven by homicides (see Annexes I.11 to I.13). A significantly less important position is occupied by suicides in the external cause-of-death distribution.

Homicide is the main external cause of death in Colombia for both sexes, and for males in Brazil and Venezuela (see Annex I.10), while transport accidents are the main external cause of death for females in most of the countries, as well as for males in Chile and Mexico. Homicides have negative contributions for all ages to the differences in life expectancy at birth in towns and rural areas for both sexes in Colombia and for males in Mexico. In Colombia, contributions are even higher (positive or negative) at ages 15 to 45 years for males.

For their part, males in Brazil and Venezuela are the only subpopulations whose contributions (negative or positive) at ages 15 to 30 are inversed to those made by any other age groups. This means that, for both countries, external causes of death among all ages except 15 to 30 show an advantage in the main and large cities and a disadvantage in towns and rural areas. It is only at ages 15 to 30 that the contribution to differentials is negative for the main and large cities and positive for towns and rural areas. Homicides are highly concentrated in these age groups in the main and large cities, with violence being a phenomenon deeply rooted in the urban slums. This concentration of violent deaths makes non-city territories comparatively more advantageous. Chile, the country least affected by homicides, maintains the same pattern of having an advantage in the main and large cities and a disadvantage in towns and rural areas. In the Chilean case, injuries constitute the main driver of the differential and, to a lesser extent, transport accidents for both sexes.

There is a similar pattern in how specific external causes contribute to differences in life expectancy for both sexes, and the country pattern seems to be more important in this sense. Males are undoubtedly more affected than females, thus differences among sexes are related to the intensity of the contributions in years, although they correspond to the age contributions to spatial-group differentials. When all external causes of death are considered, sex patterns are different due to the opposite trends of homicides and traffic accidents, and violent death has the least impact on female subpopulations.

Figure 9.10 Contributions (in years) of external causes of death to differences in male life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).

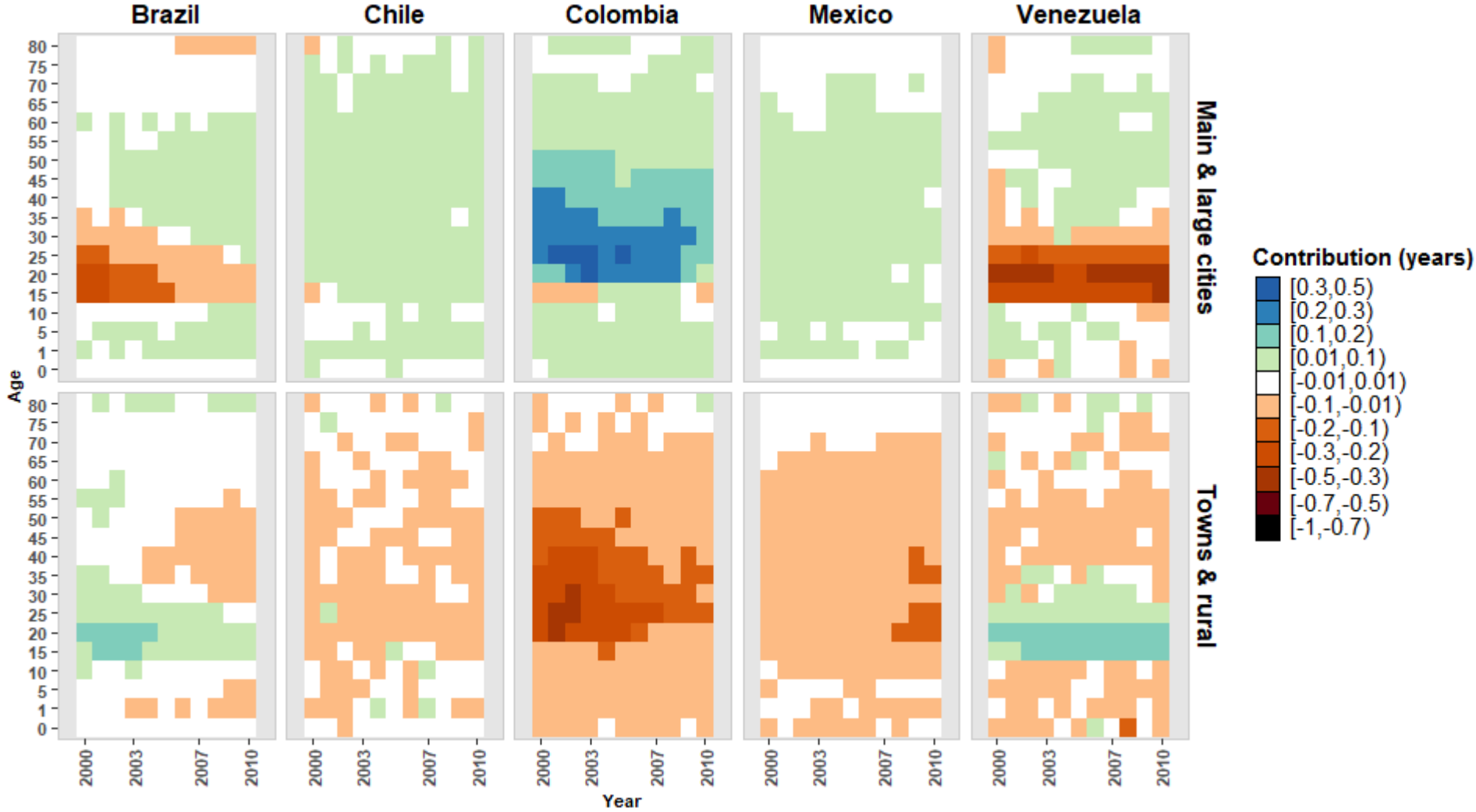
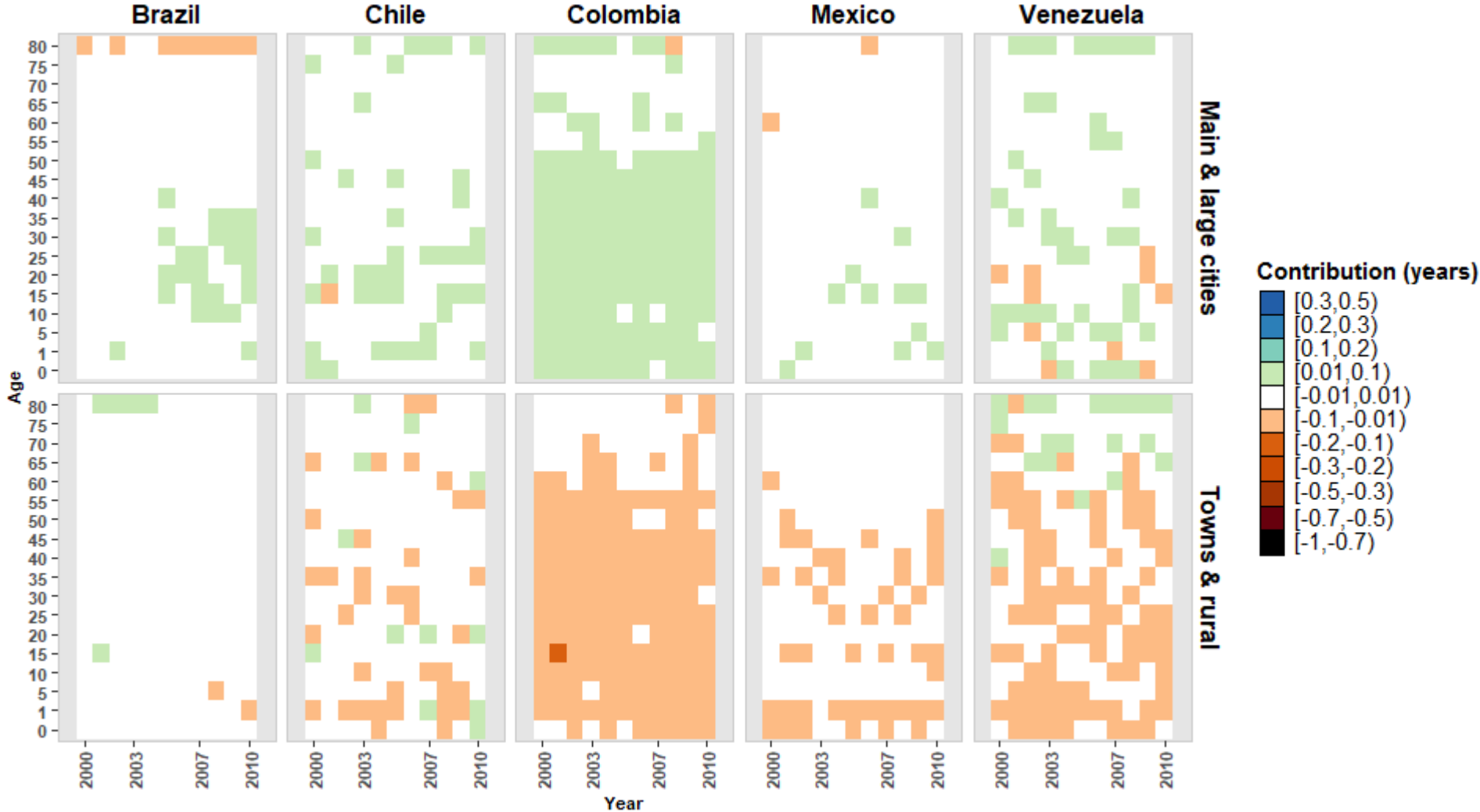


Figure 9.11 Contributions (in years) of external causes of death to differences in female life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).



#### **9.2.4 Contribution of diabetes to spatial-group differentials**

During the period of analysis, diabetes is not a widespread cause of death among the countries. It is only in Mexico where the diabetes mortality rate is higher than respiratory diseases for both sexes (see Annex I.14). After Mexico, Venezuela is the second highest country in terms of mortality rates due to diabetes. Figures 9.12 (males) and 9.13 (females) display the age contributions of diabetes to spatial-group differentials in life expectancy at birth. Diabetes has a contrary effect on spatial-group differences according to sex. For males, diabetes has mostly negative contributions in men living in the main and large cities and positive contributions in males living in towns and rural areas. For females, diabetes has mostly positive contributions for main and large cities, while a combination of positive and negative contributions occurs in towns and rural areas.

Males in Brazil and females in Chile seem to be equally affected by diabetes, regardless of whether they live in the main and large cities or towns and rural areas. In both cases, medium-sized and small cities are worse off than the rest of the country due to diabetes. Diabetes in Mexico represents an unusual case among the countries: cohorts are more affected in towns and rural areas, whereas an opposite effect is recorded only for females in the main and large cities. This same pattern of more affected cohorts in towns and rural areas is also observed for the age contribution of circulatory diseases and neoplasms to spatial-group differentials in life expectancy at birth.

#### **9.2.5 Contribution of infectious, digestive, and respiratory diseases to spatial-group differentials**

In Figures 9.14 (males) and 9.15 (females) are presented the age contributions of infectious, digestive, and respiratory (I.D. & R.) diseases to spatial-group differentials in life expectancy at birth. In general, for males, these diseases contribute positively to the main-and-large cities advantage in life expectancy when compared with other spatial groups. The only exception is Venezuela, where I.D. & R. age contributions to spatial-group differentials in life expectancy at birth are mostly negative in the main-and-large-cities group.

The disadvantage of towns and rural areas is prevalent at infant ages and more diffuse regarding adult mortality. In Brazil and Chile, medium-sized and small cities have worse performance than any other spatial group regarding I.D. & R. diseases. In contrast, in Mexico, this spatial group seems to be the one with positive age contributions to the differentials, because both the main-and-large-cities group and towns-and-rural-areas group show negative contributions from I.D. & R. diseases. Town and rural areas in Colombia, for their part, display both positive and negative contributions, depending on the age. At young adult ages, it is positive, and then becomes negative at older adult ages. Likewise, in Venezuela, the disadvantage of the towns and rural areas extends to the population at ages 40 and below, then the contributions become positive above this age limit.

Figure 9.12 Contributions (in years) of diabetes to differences in male life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).

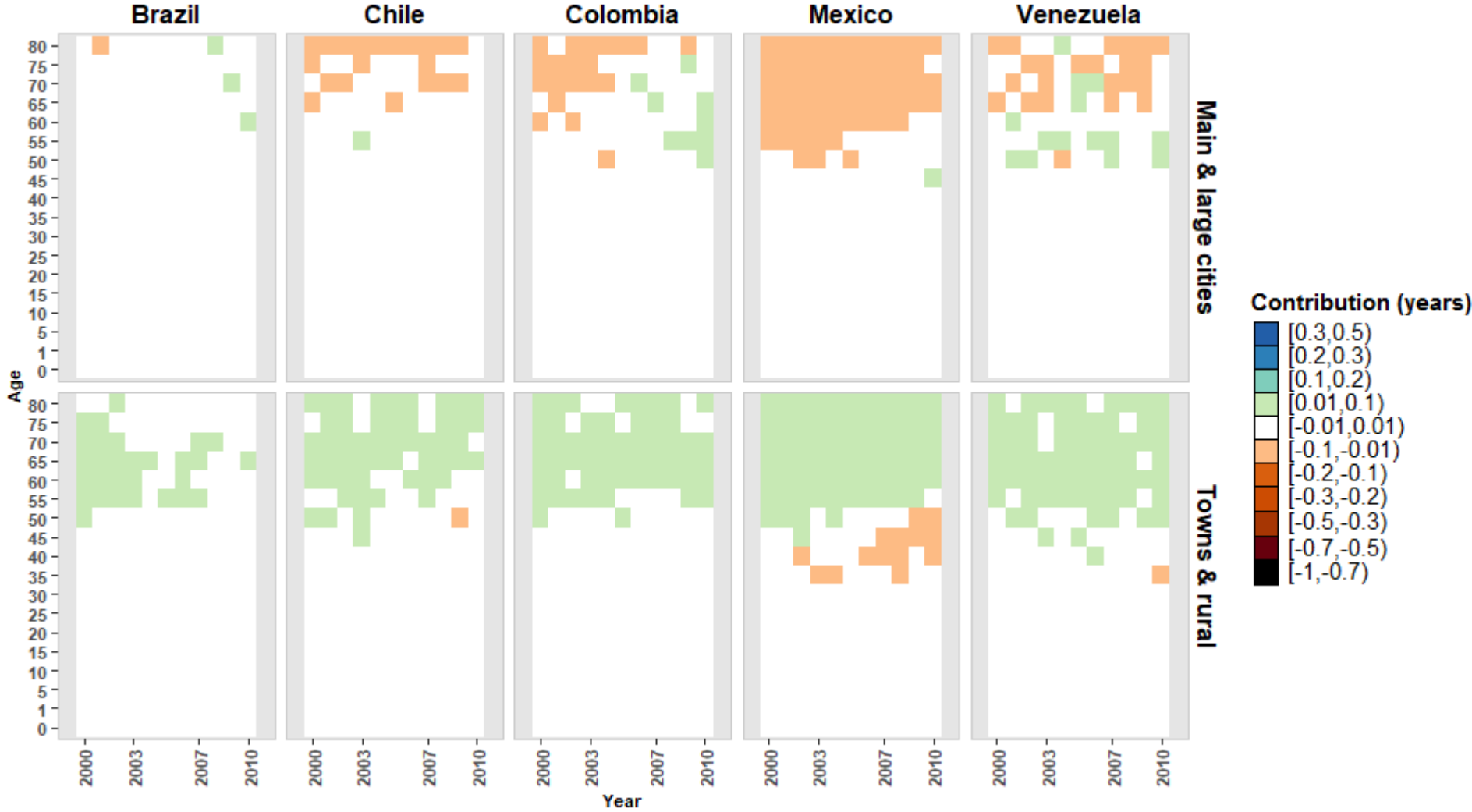
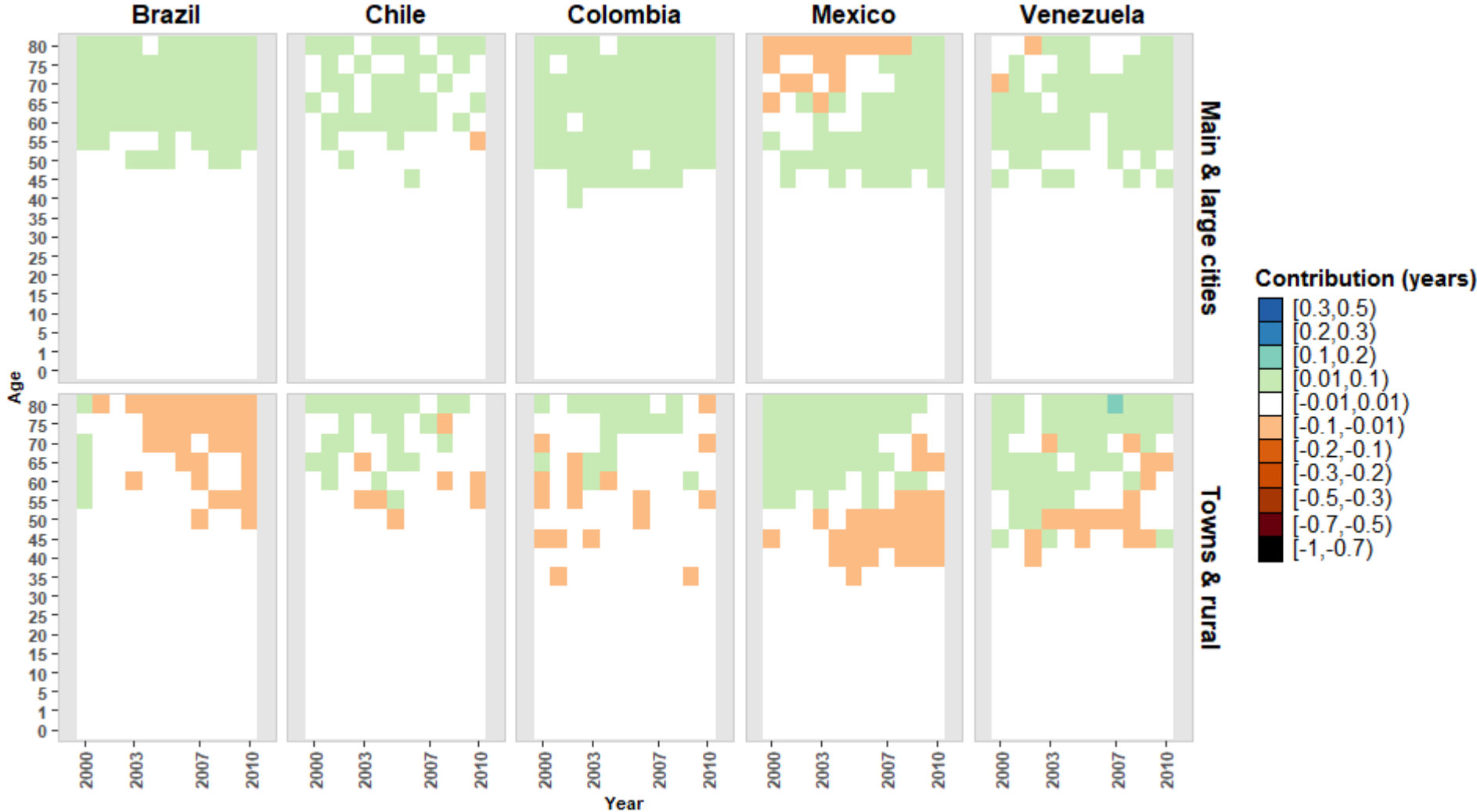


Figure 9.13 Contributions (in years) of diabetes to differences in female life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).



For females, I.D. & R. diseases contribute to spatial-group differentials in childhood ages under 5 years old and at adult ages. In general, they have positive contributions in favor of the main-and-large-cities groups for all countries except Mexico, where the population aged 60 and above has negative contributions to the spatial-group differential. In towns and rural areas, I.D. & R. diseases contribute negatively at most ages in most of the countries. It is only in Brazil where a clear advantage of females age 55 and over is seen. Older adult females in Brazil have a worse performance in regard to I.D. & R. diseases as causes of death when living in medium-sized and small cities than they do in other spatial groups

Regarding specific causes of death among I.D. & R. diseases, respiratory diseases are the ones with the highest rates among males in Venezuela, Brazil and Colombia. In Chile and Mexico, respiratory diseases also have the same rates as digestive diseases, depending on the spatial group (see Annex I.14); and infectious diseases are the lowest of all three diseases for all countries. For female subpopulations, respiratory diseases have the highest mortality rates for all countries but Mexico, where respiratory and digestive diseases have almost equal rates. In Venezuela, respiratory diseases contribute negatively to the main and large cities, while the towns and rural areas in Colombia are where respiratory diseases contribute to a disadvantage.

Among specific digestive diseases, liver diseases affect male and female subpopulations the most (see Annex I.15), especially in Mexico and Chile. Liver diseases alone have positive contributions to Mexican males living in main and large cities in comparison to other male subpopulations (see Annex I.16A and I.16B). Considering infectious diseases in ages below five years old, a consensus exists among countries in that positive contributions exist for the main and large cities and negative contributions for towns and rural areas; only Chilean females living in the medium-sized and small cities experience a disadvantage compared with other spatial groups when considering digestive diseases alone.

In summary, the advantage of the main-and-large-cities group in mortality is driven mostly by differences introduced by heart disease mortality, injuries and traffic accidents. In this sense, the advantage of the main and large cities over the remaining spatial groups exceeds the difference between the medium-sized and small cities and the towns and rural areas. These two groups share most of the disadvantage in mortality. Respiratory, digestive, and infectious diseases as well as some types of neoplasms such as those of the stomach and genitals also contribute to the main-and-large-cities advantage.

Negative contributions found in the main and large cities depend on sex and country, and they are in no way generalizable. Diabetes and neoplasms of the digestive system, for example, act negatively for males living in the main and large cities but positively for females when comparing them to other spatial groups. The same happens with homicides: it is only in Brazil and Venezuela that homicides have a largely negative impact on the main and large cities; whereas in Colombia and Mexico, the towns and rural areas are the most affected group. The next section uses specific attributable causes of death to decompose the age contribution to changes in life expectancy at birth experienced by each spatial group during the period 2000 to 2010.

Figure 9.14 Contributions (in years) of infectious, digestive and respiratory diseases to differences in male life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).

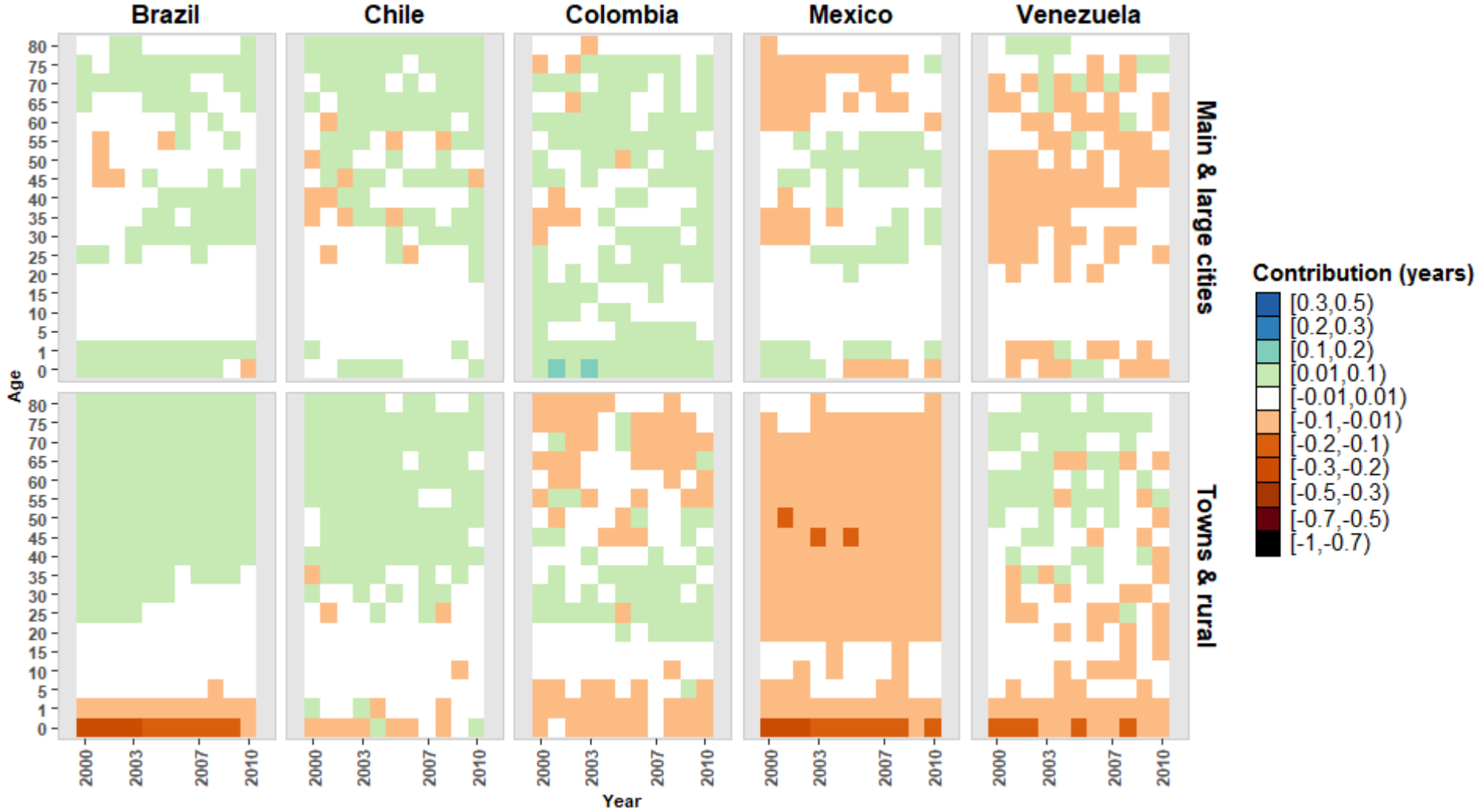
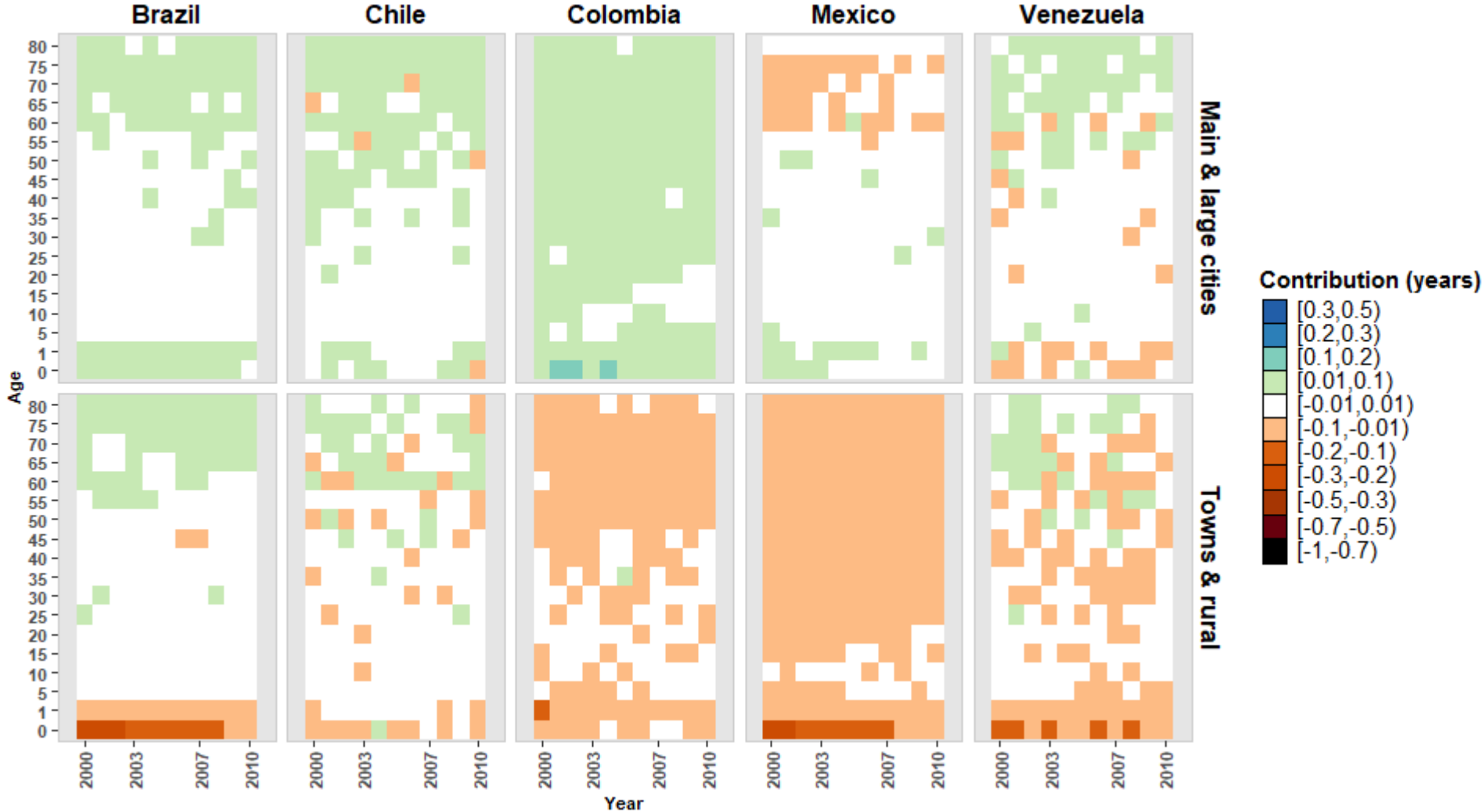




Figure 9.15 Contributions (in years) of infectious, digestive and respiratory diseases to differences in female life expectancy at birth among spatial groups (the medium-sized-and-small-cities group is used as a reference).



### 9.3 Cause-of-death contribution to changes in life expectancy

The contributions of causes of death to changes in life expectancy at birth between the years 2000 to 2010 are decomposed here using the stepwise replacement decomposition method. Five groups of causes of death are considered according to their importance in the spatial-group differentials. These are: circulatory diseases; neoplasms; external causes (homicides, traffic accidents and other accidents, all together); I.D. & R., which includes infectious, digestive and respiratory diseases; and one last group of other causes that includes diabetes (see Figure 9.16 for males and Figure 9.17 for females). All scales are similar except for external causes of death.

During the 2000 to 2010 period of analysis in all countries except for Mexico, changes in life expectancy are driven by decreasing circulatory diseases at adult ages and decreasing I.D. & R. and other diseases in children. Most of the years gained in life expectancy resulting from circulatory diseases are concentrated in ages 60 and above. Only in Colombia do gains still occur between ages 30 to 70 years.

In Brazil, changes in circulatory disease mortality increase the previous advantage of the main cities, leaving the towns and rural areas behind, which already have the highest mortality rates due to circulatory diseases at the beginning of the period. Towns and rural areas in Brazil are also the spatial group in the country that are most affected by external causes of death during the period. For this group, improvements in life expectancy are still based on decreasing infant mortality. In addition to what has been previously described for this country, Brazilian women also experience a loss of years at age 80 and over due to other causes, mostly diabetes, especially among those living in towns and rural areas.

In Chile, progress in life expectancy is driven by the reduction in circulatory diseases. This cause-of-death trend is the one that leads to convergence in the subpopulations, while the performance achieved in reduced neoplasms during the period maintains the initial advantage of the main and large cities. Medium-sized and small cities in Chile are lagging in their expected mortality reduction when compared with the gradient found at the beginning of the period. The towns and rural areas catch up with this spatial group, mainly due to the lack of reduction in neoplasms at age 80 and over, a group that is more affected by diabetes. In addition, the reduction in digestive diseases has been less efficient.

Colombia, for its part, is experiencing contributions of all ages to increasing life expectancy during the period, but with less progress in ages 80 and over in both sexes. Adult mortality improves mostly from the reduction in homicides at young adult ages and from the reduction in circulatory diseases at ages 50 to 70 years. Circulatory diseases contribute to maintaining the spatial-group differential in mortality as a gradient of urbanization.

Other causes and the I.D. & R. cause-of-death group are those that lead to convergence between the subpopulations due to their negative impact on the main and large cities. Adults living in towns and rural areas in Colombia scarcely improve by any causes other than decreasing external causes. Other than external causes, the progress observed in towns and rural areas relies on infant mortality reductions and some small gains in female young adult mortality due to circulatory diseases.

Figure 9.16 Age contributions (in years) to changes in male life expectancy at birth by cause of death, 2000 to 2010

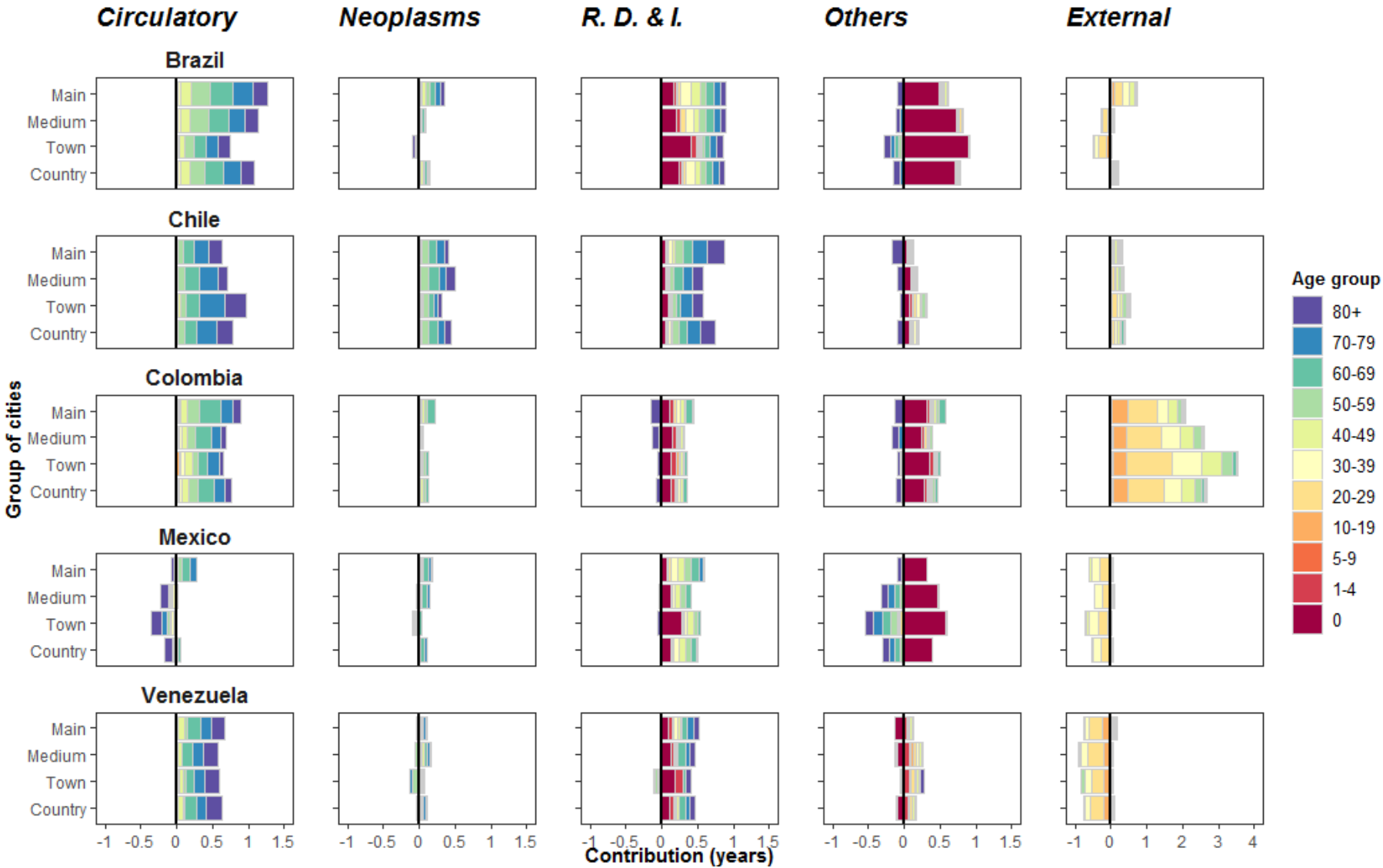
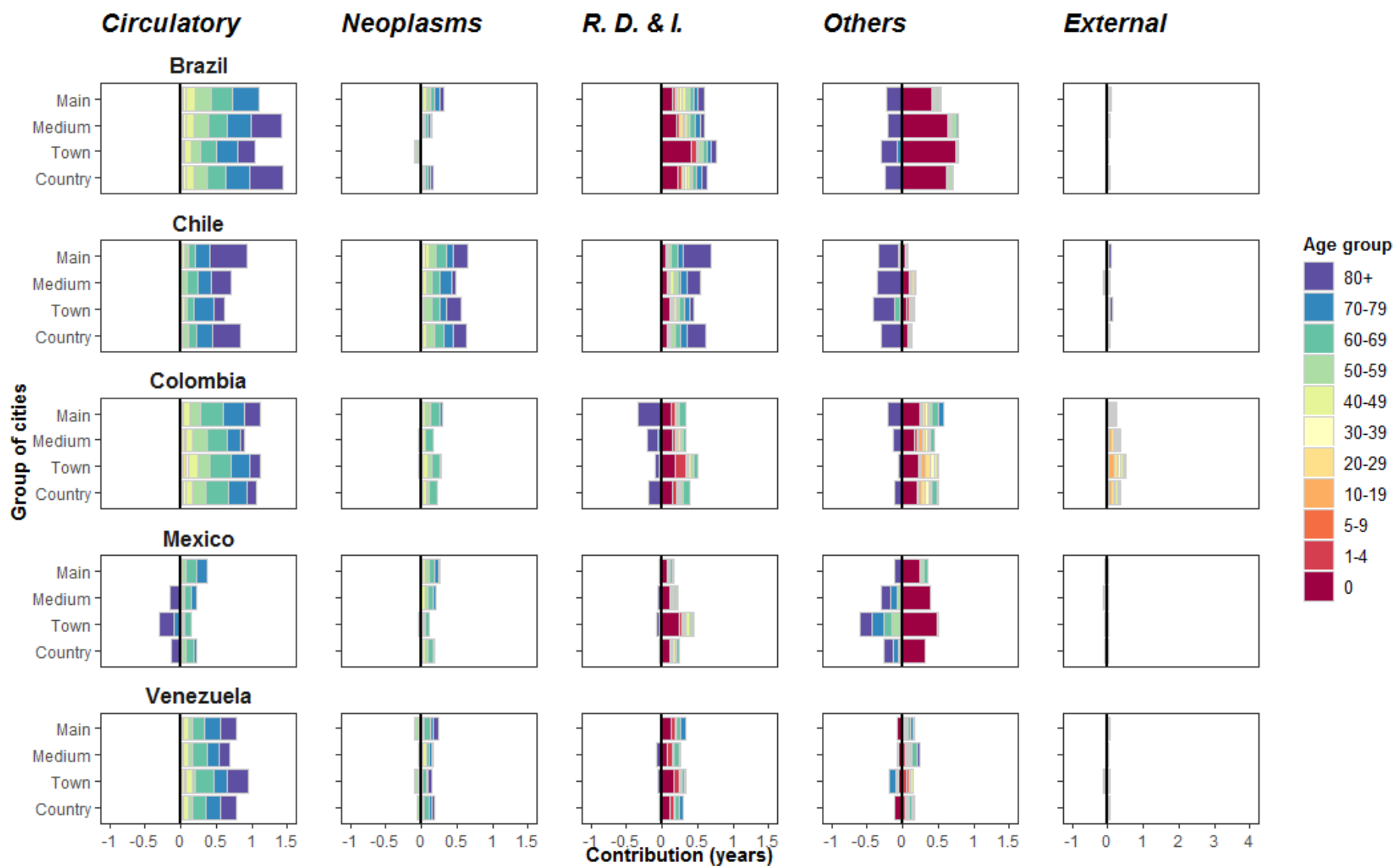


Figure 9.16 Age contributions (in years) to changes in female life expectancy at birth by cause of death, 2000 to 2010



Mexico represents the country that has seen the least progress in the period of analysis, and the only one that is losing years of life expectancy at birth due to increasing circulatory diseases and other causes at old adult ages, particularly in towns and rural areas. An incipient reduction in circulatory diseases is recorded in the main-and-large-cities group for both sexes, but only in ages 40 to 70 years. There are almost no improvements related to neoplasms during this period in Mexico, and its progress relies on infant mortality reduction due to other causes (mostly perinatal conditions). In Mexico, the other cause-of-death group is led by diabetes. Diabetes affected the sexes differentially during the period: for women, it remains at the same levels as at the beginning of the period; while for men, especially those above 40 years of age, it increases. Even more, losses in male life expectancy have made almost no progress in adult mortality and are also explained by increasing external causes of death for men ages 20 to 40 years all over the country. Towns and rural areas in Mexico represent the subpopulation with the worst performance in the sample, and its unsuccessful performance in the period contributes to an increase in the previous spatial-group differential.

Lastly, Venezuela shows consistent progress as a result of circulatory diseases in all its subpopulations at ages 50 and over. A decrease in circulatory diseases is the only positive factor in the life expectancy trend of Venezuela. The reduction in these causes of death is even higher during the period in the main and large cities, which already held the lowest mortality rates at the beginning of the period. This means that a reduction in circulatory diseases contributes to the divergence among the subpopulations for both sexes.

Neoplasms and other causes of death hardly influence changes in Venezuela's life expectancy at birth during the period. Gains to life expectancy are added only by minor improvements in the I.D. & R. group, mostly among infants. In contrast, the negative impact of external causes of death leads to losses in male subpopulations aged 10 to 40 years. In this way, stagnation seen in male life expectancy during the period is explained by losses due to homicides and equally high gains due to circulatory diseases.

In general, gains in life expectancy at birth due to the contribution of age 80 and over during the period come mostly from circulatory disease reduction. It is only in Chile that reductions in the respiratory, digestive and infectious diseases group add gains to life expectancy at birth. Female young adult (less than 30 years) mortality is the neglected age group in all countries, and only some minor improvements are recorded for Brazil and Colombia.

A key element that explains how changes occur in the period is the gradual (either negative or positive) impact on subpopulations according to their urbanization. Improvements and losses happen in a gradient among all spatial groups. All Brazilian subpopulations improve, and the highest improvements are seen in the main and large cities, similarly to the way that Mexican subpopulations in towns and rural areas are worse off than the rest of the country.

#### **9.4 Amenability of causes of death by city group**

As established in the literature, the contribution of health care may play an important role in the Latin American mortality decline. The biggest increases in life expectancy at national levels occurred in parallel with the expansion of the health care system and the urbanization process. Here, causes of death amenable to medical/health care are analyzed in the context of the

urban gradient, with a focus on the role played by public health interventions in spatial-group mortality differentials.

In order to study the amenability of cause of death, amenable and non-amenable deaths are first distinguished from each other. Then, the amenable group is divided into four sub-groups according to the level of intervention required to avoid the occurrence of death (as explained in Section 7.4.2). These are primary, secondary, and tertiary interventions, followed by a last group of causes of death that would have required a combination of measures and/or interventions in order to avoid death. Homicides have been excluded from these groups because, as seen in previous sections of this chapter, they intensely affect specific subpopulations, which have already been named throughout this chapter. Including homicides as amenable causes would hide the possible impact of other specific amenable causes in the subpopulations most affected by homicides.

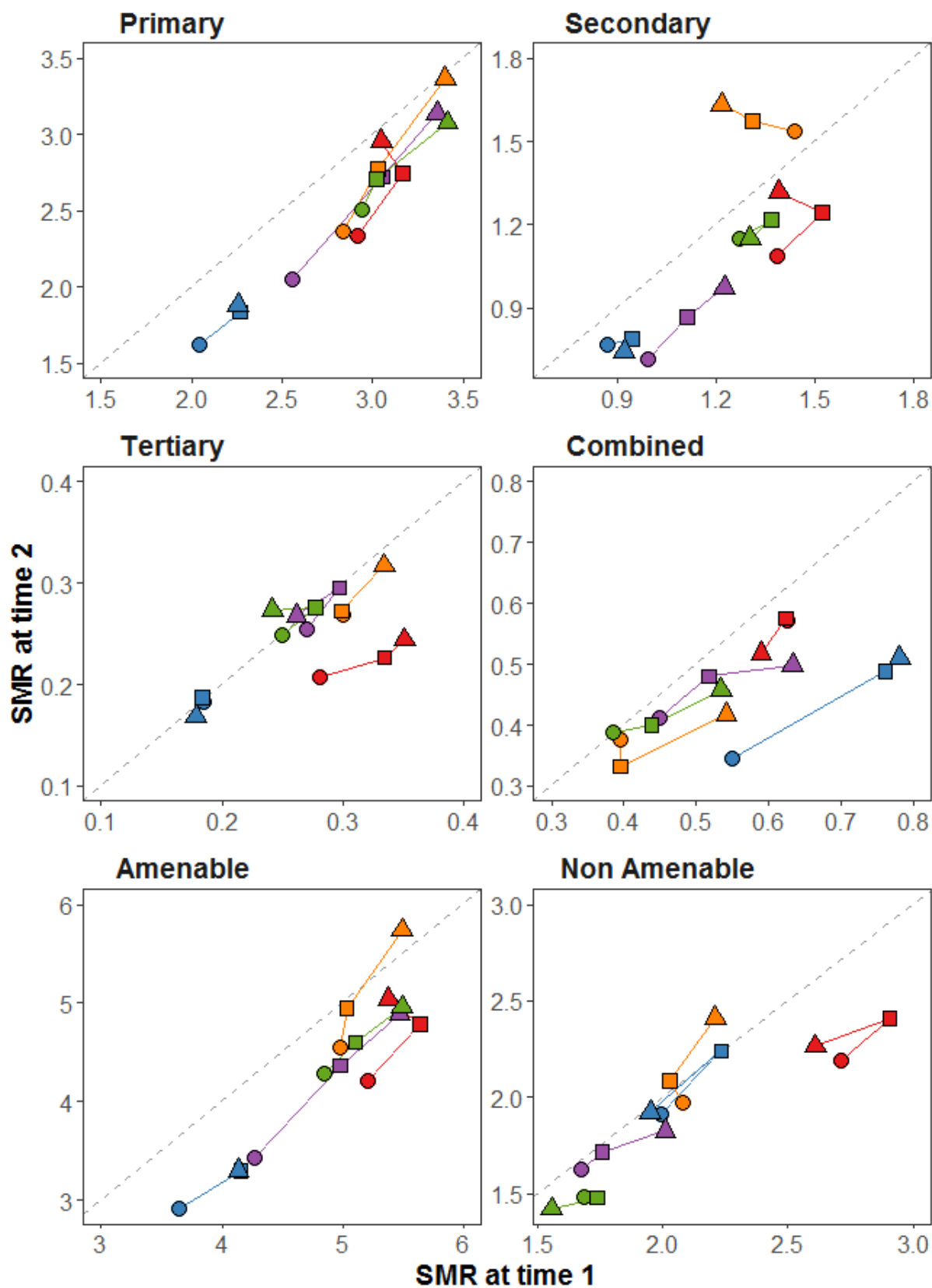
Standardized mortality rates by their amenability are indicated in Figures 9.18 (males) and 9.19 (females). On the x-axis are rates at the initial time ( $t_1$ ) corresponding to the year 2000; and on the y-axis are the rates at the final time ( $t_2$ ) corresponding to the year 2010. Axis scales are symmetrical, but different scales are used in each category. The goal here is to make it easy to perceive a subpopulation's progress by causes of death. Thus, the diagonal (dotted line) represents the limit that divides increasing rates (above) from decreasing rates (below) during the period. Countries are distinguished by colors and groups of cities by shape.

What stands out first is that there are important sex differentials in the way amenable causes are distributed in all countries. For males, causes amenable to primary interventions occur at twice the rate as causes amenable to secondary interventions, and they are nearly the same as non-amenable causes in all countries. In contrast, the distribution of female subpopulations is in general more even than the rates of these three groups. Mortality rates by causes amenable to primary intervention are the causes with the highest decrease for all countries in the period, and they are the only one in which all subpopulations improve. Mexicans living outside the main and large cities are the only ones with an unsuccessful performance in this category.

For their part, causes of death amenable to secondary and combined interventions also decrease during the period, but not at the same level as those that are sensitive to primary interventions and not in all subpopulations. In Colombian subpopulations, mortality by causes that are sensitive to secondary intervention largely decreases while, in Chile, this is more the case for mortality due to causes that are amenable to combined interventions.

At the same time, mortality rates due to causes that are amenable to secondary interventions are considerably increasing in all Mexican subpopulations, even more so in towns and rural areas. What is more, in the main Venezuelan and Mexican cities, rates of causes amenable to combined interventions are increasing. Causes amenable to tertiary interventions remain stable or increase in most of the countries, and only the Brazilian subpopulations decrease their mortality rate in the same period for this category. Similarly, a notable decrease in non-amenable causes of death is recorded in Brazil, whereas the other countries remain stable or increase their rates in most of the subpopulations. In general, Chile is the country with the lowest rate of amenable causes, particularly those that are amenable to primary interventions.

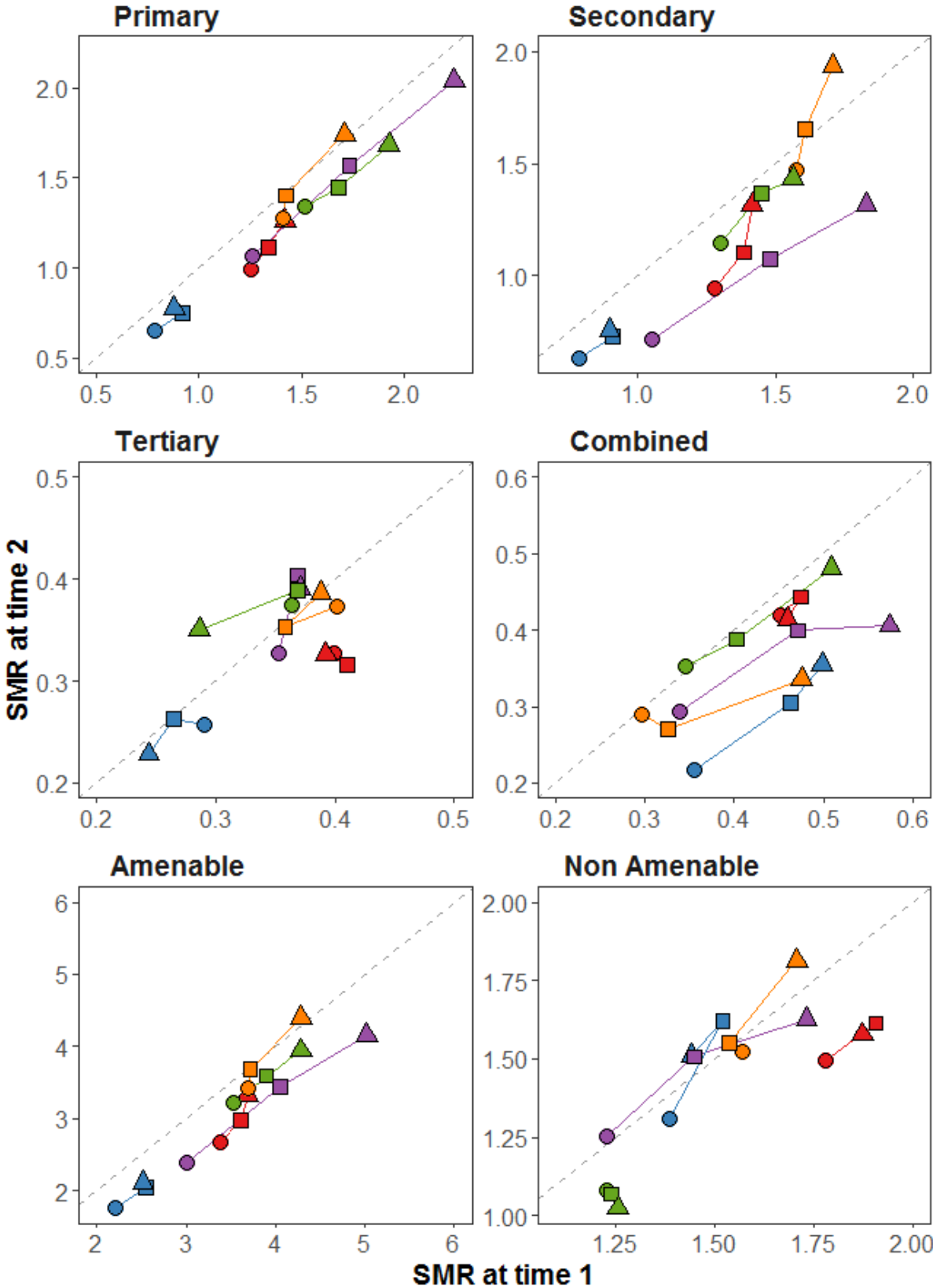
Figure 9.17 Male standardized mortality rates by cause-of-death amenability, 2000 vs. 2010



Spatial groups ○ Main & large cities □ Medium & small cities △ Towns & rural

Country ● Brazil ● Chile ● Colombia ● Mexico ● Venezuela

Figure 9.18 Female standardized mortality rates by cause-of-death amenability, 2000 vs. 2010



Spatial groups ○ Main & large cities □ Medium & small cities △ Towns & rural

Country ● Brazil ● Chile ● Colombia ● Mexico ● Venezuela



Causes of death amenable to primary intervention (for males) and a combination of primary and secondary interventions (for females) exhibit a clear gradient between the different spatial groups. It is in the main and large cities of all countries that mortality rates amenable to primary interventions achieve the lowest rates. What is more, the advantage for some countries such as Chile and Colombia exists only for the main and large cities; while in Brazil, Mexico and Venezuela, the advantage introduced by lower mortality rates due to primary interventions spreads across all cities and, to a lesser extent, reaches the towns and rural areas. Causes amenable to tertiary interventions add the least to the spatial-group differentials. Only males in Brazil and females in Colombia show some gradient among their spatial groups. In the same sense, no category shows a pattern that infringes on the main and large cities in respect to other spatial groups.

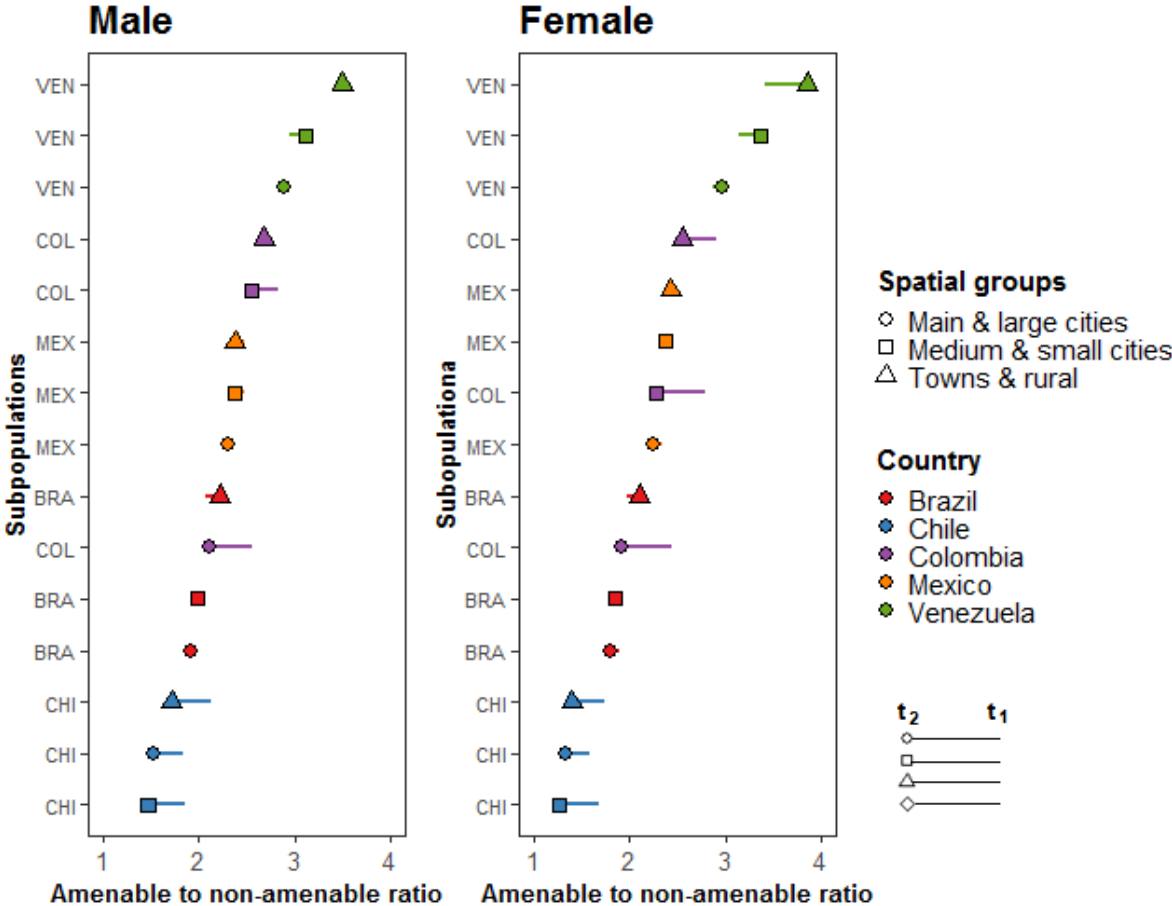
The age distribution of changes by amenability is biased toward specific age groups. Gains in life expectancy due to deaths amenable to tertiary interventions, for example, occur exclusively in the under-one-year-of-age population. Conversely, for deaths amenable to secondary interventions in all countries, contributions to changes (positive or negative) in life expectancy affect populations aged 50 and over (Annex I.20 for males and I.21 for females). In general, changes in amenable causes of death during the period have a higher positive impact on children in most of the countries. Only the Chilean population aged 60 years and over has benefited more from reductions in amenable causes. In contrast, it is only in Mexico that the population aged 80 and over has worsened due to amenable causes.

With respect to non-amenable causes, they also present a gradient in which the main and large cities maintain the lowest rates, while towns and rural areas present the highest. This situation is seen for both sexes; but it is even clearer for women, for whom the advantage of the main-and-large-cities group is missing only in Venezuela, where non-amenable causes are decreasing equally among this spatial group. Non-amenable-causes contribute to changes in life expectancy mostly in adult ages; only Brazilian infants living outside the main and large cities contribute positively to reducing mortality from these causes (see Annex I.20 and I.21). For their part, Mexican females and males living in towns and rural areas are the only subpopulations with simultaneous increases in amenable and non-amenable mortality rates. The worsening of general living conditions in Mexican towns and rural areas may be influencing these outcomes. This runs in contrast to the Brazilian and Venezuelan cases, in which improvements in general living conditions beyond the public health system are reducing non-amenable cause-of-death mortality rates.

Figure 9.20 displays the amenable to non-amenable cause-of-death ratio in 2000 and the year 2010 by sex, country and spatial group. Lower ratios indicate higher proportional weights of non-amenable causes in the overall death rate. Subpopulations are ordered on the y-axis according to their ratios in the year 2010. For both sexes, the hierarchy is the same, with only Colombian medium-sized and small cities showing larger proportions of deaths due to amenable rather than non-amenable causes when comparing males with females. A country pattern prevails in the amenable to non-amenable cause ratio. However, the main-and-large-cities groups in all countries have fewer amenable than non-amenable deaths for both periods. Only Chile breaks this common pattern. This is because the negative contributions to increasing life expectancy in the medium-sized and small cities during the period come from non-amenable causes of deaths at ages 80 years and over. Regarding changes over this period, Brazilian towns and rural areas as well as all Venezuelan subpopulations see increases in the

amenable to non-amenable cause ratio during the period, whereas it remains stable or decreases in all the other subpopulations.

**Figure 9.19. Amenable to non-amenable cause-of-death ratio by country, sex and spatial group, 2000 and 2010**



In summary, the amenable grouping taken by this research includes the following as primary interventions: safe roads; safe housing; drinking water; sewage disposal systems; health policies focused on large-scale immunization of populations; elimination of disease vectors; distribution of antibiotics; and access to initial emergency and trauma care. All these elements are recognized by the literature as the main determinants of the historical mortality decrease in Latin America and are identified in this research as the main drivers of spatial-group differentials, even in the most urbanized countries such as Chile. This means that the uneven distribution of basic urban infrastructure and access to basic services continue to introduce mortality differentials in the region.

The main-and-large-cities group is privileged in terms of policies, as they maintain lower levels of amenable mortality as a result of primary interventions at the beginning of the period; thus, they benefit as much as the other groups in most countries. Even more, they also benefit the most from reduced mortality due to secondary interventions, which are linked to basic access to general medical care, medication and regular treatment. The spatial-group differential by amenable causes emerges as a gradient for all the countries. However, the gap for some countries – such as Venezuela, Brazil and Mexico – is especially important for towns and rural

areas versus all cities, regardless of size; while in other countries like Chile and Colombia, it is the main and large cities that remain the most significantly advantaged group.

## 9.5 Conclusion

In this chapter, I examine the causes of death that can explain the spatial-group mortality differentials in the region, with a focus on those that act as the main drivers of mortality changes during the period. As seen throughout Chapter VIII, infant and young adult mortality establish the spatial-group differentials as well as most of the variance among countries. However, it is the progress in older adult mortality that is responsible for changes seen in the period. In this sense, the primary causes of the initial differentials are the lethality of traffic accidents and injuries, perinatal conditions, and – to a considerably lesser extent – infectious diseases.

Regarding changes in older adult ages over the period, the main driver is a reduction in circulatory diseases at age 45 and over. The main and large cities in Latin America have been the most successful at reducing circulatory diseases in older adults. The achievement of this reduction is known in developed countries as the cardiovascular revolution; though it has spread less to other subpopulations in the countries analyzed here, especially those in towns and rural areas. Neoplasms play a less relevant role regarding changes in mortality. It is only in Chile where neoplasms constitute the most important cause of death. However, its prominence does not introduce any spatial-group differential.

In general, no cause of death acts against the advantage of the main and large cities, even during periods of overall deterioration in all countries evenly. Causes amenable to primary interventions are the main drivers of spatial-group differentials, even in the most urbanized countries such as Chile. This means that it is the uneven distribution of basic urban infrastructure and access to basic services that explain mortality differentials among Latin American subpopulations. Exceptions to this broad generalization exist, as in Mexico, where circulatory diseases increase during the period but affect the main-and-large-cities group less than anywhere else in the country. Others are the main-and-large-cities groups in Brazil and Venezuela, where homicides are more important.

Communicable diseases seem to play a negligible role in defining mortality patterns in Latin America during the first decade of the twenty-first century. In terms of communicable and non-communicable diseases in the countries, the idea of a coexisting mixed epidemiological profile that was presented by Frenk et al. (1991) appears to no longer be pertinent to this region. The dissolution of this mixed epidemiological profile is probably the result of overall improvements in these countries leading to decreases in infant mortality. This does not mean, however, that contradictions in the national epidemiological profiles have been diluted for all countries; Mexico still shows signs of being trapped in this polarized and prolonged transitional model. Instead, the urban/rural division has generated new inequalities that go beyond communicable and non-communicable diseases in the epidemiological profiles of these countries. Nowadays, subpopulation gaps in mortality are what drive these countries' efforts to develop geographically equitable capacities for overcoming non-communicable diseases, in particular by reducing heart disease mortality at older adult ages and avoiding death by external causes.

## 10. SPATIAL DIFFERENTIAL IN LATIN AMERICAN HEALTH TRANSITION

The term “health transition” refers to the process of change in the epidemiological profile of a population. It explains how changes in the diseases and cause-of-death patterns result from the interaction of demographic, economic, socio-cultural and environmental patterns. Changes in the mortality profiles do not benefit all countries or subpopulations equally; but progress spreads unevenly across subpopulations. Initial changes occur in the most favored segments of the population, who benefit more rapidly from overall improvements than do the rest of the population. Later on, the lagging subpopulations catch up to the initial advantage, and the mortality reduction process occurs in successive stages of divergence/convergence among subpopulations (Vallin and Meslé 2004).

As seen in previous chapters, the unequal development of spatial areas in Latin American countries has led to an advantage held by urban populations, especially in capital cities when comparing them to the rest of the countries’ territories. Likewise, the health transition in Latin America until the nineties has generally appeared first in urban locations and tended to proceed more rapidly in countries with higher levels of urbanization. Given this framework of the health transition, we might ask ourselves: What can Latin American subpopulations tell us about changes in mortality patterns and the cause-of-death evolution during the first decade of the twenty-first century? Which subpopulations are leading changes in mortality? Which causes of death are driving divergence/convergence among subpopulations beyond the country level?

In order to answer these questions, this chapter is divided into four sections. The first summarizes the mortality patterns found in all subpopulations using two statistical analyses: Principal Component and Hierarchical Cluster Analysis. These allow classifying the similarities and differences by group of cities beyond the country level. As input, I used some of the indicators computed throughout Chapter three: infant mortality; risk of dying between ages 15 and 45 and between 45 and 65; life expectancy at age 70; and their changes in the period of analysis.

In the second section, cause-of-death distribution and its evolution are examined beyond country borders. I look for the causes of death driving changes in the subpopulation clusters created in the first part of the chapter, and I partitioned them according to their performance throughout the health transition during the period of analysis. Following this, the third section decomposes cause-of-death contributions to changes in life expectancy at birth by using as a reference the subpopulations considered to be the most advanced in the framework of the health transition. Because the aim of this chapter is to analyze differentials together with their evolution, the algorithm of contour replacement decomposition method separate in additive components the age-contributions to the initial difference and in-between trend during the period of analysis from final differences among subpopulations. Finally, the fourth section is dedicated to providing brief conclusions.

### 10.1 Grouping subpopulation mortality patterns

Throughout Chapter eight, a combination of indicators was used to characterize specificities in the mortality patterns of all subpopulations. This section merges all these indicators together in order to categorize subpopulations according to their general mortality patterns. As for data quality, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) are used to

provide a synthetic view of the mortality patterns in the subpopulations beyond their national levels. The aim is to classify the 30 subpopulations (plus 10 country populations for illustration) based on (dis)similar levels and changes during the ten-year period in infant mortality (infant mortality rates), young adult mortality ( $_{30}q_{15}$ ), older adult mortality ( $_{20}q_{45}$ ), and life expectancy at 70 years old. Both analyses are carried out with the statistical program SPAD.

The PCA results are presented as a principal component subspace scatterplot in Figure 10.1 (see Annex H, Table H.1, for the statistical coefficients of the principal component analysis of mortality patterns in these subpopulations). The first two axes explain 72.3 percent of the variance: axis 1 has an eigenvalue of 3.647, equivalent to 45.6 percent; while the eigenvalue of axis 2 is equal to 2.134 and equivalent to 26.7 percent. A third axis, with an eigenvalue of 0.9, indicates that 11.6 percent of the variance is disregarded. This third axis has the strongest contributions from the variable “changes in  $_{30}q_{15}$ ” (the only change that is introduced when considering the third axis is to split the subpopulations into seven clusters by dividing the yellow cluster into two).

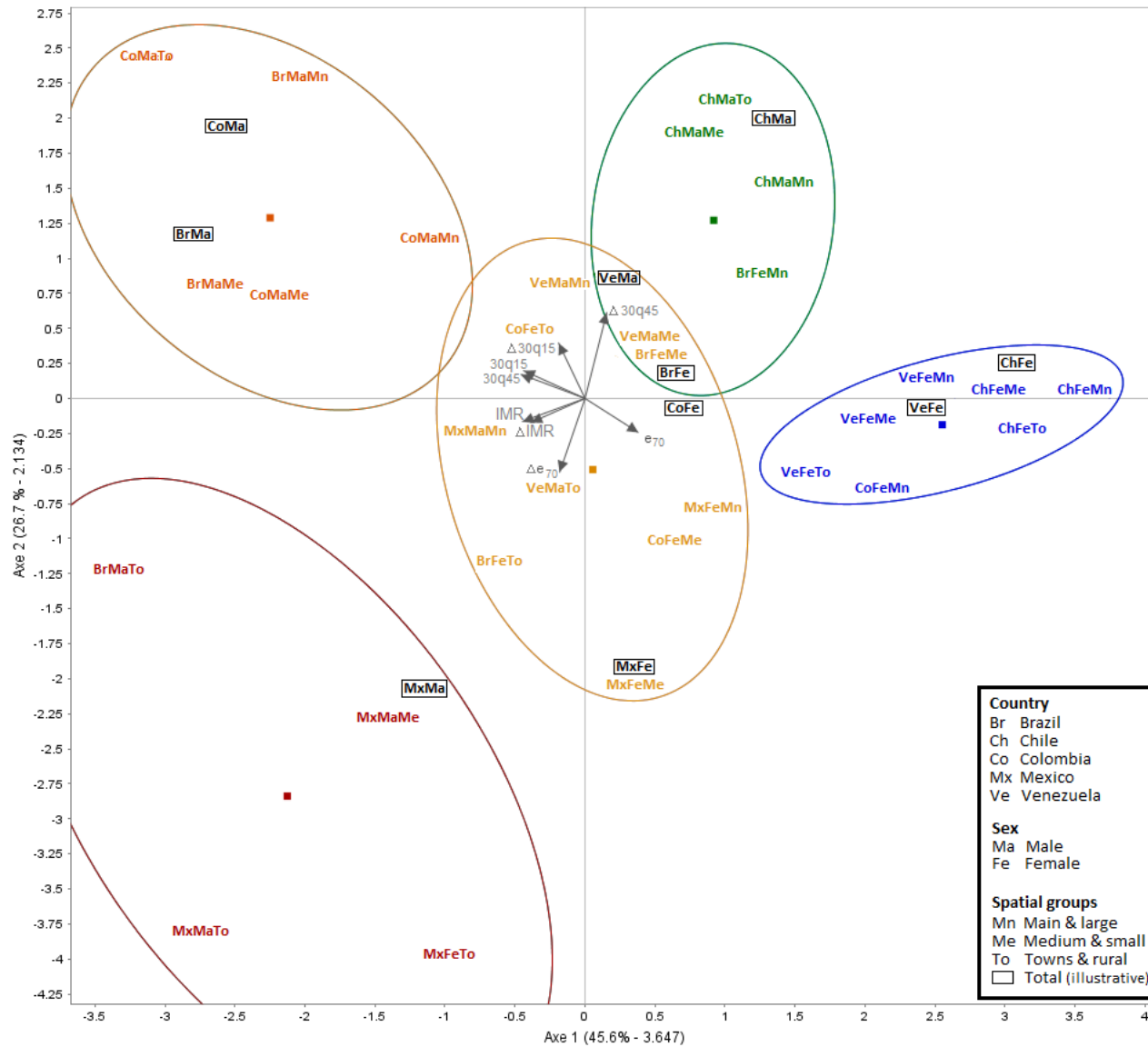
Together with the two-dimensional principal component subspace, Figure 10.1 displays the distribution of the subpopulations among the active variables. To facilitate comparison, all values have been standardized to their mean in  $t_1$ , and all changes (reductions or gains) are equivalent to the same mean in  $t_1$ . Therefore, reductions or gains equal to one imply that they are equal to the same value of the mean in  $t_1$ . The mean values of all variables in  $t_1$  are also added.

Subpopulations are identified in the two-dimensional principal component subspace by acronyms formed from combining the countries (Ch=Chile, Br=Brazil, Co=Colombia, Mx=Mexico, Ve=Venezuela), sex (Fe=Female, Ma=Male), and spatial groups (Mn=Main and large cities, Me=Medium-sized and small cities, To=Towns and rural areas). The country populations that serve as illustrations are framed in black lines and their acronyms combine only country and sex.

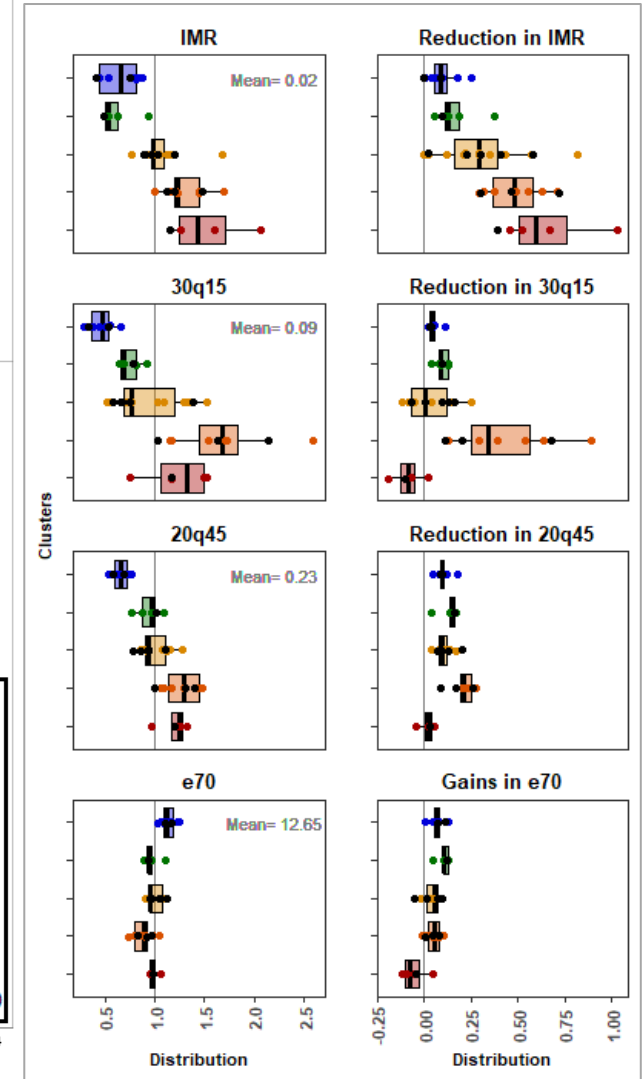
Likewise, mortality patterns are summarized in two broad dimensions- First, the *rectangularization of survival curve* on axis 1 represents the change from a wide dispersion of deaths to a concentration in the number of deaths around an older modal age, which is the product of improvements in life expectancy at all ages. Second, axis 2 summarizes the *shrinking of the mortality hump*. Both dimensions express the idea of changes in mortality patterns. Even when they may indicate an increasing or enlarging dispersion of age of death, they highlight the impact that the region’s (dis)advantages in young and old adult mortality have on mortality by age. Typifying the subpopulations allows: 1) looking deeper into the (dis)similarities between subpopulations beyond their country; and 2) summarizing their previous achievements and current performance.

Subpopulations are gathered into five clusters that do not necessarily represent different levels of mortality but, rather, differences in age-group mortality trends over the period of analysis. Table 10.1 summarizes the subpopulation composition of the five clusters, while Figure 10.2 displays life expectancy at birth trends in each country during the period 2000 to 2010 (at the top) with their respective specific mortality rates in the year 2005 (at the bottom) by cluster. The clusters in Figure 10.2 are ordered left to right from best (blue group) to worst (red group) performance.

Figure 10.1 Two-dimensional principal component subspace and grouping for mortality patterns in subpopulations



Cluster distribution in active variables  
 ( $t_1$  mean-centralized values)



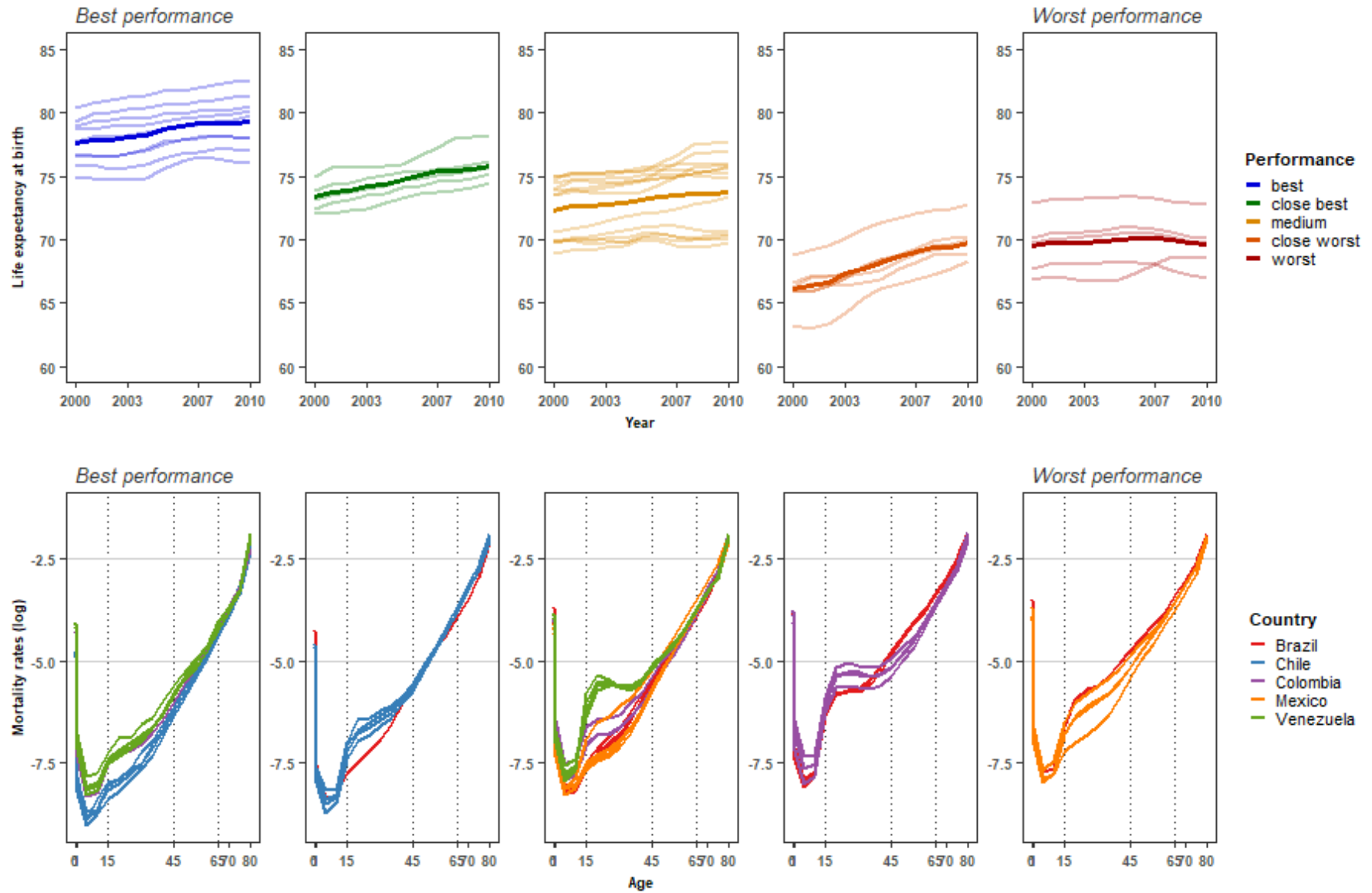
Life expectancy in the blue group (best performance) is the highest, which is in contrast to the lowest in the orange and red groups (worst performance), which are indicated on the right. Since the clusters divide not only levels but also trends in changes during the period, the life expectancy of the subpopulations in the orange group is not much higher than those in the red group – although the orange group shows constant improvements instead of stagnating, as in the case of the subpopulations in the red group. At the bottom of Figure 10.2, the specific mortality rates in the year 2005 indicate the impact of the mortality hump shrinking or increasing. The best and worst performance groups are clusters least affected by the mortality hump, while the yellow and the orange are the most affected.

**Table 10.1 Cluster composition**

Clusters	Sub-populations	Countries	City-size groups	Sex
Blue: <b>Successful</b> transition	9 (22.5%)	4 Chile 4 Venezuela 1 Colombia	3 Main city 2 Medium-sized city 2 Town & rural 2 Total	9 Female
Green : <b>Ongoing</b> transition	5 (12.5%)	4 Chile 1 Brazil	2 Main city 1 Medium-sized city 1 Town & rural 1 Total	4 Male 1 Female
Yellow: <b>Truncated</b> transition	14 (35%)	3 Brazil 3 Colombia 4 Mexico 4 Venezuela	3 Main city 4 Medium-sized city 3 Town & rural 4 Total	7 Male 7 Female
Orange: <b>Delayed</b> transition	7 (17.5%)	3 Brazil 4 Colombia	2 Main city 2 Medium-sized city 1 Town & rural 2 Total	6 Male 1 Female
Red : <b>Failed</b> transition	5 (12.5%)	1 Brazil 4 Mexico	1 Medium-sized city 3 Town & rural 1 Total	4 Male 1 Female

The division of subpopulations may correspond to different stages in the health transition. By taking into account only the age distribution of death rather than the causes of death driving the changes in mortality, I consider here two broad stages: a pre-transition phase dominated by infant mortality; and a post-transition phase, in which older adult survival is predominant. Likewise, the two clusters with the worst performance are in the early stages of the transition: they are still gaining years in life expectancy in infancy and have no important improvement in adult ages at the beginning of the period of analysis. The orange group, which has a much higher risk of dying at older adult ages than the red one does, is rapidly catching up with the medium cluster by reducing major risks of dying at young adult ages. A successful transition into a concentration of death distribution in old ages depends on future improvements in survival among the populations aged 45 years and over.

Figure 10.2 Clusters by life expectancy at birth (2003–2010) and specific mortality rates (2005).





The red group has the worst performance, even when the level of life expectancy at birth is much lower, and it shares a similar characteristic with the yellow group: they both seem to have reached a threshold because they have failed to decrease the incidence of young adult mortality. The red group is stuck in a failed transition for the period of analysis, with stagnated life expectancy and an increasing mortality risk for all adults.

In the yellow group, previous gains in life expectancy resulted from decreasing the high infant mortality and emerging gains in life expectancy above 70 years old. So far, the average of these gains has hidden the lack of improvements in young adult survival. In this group's subpopulations (yellow group), the health transition has been truncated. Any further reduction in infant mortality would not cause a significant gain in the average life expectancy unless young adult mortality is not reduced. Consequently, decreasing life expectancy at birth is recorded in this cluster.

In the two best performing clusters, it is possible to see improvements in overall adult survival. The green group is in the process of attaining two advantages: first, the same advantage that was previously achieved by the best performing group in reducing the risk of dying at age 45 to 65; and, second, life expectancy at old ages. In the green group, a transition into an old age mortality regime seems to be ongoing. The blue group shows a successful transition: the smallest risk of infant and adult mortality; and the highest, continuously increasing levels of life expectancy at age 70. This best-performing group concentrates only female subpopulations, while male subpopulations are more likely to be found in the worst-performing clusters.

Beyond the sex differential in the cluster composition, the most notable characteristic is country heterogeneity. Chile and Venezuela, the most urbanized countries, continue to be the most homogenous in the sample. In Chile, all female subpopulations have experienced a successful transition and all male subpopulations are catching up with them during the recent period. On the other hand, even when all Venezuelan female subpopulations are found in the best-performing group, males present a truncated transition. These are the only countries where, despite differences in their mortality levels by urbanization, all subpopulations point to a similar long-term trend. This indicates waves of improvements spreading to the countries, starting with the most advantaged subpopulations (the main and large cities) and rapidly reaching the most disadvantaged ones in the rural areas. This could be due to the existence of fewer geographical inequalities in the mortality determinant; or it may be because their main city's primacy (as in Chile) or large cities weight in the national wealth and population distribution (as in Venezuela) offsets the need for resources in less urbanized areas. This means that even when there are fewer resources in less urbanized than in urbanized areas, the proportional weight of the population in less urbanized areas is also small.

In the other countries, the urban advantage can be perceived in terms of levels and in how changes occur in the mortality structure. An extreme example is Brazil, where the transitions between mortality regimes occur in four different ways among their subpopulations. First, females in the main and large cities show an ongoing transition while those living in the medium-sized and small cities are truncated, and finally, females in towns and rural areas record a delayed transition. On their side, men follow the same heterogeneity in their mortality pattern: males living in the main and large cities have a truncated pass through health transition, while all other male subpopulations experience a delayed or failed transition. In terms of urbanization and the health transition, this gradient is also clear among females in Colombia, where only women living in the main and large cities group hold a successful pass through health transition during the period of analysis.

Mexico, in every sense, gathers the most disadvantaged subpopulations. Only the subpopulations in the main and large cities and those of females in the medium-sized and small cities have experienced emerging improvements in adult mortality during the period of analysis while at the same time failing to achieve significant gains in previous periods. Urbanization has acted as a “less unfavorable” scenario in the deteriorating survival of Mexicans. This failure is seen in all adult ages and in both sexes.

Combining this subpopulation cluster with an analysis of the causes of death might shine some light on the path taken by the health transition and its relationship to urbanization in Latin America. The created clusters are revisited in the next section of this chapter to analyze (dis)similarities in the causes of death among the subpopulations that have been identified as being in different phases and rhythms of the health transition.

## 10.2 Clusters of cause-of-death patterns

In this section, causes of death are analyzed in order to keep track of all subpopulations’ progress in terms of the health transition. The goal is to explore which causes of death play the most important role in the inequalities among subpopulations, specifically in terms of mortality reduction. From this point forward, subpopulations are gathered according to their clusters in Section 10.1. Figure 10.3 displays the standardized mortality rates by cause of death in the years 2000 and 2010 by subpopulation and cluster. Subpopulations are ordered first by cluster and then within each cluster according to their mortality level, from the lowest standardized mortality rate (at the bottom) to the highest (at the top). Once again, they are identified the y-axis by an acronym formed by combining their country, sex and spatial group.

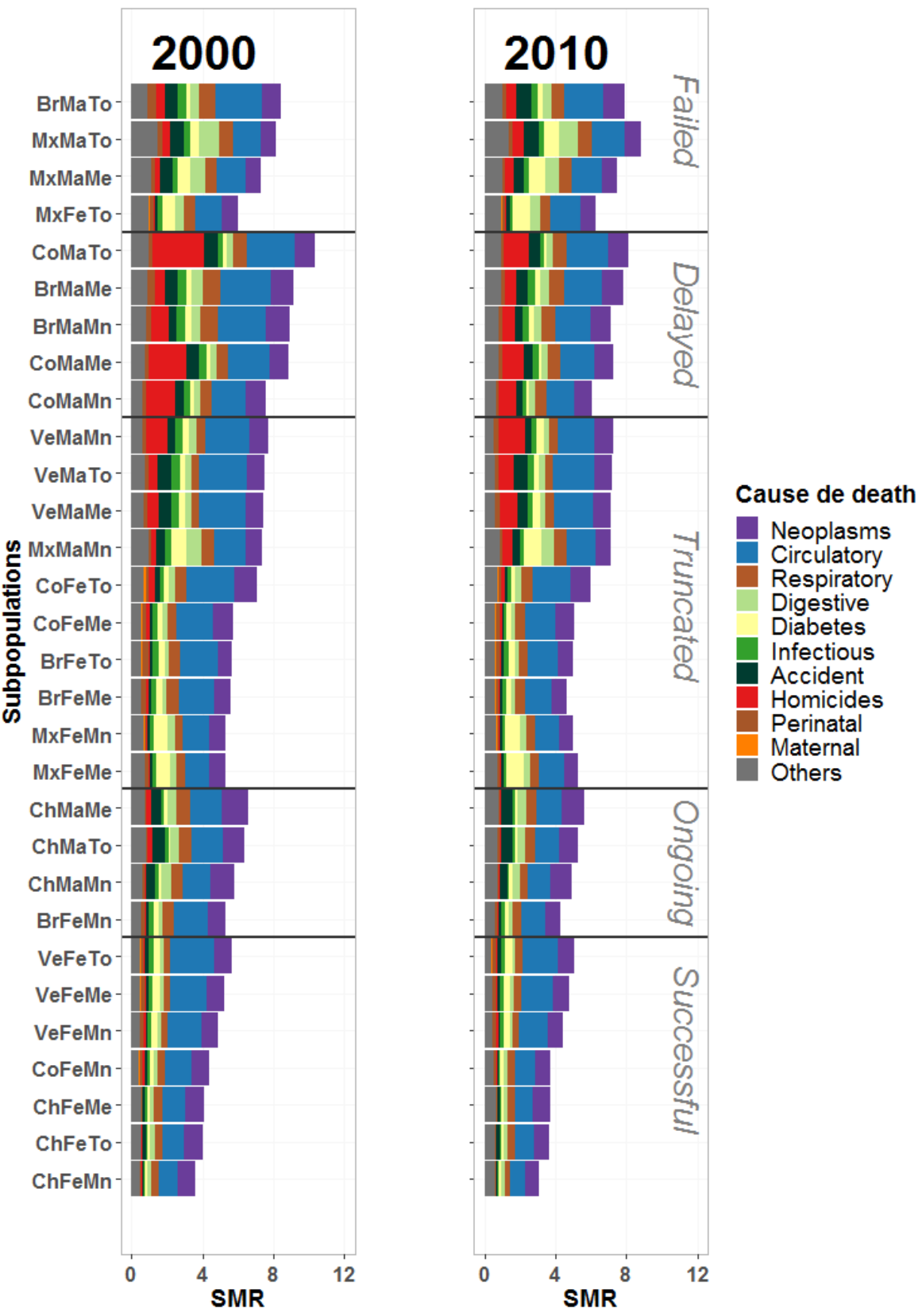
For both years, the cause-of-death distributions among the subpopulations clustered in the best-performing cluster – such as *successful* and *ongoing* – show higher proportional rates of circulatory diseases and neoplasms; whereas the worst performance clusters – such as *failed* and *delayed* – maintain higher levels of digestive, respiratory and infectious diseases, as well as perinatal conditions. In this sense, clusters are polarized in terms of the classical epidemiological transition, with the worst performance cluster driven by communicable diseases, while the best-performing cluster is driven by non-communicable diseases. For their part, homicides (for males) and diabetes (for females) seem to be more preponderant as causes of death for both years in the subpopulations classified as *truncated* and *delayed* transitions. However, different trends can be seen among subpopulations within the clusters.

The delayed-health-transition cluster gathers subpopulations in which homicides show significant reductions in the year 2010. This means they are catching up with more advanced subpopulations in the health transition, evidently due to reductions in violence. In contrast, males in *truncated* subpopulations barely reduced their total mortality levels in 2010 due to an increase in homicides. For female subpopulations in a truncated health transition, the cause of death that has hindered their progress is diabetes rather than homicides.

In terms of mortality level for the period of analysis, few subpopulations remain in the same hierarchy. In Figure 10.4, subpopulations are ranked according their mortality level measured by the standardized rates at the beginning (2000) and at the end (2010) of the period. Once again, subpopulations are indicated by their acronym and their positive changes (green), negative changes (red) changes, and unchanged positions (bold) within the hierarchy.

Subpopulations with increasing standardized mortality rates during the period are framed in black boxes.

**Figure 10.3** Subpopulations' standardized mortality rates (SMR) by cause of death and health transition grouping.



**Figure 10.4 Subpopulation ranking according to level of mortality measured by the standardized mortality rates during the years 2000 and 2010**

Ranking 2000		Ranking 2010	
1	<b>ChFeMn</b> (3.6)	(3.0)	<b>ChFeMn</b> 1
2	<b>ChFeTo</b> (4.0)	(3.6)	<b>ChFeTo</b> 2
3	<b>ChFeMe</b> (4.1)	(3.7)	<b>ChFeMe</b> 3
4	<b>CoFeMn</b> (4.3)	(3.7)	<b>CoFeMn</b> 4
5	VeFeMn (4.9)	(4.3)	BrFeMn 5
6	VeFeMe (5.2)	(4.4)	VeFeMn 6
7	BrFeMn (5.3)	(4.7)	BrFeMe 7
8	MxFeMe (5.3)	(4.8)	VeFeMe 8
9	MxFeMn (5.3)	(4.9)	ChMaMn 9
10	BrFeMe (5.6)	(5.0)	BrFeTo 10
11	VeFeTo (5.6)	(5.1)	MxFeMn 11
12	BrFeTo (5.6)	(5.1)	VeFeTo 12
13	<b>CoFeMe</b> (5.7)	(5.1)	<b>CoFeMe</b> 13
14	ChMaMn (5.8)	(5.3)	MxFeMe 14
15	MxFeTo (6.0)	(5.3)	ChMaTo 15
16	ChMaTo (6.4)	(5.6)	ChMaMe 16
17	ChMaMe (6.6)	(6.0)	CoFeTo 17
18	CoFeTo (7.1)	(6.1)	CoMaMn 18
19	MxMaMe (7.2)	(6.3)	MxFeTo 19
20	<b>MxMaMn</b> (7.3)	(7.1)	<b>MxMaMn</b> 20
21	<b>VeMaMe</b> (7.5)	(7.1)	<b>VeMaMe</b> 21
22	VeMaTo (7.5)	(7.2)	BrMaMn 22
23	CoMaMn (7.6)	(8.8)	VeMaTo 23
24	<b>VeMaMn</b> (7.7)	(7.3)	<b>VeMaMn</b> 24
25	MxMaTo (8.1)	(7.3)	CoMaMe 25
26	BrMaTo (8.5)	(7.5)	MxMaMe 26
27	CoMaMe (8.8)	(7.8)	BrMaMe 27
28	BrMaMn (8.9)	(7.8)	BrMaTo 28
29	BrMaMe (9.1)	(8.1)	CoMaTo 29
30	CoMaTo (10.3)	(8.8)	MxMaTo 30

In bold, subpopulations that remain in the same position compared to all subpopulations' SMRs for the years 2000 and 2010. Red lines imply a worse position in 2010 compared to 2000, while green lines indicate a better position in 2010 than in 2000. Subpopulations framed in black boxes represent increasing SMR during the period. In parenthesis are the standardized mortality rates for the years 2000 and 2010.

The period under analysis corresponds to a time in which different changes occur for the subpopulations. Even when almost all subpopulations reduce their mortality levels by the year 2010, mortality dispersion among subpopulations is relatively widespread. In the year 2000, the

subpopulation with the highest mortality level (Colombian males living in towns and rural areas: CoMaTo) has 2.8 times the standardized mortality rate as the lowest-mortality subpopulation (ChFeMn); while in the year 2010, the highest-mortality subpopulation (Mexican males living in towns and rural areas: MxMaTo) has 2.9 times the standardized mortality rate of the lowest-mortality subpopulation.

Most of the changes seen in the hierarchy of subpopulations' performance are a result of mortality decreasing more slowly in some lagging subpopulations that accumulate in the failed-health-transition cluster. The only exceptions to this are seen in the subpopulations of both sexes living in Mexican medium-sized and small cities as well as those in towns and rural areas, in which both groups see overall levels of mortality that are higher in 2010 than in 2000.

Changes in subpopulations during the period are a result of reductions or increases in different causes of death. In most cases, these changes depend on the levels that these subpopulations have at the beginning of the period. This means previous trends in cause-of-death distributions have an effect on cause-of-death patterns during the period of analysis and, consequently, on the final cause-of-death distributions. This being the case, the next section includes the age decomposition of cause-of-death contributions made at the initial and final times, as well as during the whole period under study.

### 10.3 Differentials driven by cause of death

The of age contributions (in years) to differences in life expectancy at birth among a subpopulation's cluster were decomposed in order to check causes of death drive differentials among the age-group mortality. The best-performing subpopulation was chosen as a benchmark to decompose the differentials. The algorithm of contour replacement was the method used to decompose age contributions in life expectancy at birth, by which three sets of results are shown here. First, we have the age contributions to the *final* difference in life expectancy at birth of all subpopulations compared with the best-performing subpopulation. By *final*, we are referring to the age contribution to differences found at the end of the period of analysis (2010). This *final* difference is split into two additive components, which constitute the second and third sets of results: age contribution of the *initial* difference in life expectancy at birth; and age contribution to the *changes* in each subpopulation over the ten-year period. Decomposing a subpopulation's differential allows us to simultaneously disentangle which causes of death are driving a subpopulation's progress in the health transition among both single subpopulations and clusters.

The subpopulation with the best performance during the period is selected in order to set the benchmark for comparing all subpopulations, regardless of sex, country or spatial cluster. Among the subpopulation clusters identified as having a *successful* path through the health transition, we use Chilean females living in the main and large cities group (ChFeMn) as "the best-performing subpopulation" in the period. This is because they have the lowest mortality level in the year 2000, with a standardized mortality rate of 3.6 per one thousand inhabitants; and they maintain their position as the lowest-mortality subpopulation in the year 2010, with a standardized mortality rate of 3 per one thousand (as seen in Figure 10.3 and Figure 10.4).

Around one quarter of deaths registered in Chilean females living in the main and large cities group during the year 2000 was due to circulatory diseases, while neoplasms caused another quarter. The remaining half of the registered deaths in ChFeMn is split between respiratory

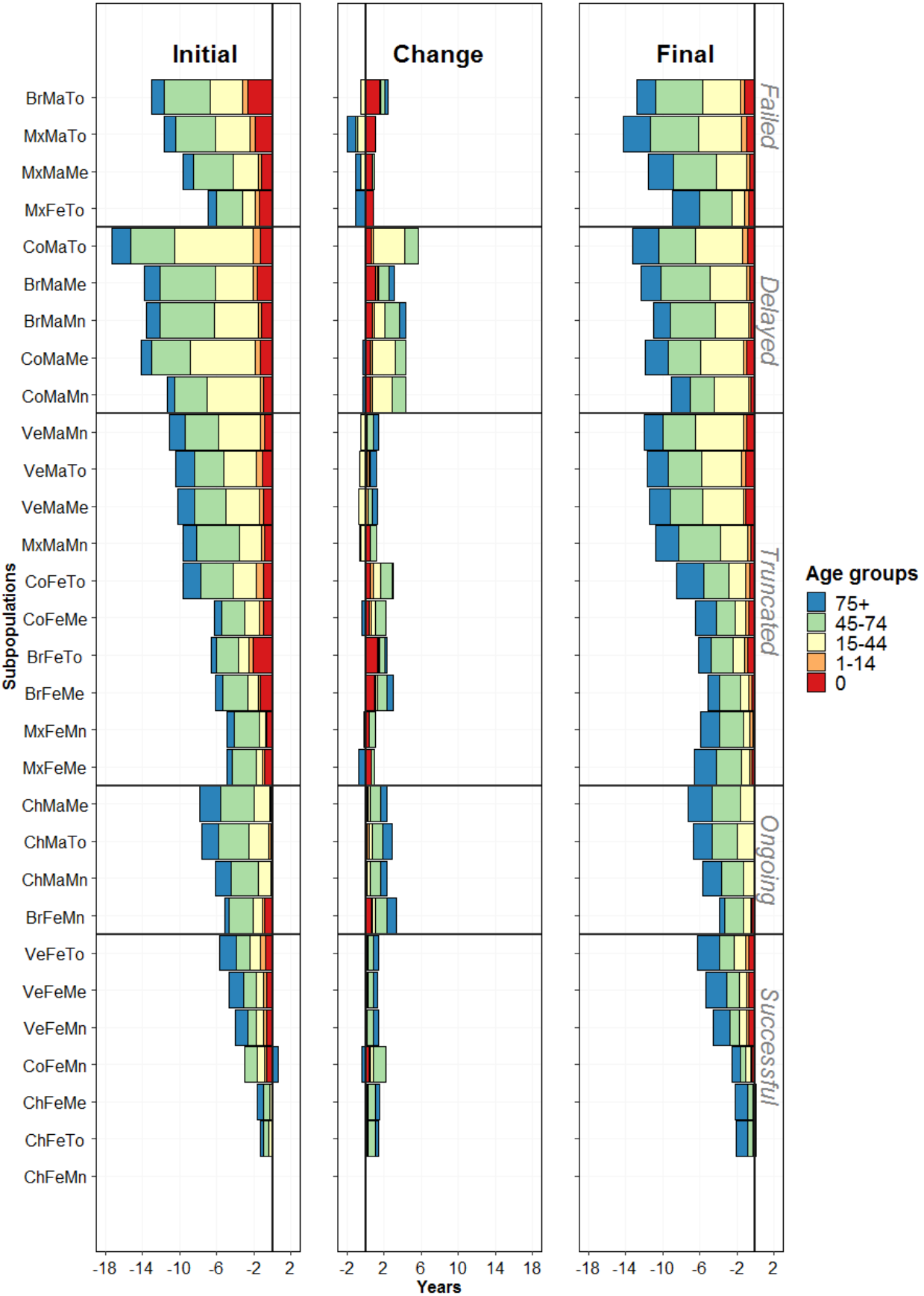
diseases and external causes. Already in 2000, a very low infant mortality rate is characteristic of this subpopulation. During the period 2000 to 2010, mortality rates for ChFeMn decreased mostly as a result of mortality due to circulatory diseases becoming reduced at older adult ages, which consequently gives more importance to neoplasms' contribution to overall mortality at the end of the period. In this sense, comparing ChFeMn with other subpopulations allows us to keep track of subpopulations' progress in a mortality regime dominated by degenerative diseases and in which adult mortality is the main driver of changes. At the same time, the best-performance benchmark is set by using what has been in fact achieved by Latin American subpopulations in terms of the region's improvements in mortality.

First, Figure 10.5 displays the age contributions by all causes of death to differences in life expectancy at birth among the subpopulations, and these are followed by age contributions of specific causes of death: circulatory diseases (Figure 10.6); neoplasms (Figure 10.7); IDR&M (infectious, digestive and respiratory diseases, and maternal conditions, Figure 10.8); diabetes (Figure 10.9); external causes of death (Figure 10.10); and the remaining group of other causes of death (Figure 10.11). The cause-of-death grouping is selected according to their proportions in the overall mortality. Causes of death in IDR&M are grouped together due to their representing causes with remaining importance to the differentials in mortality among subpopulations – although they already have low rates, as seen in Chapter IX.

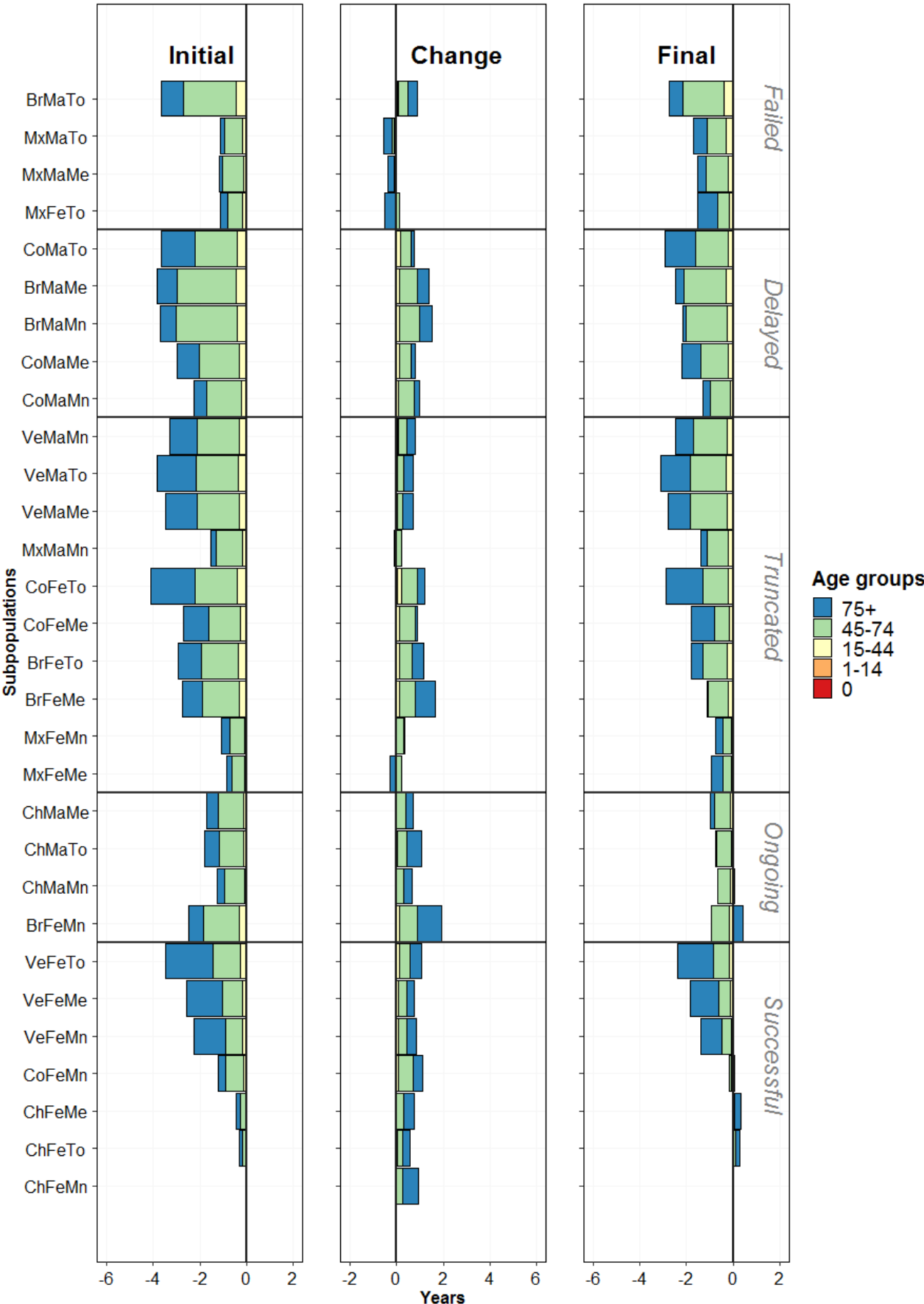
The data assessment carried out in Chapter six on the misreporting of age has revealed some exaggeration at old ages for some subpopulations. In order to overcome this, the last age interval in the life tables estimated in this research is age 80 and over. However, if rapid improvements in age declaration have taken place during the period of analysis, age of death seems to be diminishing as an artificial result of more precise declaration. This is the case for Colombia, where great improvements in age declaration occurred in the registered data for its main-and-large-cities group. Thus, a false increase in mortality may appear for the last age interval when comparing the contributions of this population at the beginning and end of the period. One should keep this in mind when analyzing the CoFeMn age contributions

As said before, clusters are representative of changes in the epidemiological profile of the subpopulations. The subpopulations considered to be *successful* on their path to the health transition are those with, on the one hand, the lowest levels of circulatory diseases in ages 45 to 74 at the beginning of the period and, on the other, an important reduction in the contribution of these diseases at age 75 and above during the ten-year period of analysis. This group is the only case in which neoplasms (see Figure 10.7) and other causes of death (see Figure 10.11) play an important role in old adult mortality. "Other causes" of death appear to negatively contribute to changes in the 75+ age group, probably due to the increasing importance of degenerative diseases such as Alzheimer's, Parkinson's, and dementia, among others. This is a heterogeneous group in terms of the countries under analysis, but it composed exclusively of female subpopulations. At the end of the period, this group's advantage can be noticed at all age groups, even when some of the positive contributions are explained by changes in mortality patterns of populations under 45 years old. The *successful* cluster comprises only those that have entered the cardiovascular revolution.

**Figure 10.5 Age contributions (in years) to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.**

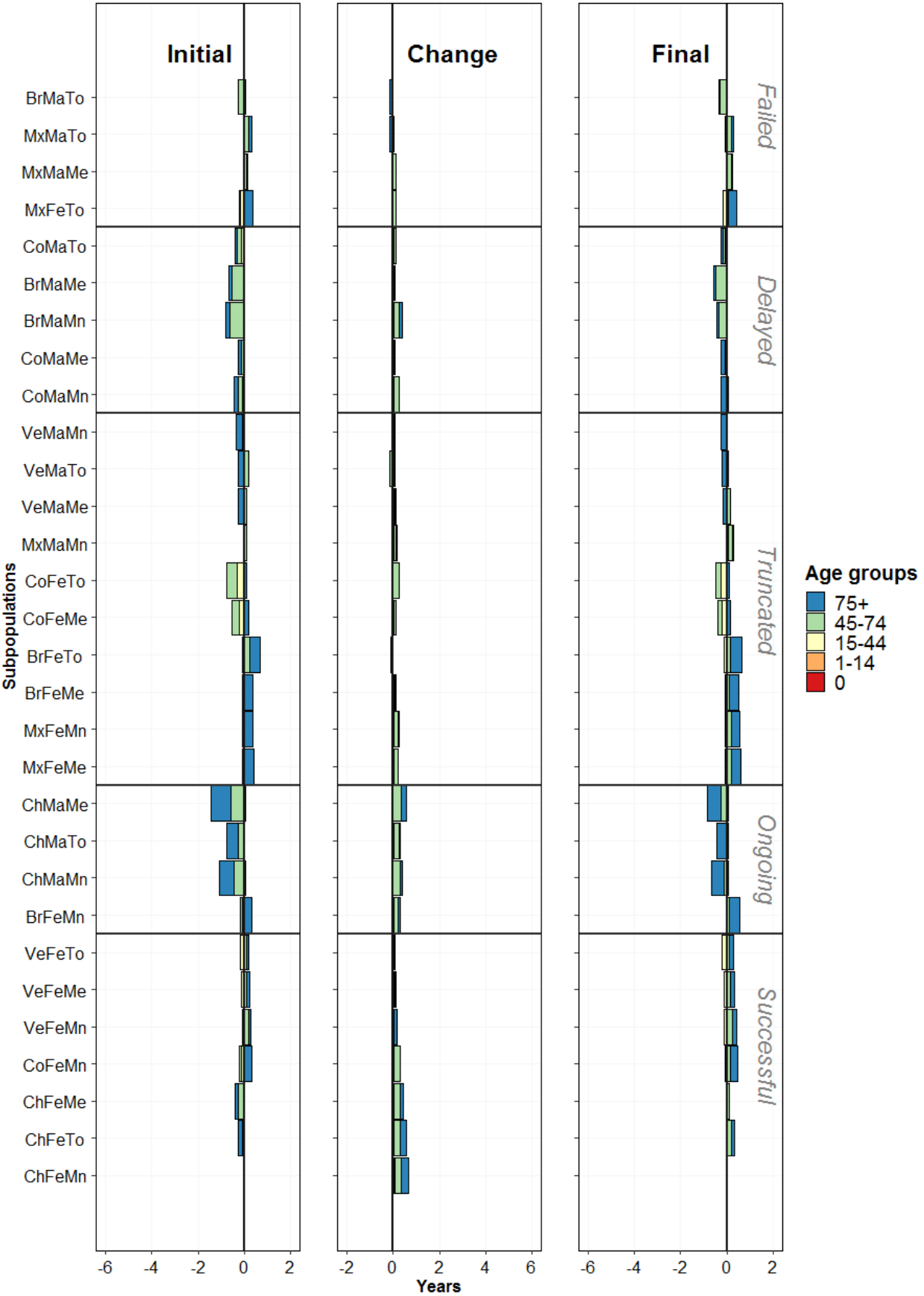


**Figure 10.6 Age contributions (in years) of circulatory diseases to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.**

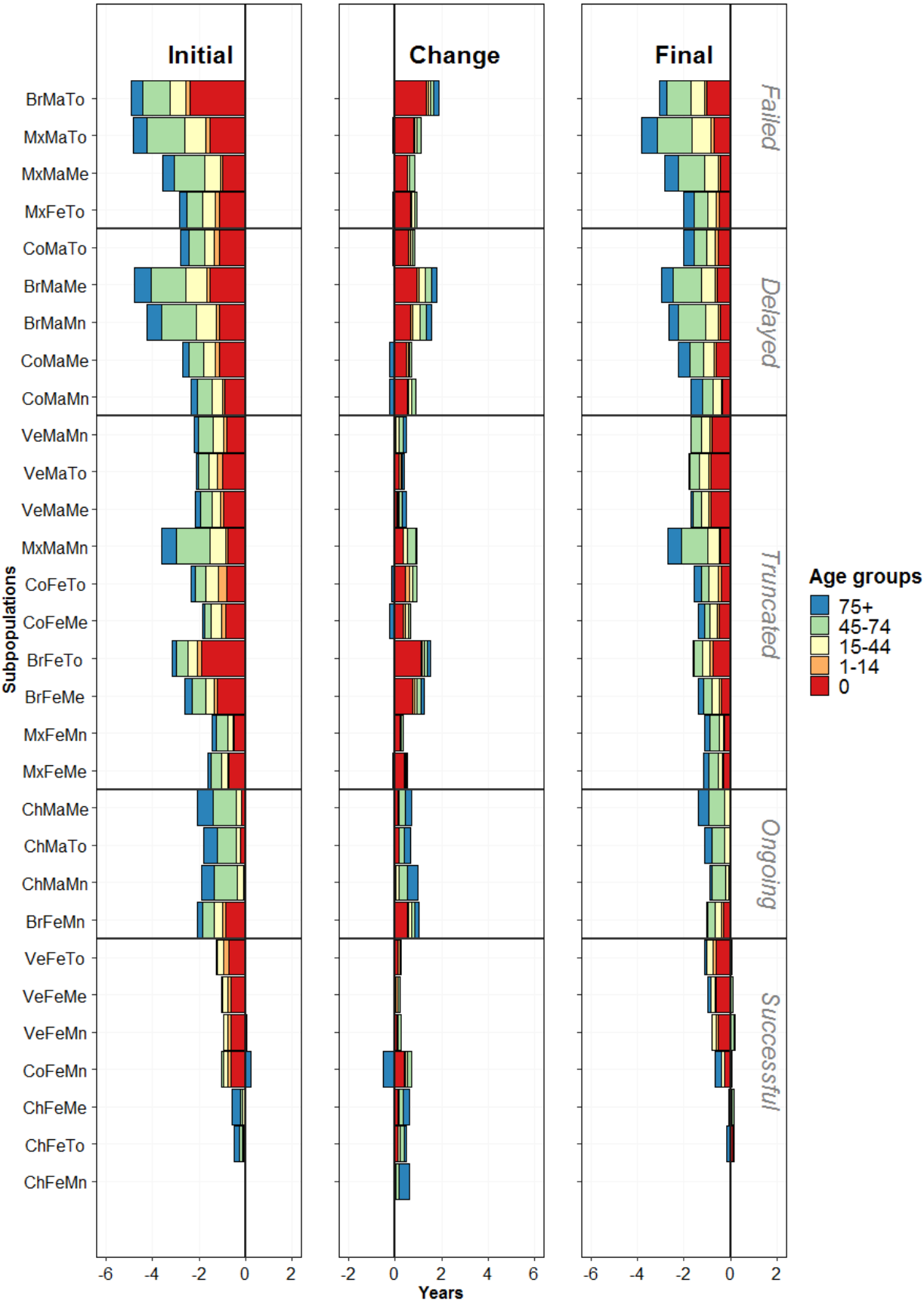




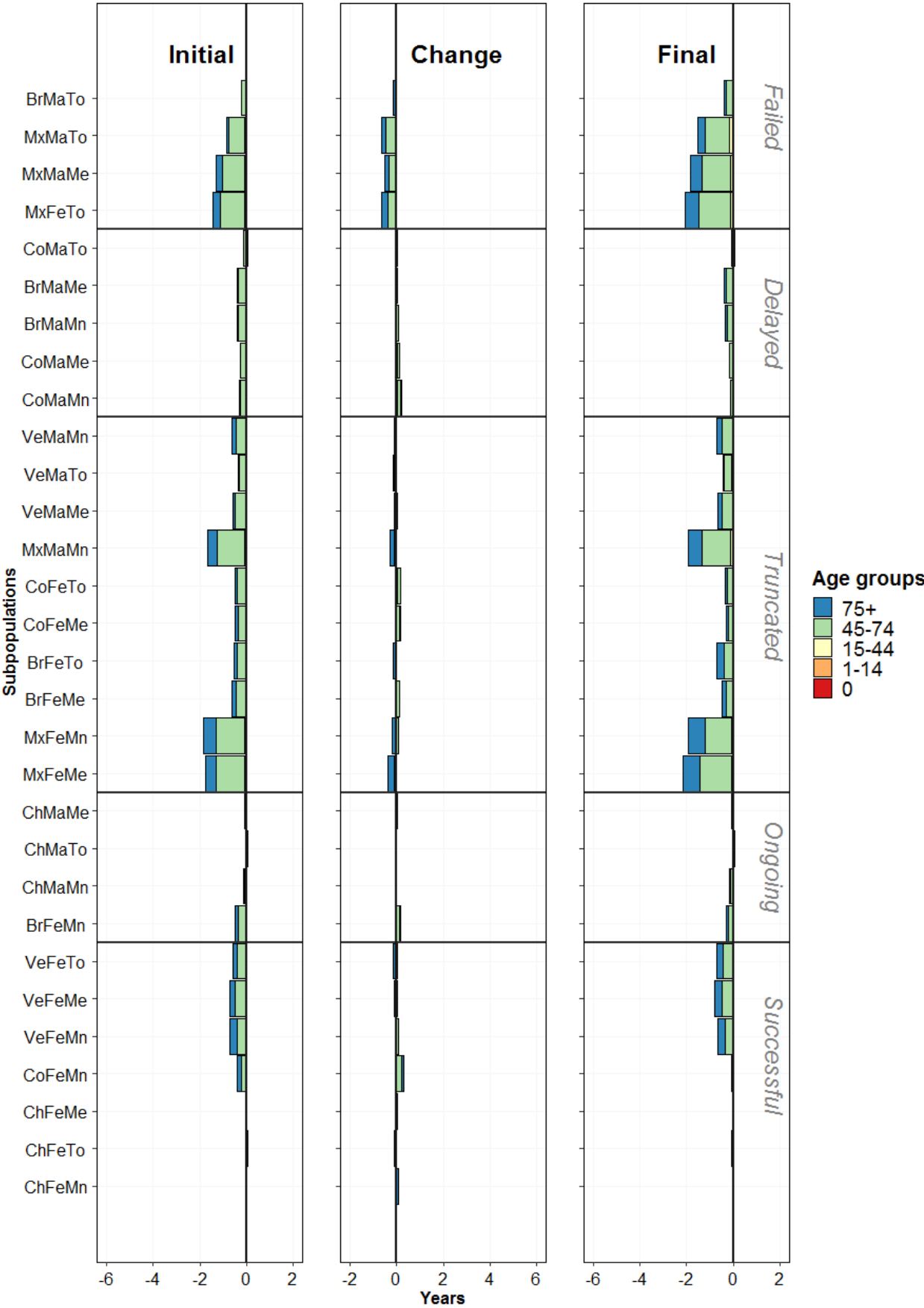
**Figure 10.7** Age contributions (in years) of neoplasms to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.



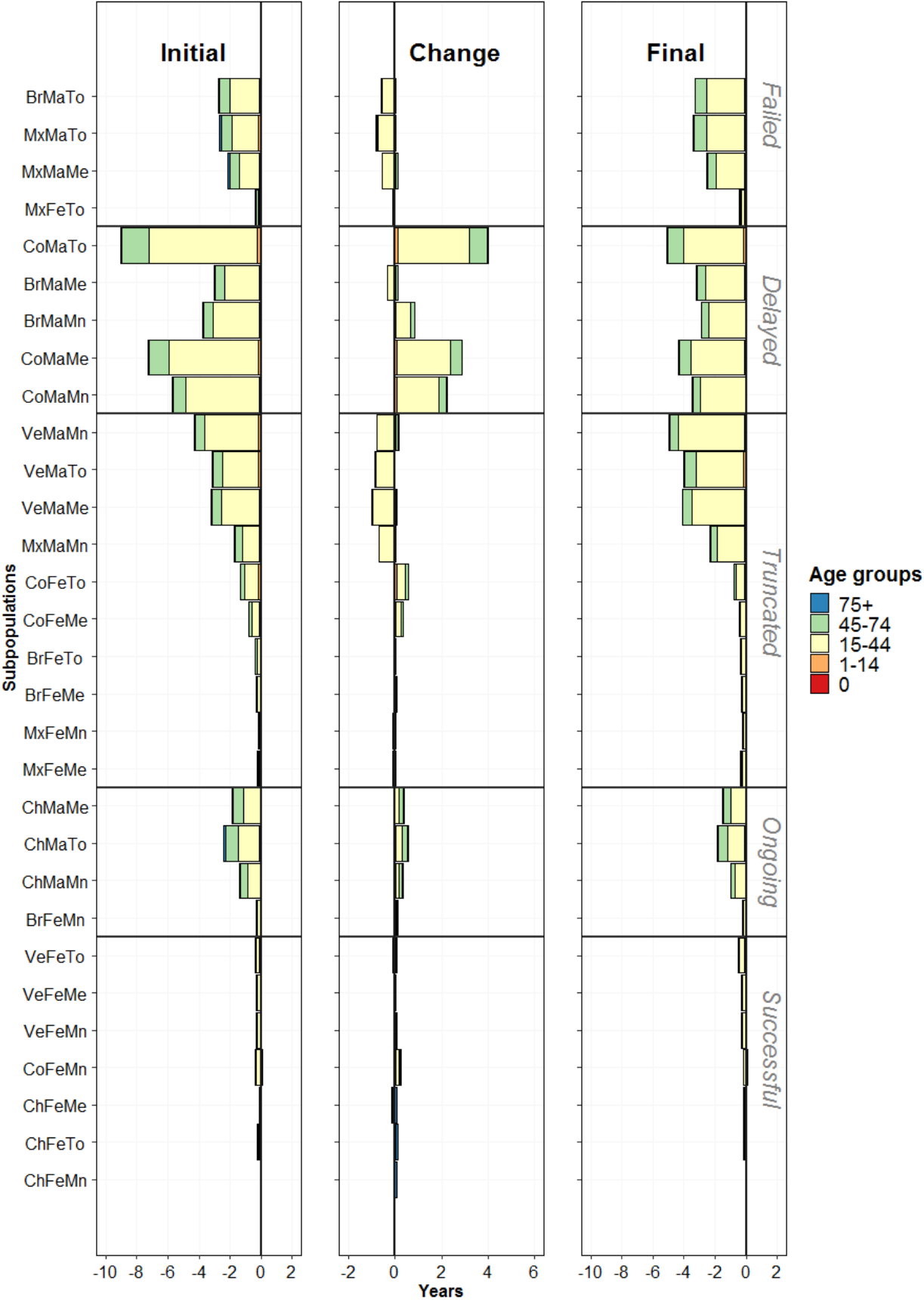
**Figure 10.8** Age contributions (in years) of infectious, digestives and respiratory diseases, and maternal conditions to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.



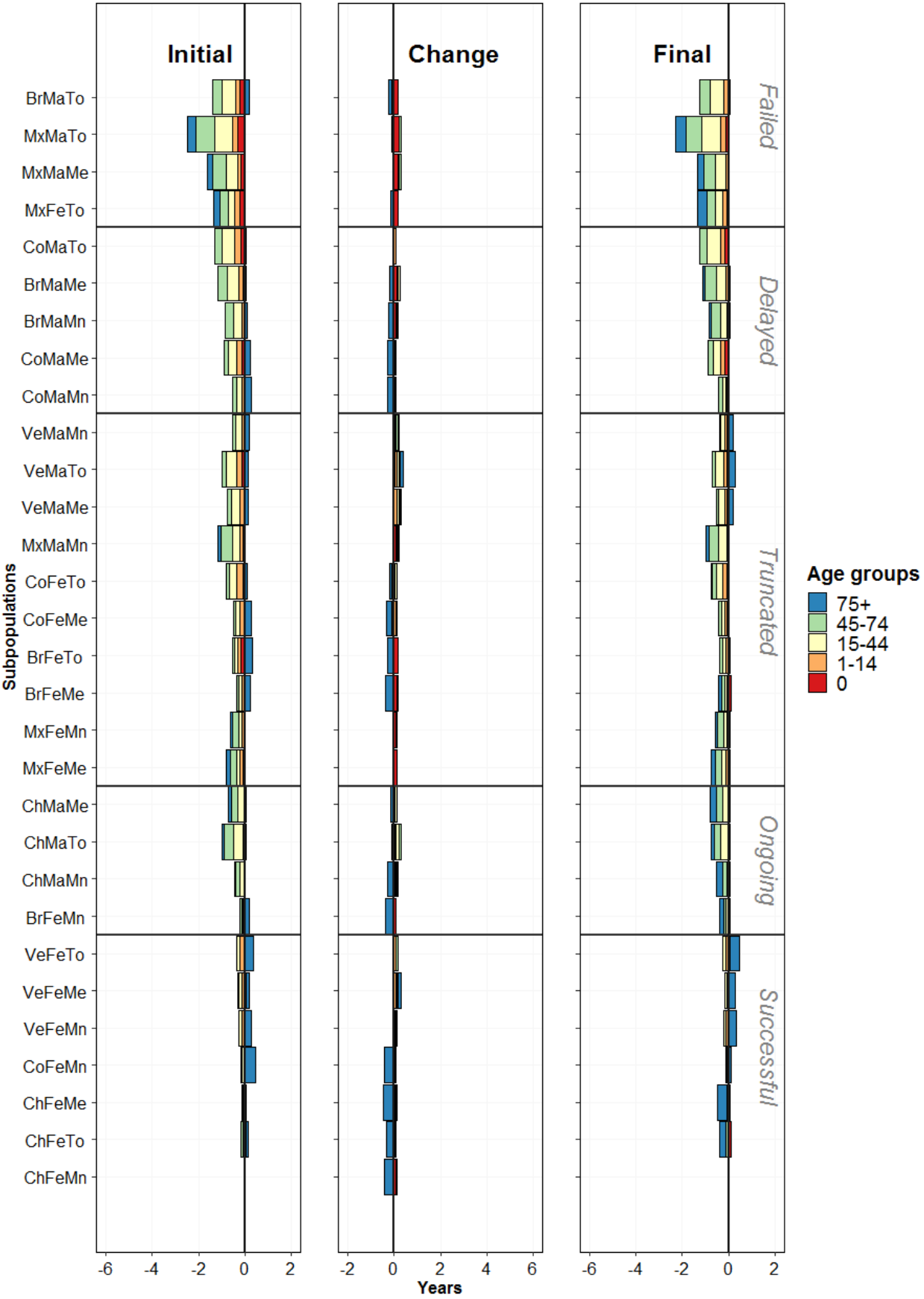
**Figure 10.9** Age contributions (in years) of diabetes to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.



**Figure 10.10** Age contributions (in years) of external causes of death to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.



**Figure 10.11 Age contributions (in years) of other causes to differences in life expectancy at birth among subpopulations and the best-performing subpopulation (ChFeMn), 2000–2010.**



The best-performing subpopulation's life expectancy at birth (ChFeMn) contributes to the final differences among other subpopulations by an increase of around two years during the period (see Figure 10.5). More than one year of the positive contribution is due to a reduction in mortality at age 75 and over due to circulatory diseases (see Figure 10.6). The remaining contributions to life expectancy at birth come almost entirely from populations aged 45 to 74 years, specifically as a result of the reduction in the contributions from circulatory diseases and, to a much lesser extent, from neoplasms. The similarities of subpopulations within this group are a result of older adult mortality patterns. However, the remaining differences in young adult and infant population mortality persist among these subpopulations at the initial and final times of comparison.

Improvements in adult mortality are even greater in the subpopulations clustered as *ongoing* in the health transition when compared with those having a successful health transition. The *ongoing* cluster includes lagging female and male subpopulations that are catching up with the initial advantages of their female counterparts in the *successful* cluster. Likewise, their improvements are leading to convergence with the best-performing subpopulation. In addition, they are a result of reductions in the remaining levels of IDR&M diseases and conditions as well as external causes of death in the adult population. This cluster is in need of a greater reduction in circulatory diseases among populations aged 45 to 74 years in order to shorten the final disadvantage in comparison to the *successful* cluster. It is possible that the subpopulations in this group are passing through the cardiovascular revolution during the period of the analysis and are still in the process of decreasing the proportional weight of death due to circulatory diseases at young adult ages.

The *truncated* cluster combines subpopulations with different epidemiological profiles at the beginning of the period and whose causes of death show dissimilar trends. The small progress made by this cluster occurs mostly in populations aged 45 to 74, but it is in no way what could be expected due to its high level of mortality in comparison to the best-performing subpopulations. There are some small improvements due to IDR&M diseases and conditions in the infant populations, but hardly any changes occur at ages 75 and above during the period in mortality. Even more concerning than the stagnation indicated by the subpopulations in this cluster is the negative contribution of some causes of death to reductions in the subpopulation differentials.

The *truncated* cluster summarizes the subpopulations that, on the one hand, maintain persistent levels of IDR&M diseases and conditions at young ages while not properly benefiting from the cardiovascular revolution; and, on the other, those that already suffer from the consequences of man-made diseases such as homicides and diabetes. This cluster represents the polarized and prolonged epidemiological transition highlighted by Frenk et al. (1991) in their analysis of the Latin American health transition model. The reason for this is that there is no clear resolution of their transition process, but rather a continuous stagnation in the duality of epidemiological profiles. In these subpopulations, other dimensions such as wealth, education, and race, among others, could be playing a more important role in establishing mortality gaps. Thus, the dissimilar epidemiological profiles seen at the aggregated level are in fact a combination of largely unequal subpopulations.

In contrast to the subpopulations within the *truncated* cluster, the subpopulations labeled as being in a *delayed* health transition show the largest improvements at all ages, particularly at adult ages between 15 and 74 years. These subpopulations are catching up during the period with the advantages achieved by better performing subpopulations. Between the best-

(ChFeMn) and worst-performing (CoMaTo) of all subpopulations at the initial period (2000), there is more than a seventeen-year gap that negatively contributes to the final difference in life expectancy at birth (see Figure 10.5). During the period, the highest gain (close to 6 years) corresponds to these subpopulations, and the final difference turns out to be more favorable to CoMaTo, even when taking into account that ChFeMn continues decreasing its levels of adult mortality. This pattern is followed by all subpopulations in a delayed health transition. These subpopulations have not failed in benefiting from the health transition in their respective countries, but their progress has occurred later due to violent civil conflicts. Far from a successful health transition, their improvements in mortality at age 75 years and above are negligible; and their future progress depends on their capacity to initiate a decline in circulatory diseases at ages 45 to 74 years.

Lastly, the subpopulations on a *failed* path to their health transition are those who do not necessarily have the highest mortality levels in the year 2000. They either increase their differentials in comparison to the best-performing subpopulation or they did not accomplish a reduction due their combined and simultaneous negative and positive contributions from different causes of death. Increasing circulatory diseases, diabetes and external causes act against improvements in the adult mortality of this cluster. Its subpopulations witness a general deterioration in adult mortality. The subpopulations in a *failed* health transition group maintain persistent infant mortality at the initial time, and its reduction is the only driver behind improvements in this cluster. Contributions to life expectancy from this age group come mostly from diminishing IDR&M diseases and conditions. Considering the age and cause-of-death pattern, it is possible to say that this group has not completed its path through an epidemiological profile that is dominated by non-communicable diseases.

In general, the positions of the subpopulations reflect their path through epidemiological changes, in which stagnating levels of IDR&M diseases and conditions contrast with declining circulatory diseases. Increasing neoplasms is seen at old ages in subpopulations where circulatory diseases are diminishing, as in the *ongoing* and *successful* cluster; while diabetes presents a less straightforward pattern that affects only specific subpopulations. At least two catching-up processes are evidenced among the lagging and best-performing subpopulations: one is indicated by the reduction in IDR&M diseases in the *truncated* and *delayed* clusters' subpopulations; and the other is due to diminishing circulatory diseases in the *ongoing* cluster's subpopulations. In these two processes, some subpopulations are left behind and others are catching up. Positive and negative changes occur for most subpopulations mainly in ages 15 to 74 years. Remaining infant mortality no longer appears to be the main driver of improvements in the region; while mortality patterns in populations aged 1 to 14 years neither introduce significant differentials among subpopulations nor contribute any changes during the period of analysis.

#### **10.4 Conclusion**

Latin American mortality decline during the first decade of the twenty-first century seems to be driven by different ages and causes of death. A country gradient is observed in in this process, as subpopulations maintain similar levels as their counterparts in their respective countries, regardless of their spatial cluster. The similarities are evident more at the beginning of the

period of analysis, and they are a result of the countries' abilities to overcome IDR&M diseases and conditions, especially at young ages.

The first factor that causes differentials among these clusters is urbanization, meaning that a subpopulation differs according to the overall urbanization level of their country. Clusters summarize this differential: the *successful* and *ongoing* clusters contain mostly subpopulations from the most urbanized countries, which have overcome circulatory diseases and experience increases in neoplasms and diabetes; while the *failed* and *delayed* clusters comprise subpopulations from mostly less urbanized countries that are still stagnating with reduced IDR&M diseases and conditions while circulatory diseases are increasing. In the middle are subpopulations with mixed epidemiological profiles in which mortality improvements seem to be *truncated* for the period.

Within the countries, the drivers of subpopulation differentials vary. In Brazil, the urban gradient establishes major differentials among subpopulations in the process of moving forward in the health transition. In regard to the Brazilian subpopulation's differential linked to urbanization and its stage in the health transition, it seems to be greater than what would be expected from looking at just the mortality level differentials among its subpopulations. This means that – while the main and large cities in Brazil are experiencing fast progress in reducing circulatory diseases at older adult ages – its towns and rural areas are still lagging in their ability to reduce infant mortality.

To a lesser extent, the same occurs in Mexico and Colombia, where the main and large cities are largely more privileged than the subpopulations in the rest of their respective countries, with towns and rural areas neglected and barely managing to catch up with the advantages held by the main cities. The progress of Brazilian, Mexican and Colombian subpopulations are not converging, and they advance in their own health transitions at different paces, with towns and rural areas continuing to lag behind. For their part, sex differentials seem to be more important than urbanization in establishing differentials among subpopulations in Chile and Venezuela, where females benefit significantly more than males, regardless of where they live. In the Venezuelan case, this is even more pronounced because males no longer benefit as much as they previously did from the advantages of urbanization, which their female counterparts continue to do.

In summary, a catching-up effect is seen among countries (according to their urbanization level) and subpopulations (with towns and rural areas following in the path of main and large cities). However, these countries and subpopulations are benefiting differently from the progress achieved. This difference is sometimes hidden when analyzing mortality at the country level, because subpopulations undergoing a *failed* or *truncated* health transition coexist with subpopulations that are considered to be *successful*; thus, the noticeable progress seen in some countries at the national level could indeed be relying on subpopulations with different epidemiological profiles that are evolving in parallel with immutable differentials.



## CONCLUSIONS

From the literature review, one can conclude that in a context of rapid population growth -such as the one behind recent urbanization processes around the globe- the relation between urbanization and mortality decline is not necessarily depending on economic development. Recent urbanization has mostly occurred disentangled from development but not from population growth, which depends on fertility and mortality patterns. Beyond the increase of urban population, urbanization is thought to be associated with improvements in infrastructure and socioeconomic circumstances, both of which lead to better health outcomes and declining mortality. In addition, the city plays an important role in developing and concentrating innovations, which later spread by means of the urbanization process. Two outcomes of mortality patterns result from the recent urbanization processes: an *over-urbanization* effect, which is seen as an *urban penalty*; and an *urban bias* effect, evidenced by the persistent *urban advantage* in mortality. This means that rapid urbanization could be either detrimental or beneficial to populations living in urban spaces, and its relationship with development determines the urban-rural differential in mortality over the long term.

Urbanization and development have undeniably had a positive relationship in Latin America. Concentrating goods and services in large cities consistently results in resources being strategically used to develop the region in the context of exceptional rapid population growth. One should keep in mind that while Latin America is presented as one of the most urbanized regions in the world, it is also one of the least populated. The period of city expansion coincides with rapid mortality decline and reductions in infectious diseases at the national level. Spatial urban-rural mortality differentials emerged at the beginning of the urbanization process, when some areas developed more rapidly than others. The main and large cities were the first to see the introduction of sanitary controls, medical advances, the large-scale immunization of populations, the elimination of disease vectors, distribution of antibiotics, and the large-scale construction of drinking water and sewage disposal systems. All of these elements identified as playing the most important role in changing the region's epidemiological profile.

In the process in which a country goes from a mostly dispersed pattern of human settlement to one that is concentrated mostly in large cities, mortality has persistently declined faster in urban areas than in rural areas in Latin America. The urban advantage in mortality can be viewed as an outcome of resource reallocation and livelihood strategies that have favor the cities, especially the main and large cities. The privilege given to the capital cities and all the macro-level strategies adopted in the region play a key role in understanding the urban-rural differential in mortality decline. Increased urbanization and mortality decline cannot be detached from one another because the urban bias in resource allocation has been transversal in the region's developmental macro-policies. This could be the reason why mortality decline tends to proceed more rapidly in countries with higher levels of urbanization, as well as it is why the health transition has advanced more consistently in the main and large cities. Without refuting that Latin American cities have a history marked by poverty, precariousness, great inequality, insecurity and informality, the largest cities in the region have historically benefited the most from the development and modernization that occurs during urbanization processes.

Periods of full-blown macroeconomic, political, and institutional instability during the eighties made it difficult for some countries to stop the negative effects introduced by rapid urbanization. Reductions in public investment and a sweeping wave of privatization driven by neoliberal economic policies occurred just after the period of rapid urbanization in the region.

Cuts in public investment stopped the expansion of goods and services beyond the urban areas, at the same time, that there was a discontinuation of strategies to improve housing quality and to expand public facilities into the existing self-built shantytowns; subsidies disappeared; and public services were outsourced. Consequently, inequalities increased in the largest cities. Despite the incipient economic growth during a brief period in the nineties, little progress was made in achieving equitable income distribution. In the end, economic recovery did not make up for the increase in poverty that occurred during the eighties, and Latin America continued to be the most unequal region of the world.

Inequalities can be found in the process of mortality decline, which, at the national level, is driven by the growth of urban areas with their advantageous position, especially the large cities and capitals. When the largest cities stopped growing and reducing their decline, the medium-sized cities were unable to continue making noticeable improvements in the national context, which led to a sort of stagnation in improvements at the country level. Undoubtedly, changes in economic policies conceived for de-concentrating the largest cities during the phase of import substitution policies have favored medium-sized and small cities thus made them economically competitive. However, they still lag behind in several dimensions such as education, culture, recreation, and technological diversification. Indeed, it is only recently that Latin America started experiencing changes in the proportional wealth distribution in favor of medium-sized and small cities.

As a direct result of stagnation in public expenditures, access to effective health care and medications became more limited and the epidemiological profile in the region started to be representative of these changes. From this period on, changes in mortality patterns have been more greatly associated with individual access to commodities. The slowdown in life expectancy during the nineties coincides with epidemic outbreaks of previously eradicated diseases (such as cholera), a rise in diabetes, increasing to stagnating proportions of deaths due to cardiovascular diseases, and the spread of violence-related deaths. These were the added effect of the crisis to an epidemiological profile still showing high levels of infant mortality due to the remaining importance of infectious diseases in some subpopulations.

This context constitutes the starting point of the period of analysis for this research. Using cause-of-death analysis, I gained insight into the level of (under)development of the Latin American cities according to their sizes. In addition, it explained how their different levels could be translated into diverse, coexisting epidemiological patterns, commonly hidden when following an analysis of the national context. Seven countries were initially selected for carrying out this research. They were chosen based on their urbanization processes (measured as a percentage of the urban population) and their stages in the mortality transition (measured through their life expectancies). All cities were separated into three spatial groups according to their size and the dynamics of their historic demographics: the main-and-large-cities group (500,000 inhabitants or more); the medium-sized and small cities group (between 20,000 inhabitants and 499,999 inhabitants); and the towns-and-rural-areas group (less than 20,000 inhabitants).

Carrying out cause-of-death analysis at the subnational level involved great efforts to keep geographical areas comparable in terms of urbanization while also following these territories through time as well as through a vast number of demographic databases. I dealt with this challenge by classifying Minor Administrative Divisions (MIADs) according to their city's population size in the year 2000. With this classification, the geographical space occupied by the MIAD in the year 2000 was followed backward and forward through time, independently of

changes to the MIAD boundaries, namely by either splitting or merging them with other administrative divisions. Fixing a MIAD's geographical territory ensures being able to attach accurate events and person-years-lived to the same physical space.

After a thorough assessment of data quality at the spatial group level for the initial seven selected countries, it was possible to conduct an analysis of their mortality trends on only six of them, and at the end, only five countries had data that was accurate enough to estimate their spatial-cluster cause-of-death patterns. This means cause-of-death analysis was carried out for Brazil, Chile, Colombia, Mexico and Venezuela, while Peru was considered only for the age-specific mortality trend analysis and Ecuador was completely disregarded. In order to guarantee comparability in the cause-of-death coding of the International Classification of Diseases in its 10<sup>th</sup> version, the period of analysis focused on the years 2000 to 2010. One exception is Peru, for which the period 2003 to 2013 was used in the analysis, due to the country's data availability.

The literature review revealed that cases with the worst data quality – such as those with important proportions of unknown causes of death or ill-defined causes – are likely to be concentrated in social groups with less education and income while living under poorer conditions than the rest of the population (Arriaga 1999). At the same time, these populations are likely to be those with the highest mortality (Vallin 1979). By correcting mortality estimates for each spatial group independently, data quality issues were adjusted better. Because higher concentrations of services, goods and wealth occur in the larger cities rather than rural areas, the results underscore a positive relationship between urbanization and overall data quality. The most urbanized countries have the best data quality (Chile and Venezuela), while the least urbanized ones have the worst (Ecuador and Peru), regardless their mortality levels. Equally, the largest cities in each country have the best data quality when compared with the rest of the national territory.

Once data quality was guaranteed, classical demographic methods were invoked to properly assess whether Latin America has an urban (dis)advantage in mortality and, if so, whether it equally affects all ages and sexes during the period of analysis. In order to determine differentials in the spatial groups, I constructed standardized mortality rates and period life tables, then applied decomposition methods on life expectancy at birth by causes of death. This answered all of my research questions and allowed me to test my research hypothesis for this study.

The first finding of this research confirmed the persistence of the urban advantage in mortality during the first decade of the twenty-first century, as found historically throughout the literature review. Urban mortality maintains an advantageous position in terms of the initial and final levels during the period of analysis. All urban areas are better off than towns and rural areas, and the main-and-large-cities group has the lowest level of mortality. The urban advantage is seen in all countries, irrespectively of their mortality levels and proportions of urban population. However, the fact that the main-and-large-cities group has the highest life expectancy does not mean that all main and large cities have an exceptionally good performance in declining mortality; they just represent the best performance in their respective countries.

This advantage unequally affects sexes: females benefit largely from the urban advantage in comparison to the male populations in all countries. With Mexico as an exception, all female populations living in the main and large cities have both the best performance in their respective countries and continuous increases in life expectancy during the period of analysis.

For male populations, this is not always the case. The effect of increasing violence is associated with social inequality mostly found in urban agglomerations and “slums”, and it has deeply affected male subpopulations in Brazil and Venezuela’s main and large cities. The impact of violence alone has caused Venezuela’s main and large cities to lose their advantage in terms of mortality decline for the male subpopulation. Political-related violence together with institutional weakness in the *rule of law* have resulted in a proliferation of crime. Most Latin American countries experienced a fragile legitimacy of the state after periods of political upheaval and economic crisis during the eighties and nineties. This and a genuine culture of violence led to increasing homicide rates. The only detrimental elements acting against the main and large cities mortality patterns are the effects of violence-related deaths.

Differentials between spatial groups also vary among countries. The urban advantage may be seen at a dissimilar threshold, depending on the urbanization level of the country. It also may be independent of the country’s mortality levels and relative importance of capital cities. Thus, in the most urbanized countries of the sample (Chile and Venezuela), the main and large cities have the most distinctive mortality patterns when compared with other spatial groups; whereas the mortality patterns in less urbanized countries contrast urban and rural. This means that in less urbanized countries (Colombia, Mexico and Peru), the cities are more alike, whether they be main, large, medium-sized or small; while they are all different from the towns-and-rural-areas group.

When looking for age-specific trends driving the spatial-group differentials during the period of analysis, the general findings highlight that there is no spatial group that consistently registers constant improvements or deterioration for all age groups during the period. The best performing spatial group in terms of reducing the risk of dying at older adult ages is undoubtedly the main-and-large-cities group for all countries; whereas it is the towns and rural areas that see the most important decrease in the still relatively high infant mortality rate. Likewise, convergence in the subpopulation age-specific mortality levels occurs at infant ages for all the countries, while divergence is seen in older adult mortality. Convergence comes from the catching up of towns and rural areas, which are laggard populations in reducing infant mortality. Divergence at older adult ages, for its part, is due to the greater advantage of the main and large cities compared to other spatial groups.

Hardly any improvement exists in older adult ages outside the main and large cities. In fact, adult mortality reduction is related to urbanization and shaped by an urban gradient. The medium-and-small-cities groups are lagging in reducing the risk of dying not just at older adult ages, but even at young adult ages in some cases such as Brazil. Even Chile, the country with the lowest risk of dying at all ages, displays almost no improvements in the older adult mortality of its medium-and-small-cities group. For their part, towns and rural areas in most countries continue to lag in declining mortality at ages 15 and over.

Adult mortality does not follow a straightforward declining trend in all main-and-large-cities groups. There are some subpopulations with a parallel increasing risk of dying at young adult ages and a declining risk of dying at old adult ages. Such cases are Mexico and Venezuela, where the main and large cities are losing their advantages over the other spatial groups because they are not reducing or are even increasing young adult mortality. These opposite trends in age-specific adult mortality cancel each other out and when seen through synthetic indexes reveals inaction in decreasing mortality.

Until recently, improvements in Latin American mortality were driven mostly by a reduction in the risk of infant death. This seems to be noticeable only outside the main-and-large-cities

groups in most of the countries during the period of analysis of this research. Nowadays, the importance of the reduction in infant mortality only occurring in towns and rural areas is far from the main driver in increasing national life expectancy. In fact, it scarcely balances the negative impact of the increasing premature death of urban young adults, when this occurs in some countries.

The slowdown in increasing life expectancy at national levels is due mostly to unsuccessful efforts to reduce mortality in populations aged 45 years and over outside the main and large cities. In this sense, as the contributions of each spatial group to national mortality trends vary from country to country (depending on the group comprising the largest proportions of the population), it is the most urbanized countries that show the highest survival. Chile, the country in the sample with the most rectangular survival curve, is not only the most urbanized but also the one with the highest levels of metropolization and main-city primacy. A composition effect of the urban/rural population distribution favors the dominance of the main and large cities within the national mortality pattern.

Another question arose in this research in regard to identifying the roles played by urban bias in resource allocation in forming mortality patterns, specifically through an analysis of the amenability of causes of death. Amenable causes of death in this research were defined according to Tobias and Jackson's refined "avoidable mortality. They classified causes of death as avoidable through one or a combination of measures categorized as primary, secondary or tertiary interventions. Considering their approach on the sample of Latin American countries analyzed in the research showed that amenable causes of death exhibited a clear gradient between the spatial groups, with the main and large cities of all countries achieving the lowest rates of amenable mortality. Since amenable deaths are largely related to the existence of public infrastructures, goods and services, one can use mortality patterns to confirm the influence of urban bias in resource allocation on regional health outcomes.

As causes of death that are amenable to primary intervention include diseases and conditions susceptible to prevention, this group includes conditions related to infectious diseases, anemia, easily detectable neoplasms, car accidents, and injuries due to malfunction of public equipment, among others. An in-depth look reveals that these diseases and conditions account for health outcomes that can be avoided through access to basic medical attention, the existence of a basic "urban" infrastructure, or by the population having a minimum standard of living. In this sense, having areas with urban structures and minimum access to goods and services seem to be relevant to the spatial differential. Thus, the concentration of populations in the main and large cities allow for greater coverage of sewage and water systems, adequate housing, and proper roads, among other goods and services. Similarly, after investigating the impact of urbanization on health and well-being in China, Hou, Nazroo et al. (2019), found that improved health outcomes in urban areas compared with rural regions might be a function of a planned urbanization process and its associated improved basic infrastructure, such as the flushing toilet (Hou, Nazroo et al. 2019).

The distribution of amenable causes of death throughout the countries persistently shows an important sex differential, regardless of the proportional weight at the national level. For males, causes amenable to primary interventions occur at twice the rate of those amenable to secondary interventions; and they are nearly the same as non-amenable rates in all countries. This is mainly the result of higher mortality rates caused by traffic accidents and injuries. In contrast, the distribution of rates among female subpopulations is in general more even in the three groups of amenable deaths, but they still have the highest rates of causes that are

amenable to primary interventions than those amenable to secondary, tertiary or combined interventions.

The pattern of causes that are amenable to primary intervention set a dissimilar spatial threshold for the influence of urban bias in comparison with the previous identifiable urban advantage in mortality. In the most urbanized countries, the observable threshold of the urban advantage pertains to the main and large cities; and in the least urbanized countries it pertains to all cities, regardless of their size, and is in contrast with rural areas. The impact of the spatial differential in causes of death that are amenable to primary intervention appears to be more related to the role played by capital cities as centers of power and wealth within each country's city system.

For countries such as Chile and Colombia, the advantage of the main-and-large-cities group comes mostly from the low rates of causes that are amenable to primary interventions. This low proportion of deaths amenable to primary intervention is not seen when comparing how all amenable causes of death are distributed in the other spatial groups. In contrast, the advantage in Brazil, Mexico and Venezuela as a result of lower mortality rates due to primary interventions spreads to all cities and, to a lesser extent, reaches the towns and rural areas. The difference between these two groups of countries might be the result of strategies for de-concentrating their capital cities. Brazil, Mexico and Venezuela have consolidated strategies for de-concentrating their capital cities by creating new planned industrial cities or by consolidating secondary industrial metropolises and agro-industrial regions, as in the cases of Manaus in Brazil, Ciudad Guayana in Venezuela, and the system of industrial cities on Mexico's northern border. With this expansion, previously isolated or remote medium-sized and small cities became important to the national populations and wealth distribution, and they were the beneficiaries of large-scale public investments. At the same time, the strategies of Colombia and Chile led to an accelerated expansion of their larger cities, thus enlarging the demographic and economic weight of the major metropolises and expanding their areas of influence.

Differences in the threshold link the total urban advantage in mortality and the advantage found only due to causes amenable to primary intervention can be explained by the diffusion of behavioral dimensions in the urbanization process. Spatial spreading of secular values also plays a role in the catch-up effect of less developed areas in the same country. This is because the impact of urbanization goes beyond changes in the physical structure, and it results in the spread of knowledge on health innovations and changes in individual behaviors. Thus, a spatial diffusion gradient also mediates the process of behavioral urbanization. Due to lack of investment and the underdevelopment of spatial areas, the adoption of urban ("modern") ideals occurs faster than the deployment of services and goods. Adopting urban ideals is not always beneficial in terms of mortality patterns for all spatial areas. Some less urbanized subpopulations are nowadays suffering from the burden of diseases and conditions that were previously associated with urban behaviors in larger cities, such as obesity, diabetes, smoking and alcohol-related conditions, as well as violence-related deaths.

In addition to the advantage set by the urban bias in resource allocation, the urban advantage might also rely on a compositional effect of the population. Most of the region's wealth is concentrated in large cities; consequently, the advantage could come from a higher concentration of the non-poor population in the larger cities rather than the urban setting per se, especially if changes in mortality during the studied period are associated more with individual access to commodities than to macro-policies or large-scale public investments.

Lastly, the main result of this research concerns the role of urban bias in the relationship between urbanization and the health transition in Latin America. Reviewing the epidemiological changes that occurred in the region, Frenk et al. (1991) developed the hypothesis that changes in the structure of causes of death occur not as a linear process or as consecutive stages in the epidemiological transition, as was initially proposed by Omran (1971). In contrast, the mortality decline in Latin America occurred under a “polarized-prolonged” transitional model, which means progress took place together with unresolved, static and long-lasting gaps among the subpopulations. This polarization results from the coexistence of significant proportions of both communicable and non-communicable causes in all countries (Frenk et al. 1991). For the authors, polarization could be diluted when dividing the national context into primary gaps due to ethnicity, poverty and urban-rural differences. Since urbanization and development are tightly linked in Latin America and the main and large cities continue to be the most advantaged subpopulation in almost all dimensions of development, it was expected that their epidemiological profile would be more advanced in the health transition, e.g., they are predominated by deaths due to degenerative disease at older adult ages. Accordingly, the epidemiological profile in towns and rural areas would comparatively have a higher incidence of deaths due to circulatory and communicable diseases.

During the period of analysis of this research, communicable diseases seem to have played a negligible role in defining mortality patterns. In terms of communicable and non-communicable diseases in the national epidemiological profiles, what is more relevant than “polarization” is the “stagnation” outside the main and large cities, specifically in overcoming the lethality of circulatory diseases at adult ages. The cardiovascular revolution experienced by developed countries is only distinguishable in the mortality structure of Latin America’s main and large cities, regardless of the country’s level of urbanization.

Because the rural subpopulations are representative of underdevelopment in the region, the towns-and-rural-areas group for most countries still adheres to Frenk et al.’s hypothesis of the “polarized-prolonged” transitional model and its simultaneous proportions of both communicable and non-communicable causes. In this sense, the remaining infant mortality (due to infectious and parasitic diseases) and adult mortality (due mostly to circulatory diseases) coexist with diabetes, alcohol and smoking-related causes of death, traffic accidents and even violence-related death. Such cases are the towns and rural areas in Brazil, Colombia and Mexico.

In terms of subpopulations, those who are *successful* or *ongoing* in passing through the health transition exist mostly in the most urbanized countries. They are on their way to overcoming the predominance of deaths due to circulatory diseases and increasing neoplasms in the older adult population. For their part, subpopulations that are *failed* or *delayed* in passing through the health transition exist mostly in the less-urbanized-countries, where stagnation still occurs in terms of reducing communicable diseases and conditions while circulatory diseases are increasing. In the middle are subpopulations with mixed epidemiological profiles, in which improvements in mortality seem to be *truncated* for the period of analysis due to the detrimental impact of external causes of death and incipient diabetes.

In general, countries and subpopulations are benefiting differently from progress, and generalizations on the pace of change are hardly accurate. In countries such as Chile and Venezuela, progress is occurring through cycles of convergence/divergence among spatial groups, but at different stages. In Chile, the gap between the main-and-large-cities group and the rest of the country is more important than the simple urban–rural distinction, as the

primacy of its main cities remains a relevant consideration when studying mortality. In Venezuela, for its part, the urban-rural difference still matters because mortality patterns among large, medium-sized, and small cities are not as large as in Chile but very different from towns and rural areas. In both countries, the sex differential seems to be more relevant in the analysis of mortality patterns rather than of spatial differentials.

Conversely, in Brazil, Mexico and Colombia, the urban-rural differential in cause-of-death structures remains in a gradient throughout the process of mortality decline. The mortality patterns of the three spatial groups are largely dissimilar, giving the idea of three separate scenarios of development. This means that development strategies that are biased to urban areas maintain a persistent urban advantage because urban subpopulations benefit significantly and more rapidly from any positive changes toward a mortality decline. What is more, the main and large cities remain pioneers of the health transition. Even when towns and rural areas in these countries experience periods of rapid progress, catching-up with the initial urban advantage does not occur, and parallel profiles coexist at national levels.

### *Limitations and perspectives*

Palloni and Pinto Aguirre (2011) identified three main problems with all the analyses ever done on mortality estimates in Latin America: 1) the mortality of children under five years of age and that of adults were usually estimated separately; 2) measurements rarely consider long-trajectories or country comparisons; and 3) estimates were hardly analyzed within the scope of an explicit theory of mortality decline (Palloni & Pinto-Aguirre, 2011). In this research, most of these issues have been overcome when analyzing urban-rural mortality.

The first two issues addressed by Palloni and Pinto Aguirre are related to the general data quality in the region. As stated in Chapter five, large improvements have been made in the Latin American coverage and quality of registry data over recent decades. However, neither historic nor recent improvements have spread evenly across countries. In most countries, censuses and surveys continue to be the most trusted sources for estimating demographic phenomena. This means that the assessment and adjustment of demographic estimates are still in need of indirect estimation methods, which so far depends on age and separate measures of infant and adult mortality. In addition, the length of the inter-census period and years of occurrence vary among countries, as well as the availability of vital statistics and population estimations. All these elements make it difficult to analyze long-term estimates and/or make inter-country comparisons.

In this research, issues related to data quality and broad inter-country comparisons were addressed through the selection of a sample of countries representing different scenarios of urbanization and mortality levels. They were chosen as representative of the heterogeneity found in the region. In order to guarantee the most accurate and coherent mortality estimates possible for the selected countries, a combination of indirect methods were used on census data to adjust the annual estimates obtained by direct methods on vital statistics data. Even more, I also relied on demographic data extending beyond the period of analysis set by this research: a period of twenty-five years (1990 to 2015) was covered in order to correctly adjust the estimates for the 2000 to 2010 period of analysis.

Still, some limitations could be found regarding the impact of international migration on subnational population estimates. Indirect methods for adjusting mortality estimates



crosscheck population counts and their events (births, deaths, and migration) at two points in time, and there is no population registry in Latin America. Therefore, census data is the only available source for calculating population counts and migration flows during the period of analysis. Census data allows measuring domestic migration counts as well as international immigration counts, but not international emigration at the subnational level. Different strategies are found in the literature for estimating international emigration flows and stock when national population counts are considered. Here, international emigration counts were calculated at the national level, but hardly any alternative exists for subnational populations when considering the current available data in the region.

In countries such as Brazil, Venezuela and Chile, where international emigration rates remained low during the period of analysis, the omission of international emigrants have low impact when calculating mortality coverage in the registry data. In contrast, in countries like Ecuador, with high international emigration rates during the period, the omission of international emigration at the spatial group level would have led to important miscalculations of the registry coverage. For that reason, I had to leave Ecuador out of the analysis; despite it is the only country in the sample representing countries with a low level of urbanization.

Apart from the occasional study on the impact of international emigration on the demographic outcomes of a country's specific region or city, there has been no rigorous, comparative assessment conducted on international emigration at the subnational level in Latin America. This is mostly due to data availability. Further research must be done on the relevance of considering international emigration counts when assessing coverage of mortality statistics through indirect methods at the sub-national level, especially in countries with high international emigration rates and low mortality coverage.

One limitation to this study pertains to the arrangements for maintaining the comparability of spatial groups by size in all countries. Since each country defines "urban population" differently, and due to using the Minor-Administrative Division (MIAD) as the geographical link between different data sources, properly rural areas could not be distinguished from towns. In this sense, I carried out an analysis on infant mortality in Latin America, contrasting dichotomous and continuous approaches to urban-rural differentials over a thirty-year period (1980-2010). This showed that the towns-and-rural-area patterns in Peru and Colombia are comparable to those in rural areas alone (Garcia 2020). This indicates that using the 20,000-inhabitant limit, as an urban and rural division might be accurate when analysing their long-term mortality trends. However, when focusing just on the period of analysis in this research, towns (urban areas with less than 20,000 inhabitants) indicated faster improvements in infant mortality when compared with properly rural areas in Venezuela, Brazil and Mexico; while Chilean rural areas seemed to be better off than towns.

As shown by this research, infant and adult mortality most definitely display different behaviours in the region, which is the reason why we cannot generalize the accuracy of any specific spatial limits, neither to all age-specific mortality patterns nor to a long-term analysis. Further research should be conducted on existing mortality pattern differences between populations living in urban areas with less than 20,000 inhabitants and properly rural areas. The main challenge to this forthcoming research will lie in achieving a comparative inter-country analysis, since few vital statistics departments in the region make simultaneously urban-rural and MIAD variables publicly available.

Similarly, it would be appealing to explore the role played by the medium-sized-and-small-cities group in mortality decline at the national level. As shown in the results obtained by this

research, this spatial group does not always occupy an intermediate level between the mortality advantage of large cities and the disadvantage of rural areas. While this group's mortality pattern in some countries is clearly comparable to that of the large-and-main-cities group, it seems in others to be more similar to towns and rural areas. Aiming to better understand the heterogeneous behavior of this spatial group, further research might require splitting medium-sized from small cities in order to find a more detailed explanation of the differences among countries. Brazil would constitute a pertinent study case, due to the dissimilar roles observed when considering sex. Females living in the medium-sized-and-small-cities group in Brazil show considerably wider differences from other spatial groups than males do, as their mortality patterns are closer to those of their counterparts living in the main and large cities.

Aside from answering the research questions set for this study, other findings should be considered for future mortality research on the region. The first concerns how the clear relationship between urbanization and overall data quality turns out to be a key element when assessing health outcomes in subnational populations. As mentioned before, the assessment of the demographic data in the seven initially selected countries demonstrated that the spatial analysis of unadjusted data could lead to the wrong conclusions, which may be driven more by spatial biases in the vital statistics system coverage than by demographic phenomena per se. Likewise, what could be initially interpreted as an urban penalty on mortality could indeed be indicative of higher coverage of the advantaged subpopulations group in the vital statistics system.

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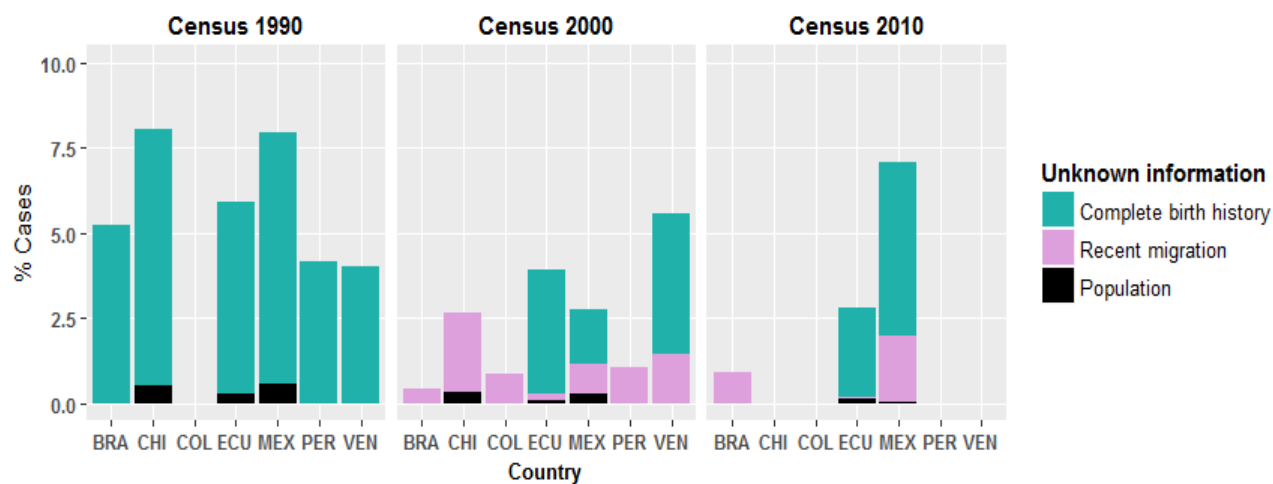
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## ANNEXES

Annexes A: Assessment of census data, Figure A.1. Proportion of cases in census with unknown information.<sup>19</sup>

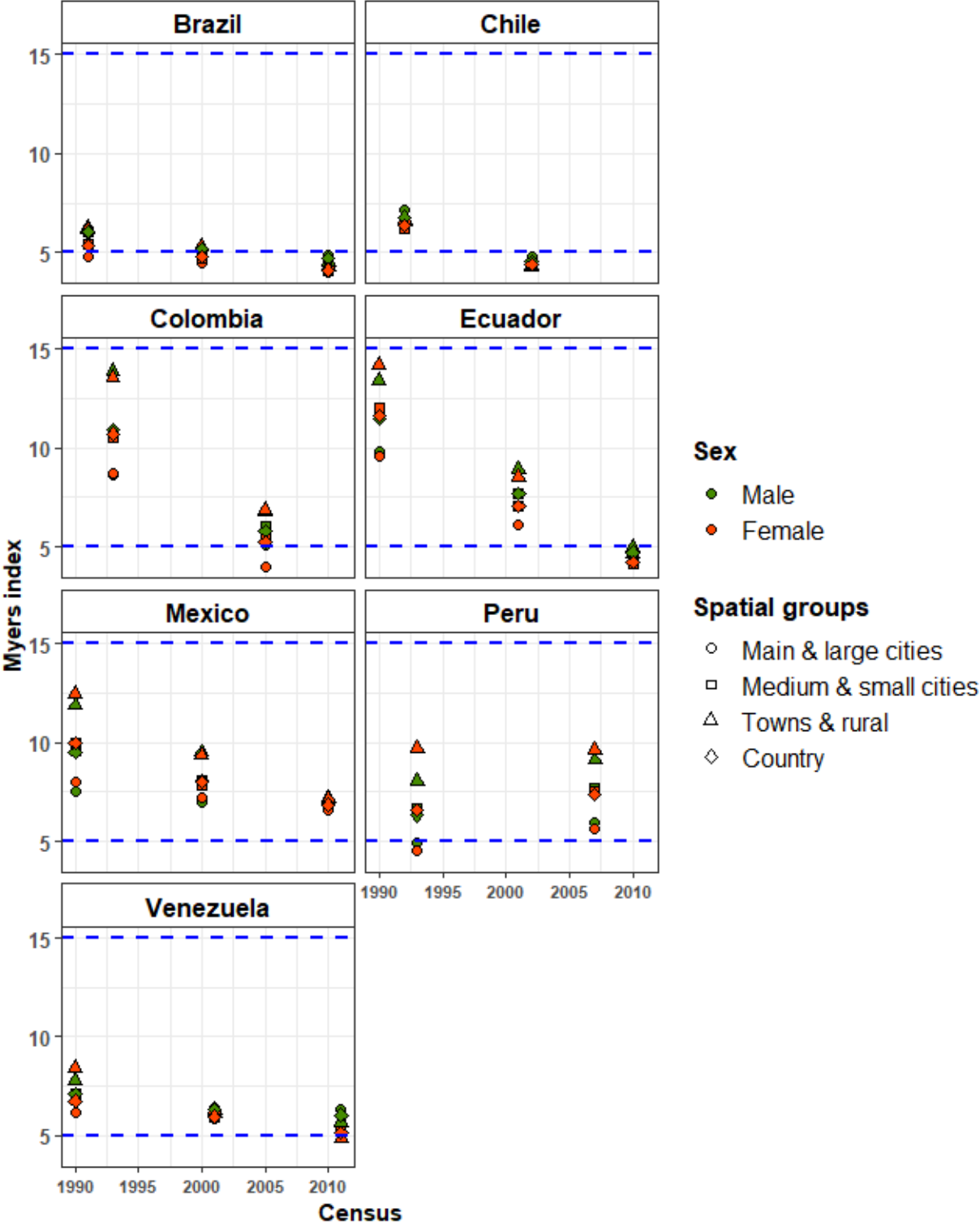


Source: Estimation using census data

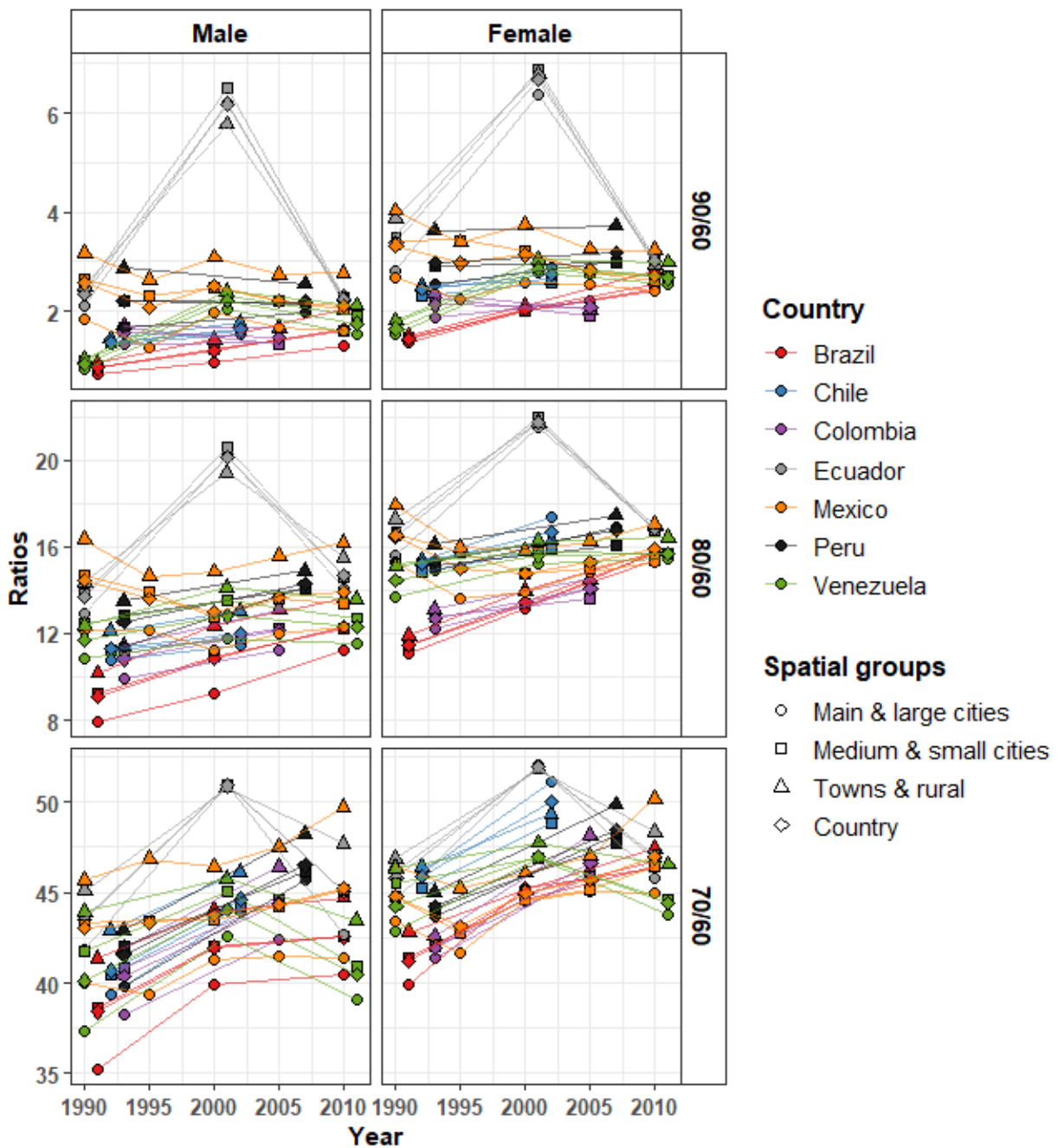
<sup>19</sup> There is least than 1 percent of cases without completed basic information in all eighteen population censuses considered for the seven selected countries (Figure A.1). It means that less than 1 percent of the cases have missing population information (age, sex or MIAD of usual residency information). However, information regarding migration and summary birth history has a much higher proportion of unknown information. Mexico and Chile nineties census round are the ones with the biggest proportion of cases with incomplete information. Their proportions of unknown population information are around 0.60 percent and missing information of summary births history around 7 percent.



Annexes A: assessment of census data, Figure A.2 Myers digit preference index.<sup>20</sup>



<sup>20</sup> The presence of age preference seems could be seen as normal around 5 (grey line) and less than 15 it is considered acceptable (Blue line). All sub-populations are below the blue line and close to normal levels. Towns and rural areas in Peru (1992) and Colombia (1992) are the only one closer to these acceptable levels than to normal levels.



<sup>21</sup> Age exaggeration is measure in three age cuts: exaggeration at age 70 and over, 80 and over and 90 and over. The intention here is to set the most convenient closing-age group in terms of comparability among the countries to apply indirect methods for determining adult mortality coverage in registered death counts. The ratio declared age-of-death at 60 and over to 70, 80 and 90 groups of Chile is used as benchmark to consider age exaggeration. Exaggeration in census data, it seems to be occurring in most of the countries over age 90. Brazil and Colombia keep levels for the three censuses round under Chilean boundary. Ecuador is the country with most evidence of persistent age misreported, especially in 1990's and 2000's census round for both sexes and all groups of cities. Age exaggeration in Ecuadorian population starts over 70 year in 1990's census. Town and rural areas in Mexico and Peru also have ratios higher than expected in all censuses conferring at population 80 and over and population 90 and over. Male populations tend to have more age-exaggeration in census data than female in all countries and periods.

## Annexes B: Migration estimations, Table B.1 Estimated annual emigration stock

Years	Female							Male						
	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela
1990	272253	242906	549479	107666	2036367	161560	102518	224970	246435	457563	104980	2357540	148240	82764
1991	299961	244389	569866	118553	2249844	182933	108715	246476	245780	475692	174364	2609758	164175	87426
1992	327668	245873	590254	129440	2463321	204306	114912	267982	245124	493821	243749	2861977	180109	92088
1993	355376	247356	610641	140327	2676797	225679	121110	289489	244469	511951	313133	3114195	196044	96751
1994	383083	248840	631029	151214	2890274	247052	127307	310995	243813	530080	382518	3366414	211978	101413
1995	410791	250323	651416	162101	3103751	268425	133504	332501	243158	548209	451902	3618632	227913	106075
1996	436749	252716	675076	174639	3341044	290898	142026	350659	243349	569008	404199	3902709	244465	113102
1997	462708	255109	698736	187178	3578337	313371	150548	368818	243541	589808	356497	4186877	261018	120129
1998	488666	257503	722395	199716	3815631	335844	159070	386976	243732	610607	308794	4470864	277570	127155
1999	514625	259896	746055	212255	4052924	358317	167592	405135	243924	631407	261092	4754942	294123	134182
2000	540583	262289	769715	224793	4290217	380790	176114	423293	244115	652206	213389	5039019	310675	141209
2001	569673	265769	819019	280754	4395186	412649	187884	443839	248874	691698	265644	5171339	337280	149082
2002	598764	269249	868322	336716	4500156	444508	199654	464385	253632	731190	317899	5303660	363885	156955
2003	627854	272729	917626	392677	4605125	476368	211425	484932	258391	770682	370154	5435980	390491	164829
2004	656945	276209	966929	448639	4710095	508227	223195	505478	263149	810174	422409	5568301	417096	172702
2005	686035	279689	1016233	504600	4815064	540086	234965	526024	267908	849666	474664	5700621	443701	180575
2006	724841	283243	1082526	521415	4953930	581140	249516	550186	267701	908709	488805	5824288	468467	193000
2007	763647	286797	1148819	538230	5092796	622194	264067	574347	267494	967752	502946	5947954	493233	205425
2008	802453	290351	1215112	555044	5231663	663248	278618	598509	267287	1026795	517086	6071621	518000	217850
2009	841259	293905	1281405	571859	5370529	704302	293169	622670	267080	1085838	531227	6195287	542766	230275
2010	880065	297459	1347698	588674	5509395	745356	307720	646832	266873	1144881	545368	6318954	567532	242700
2011	883688	302769	1364887	587266	5560581	755342	314669	646635	271178	1156946	540352	6369911	576904	246936
2012	887311	308079	1382077	585858	5611767	765327	321617	646437	275483	1169011	535336	6420868	586276	251172
2013	890933	313390	1399266	584451	5662952	775313	328566	646240	279789	1181077	530320	6471824	595648	255409
2014	894556	318700	1416456	583043	5714138	785298	335514	646042	284094	1193142	525304	6522781	605020	259645
2015	898179	324010	1433645	581635	5765324	795284	342463	645845	288399	1205207	520288	6573738	614392	263881

Source: Annual linear interpolation of the five-years "international migrant stock: migrants by destination and origin" estimations, done by United Nations Department of Economic and Social Affairs (DESA); base on census rounds estimations worldwide, and updated on 2015 (DESA 2015).

Annexes B: Migration estimations, Table B.2 Proportional distribution of emigrant stock in main origin by census and sex

Latin American origin immigrant in the United State distribution by age						
Age	census 1990		census 2000		census 2010	
	male	female	male	female	male	female
0	0,0188	0,0194	0,0216	0,0226	0,0176	0,0181
1	0,0890	0,0875	0,0824	0,0816	0,0831	0,0817
5	0,0998	0,0986	0,1036	0,1025	0,0967	0,0950
10	0,0909	0,0911	0,0907	0,0901	0,0906	0,0888
15	0,0940	0,0872	0,0916	0,0852	0,0919	0,0869
20	0,1068	0,0917	0,1031	0,0893	0,0905	0,0811
25	0,1107	0,0998	0,0992	0,0897	0,0867	0,0811
30	0,0957	0,0933	0,0911	0,0848	0,0834	0,0797
35	0,0746	0,0740	0,0837	0,0825	0,0777	0,0769
40	0,0559	0,0594	0,0658	0,0684	0,0685	0,0684
45	0,0420	0,0468	0,0500	0,0530	0,0602	0,0602
50	0,0327	0,0360	0,0359	0,0407	0,0472	0,0492
55	0,0270	0,0303	0,0239	0,0289	0,0345	0,0380
60	0,0223	0,0268	0,0181	0,0230	0,0253	0,0299
65	0,0169	0,0218	0,0142	0,0181	0,0168	0,0213
70	0,0092	0,0140	0,0112	0,0159	0,0121	0,0159
75	0,0067	0,0109	0,0075	0,0116	0,0081	0,0115
80	0,0068	0,0114	0,0064	0,0121	0,0091	0,0163

Colombian origin immigrant in Venezuela distribution by age				
Age	census 1990		Census 2001	
	male	female	male	female
0	0,0006	0,0006	0,0012	0,0019
1	0,0100	0,0078	0,0211	0,0252
5	0,0266	0,0197	0,0564	0,0636
10	0,0445	0,0391	0,0674	0,0795
15	0,0596	0,0455	0,1058	0,1360
20	0,0724	0,0591	0,1984	0,1900
25	0,0867	0,0729	0,1639	0,1393
30	0,0992	0,0972	0,1195	0,1047
35	0,1085	0,1104	0,0863	0,0788
40	0,1074	0,1174	0,0620	0,0526
45	0,1103	0,1076	0,0394	0,0369
50	0,0884	0,0922	0,0273	0,0247
55	0,0587	0,0689	0,0154	0,0160
60	0,0471	0,0516	0,0121	0,0117
65	0,0323	0,0406	0,0070	0,0112
70	0,0250	0,0296	0,0059	0,0100
75	0,0128	0,0188	0,0044	0,0078
80	0,0100	0,0207	0,0066	0,0101

Chilean origin immigrant in Argentina distribution by age				
Age	census 1991		Census 2001	
	male	female	male	female
0	0,0060	0,0048	0,0009	0,0009
1	0,0722	0,0523	0,0399	0,0353
5	0,0914	0,0717	0,1114	0,0938
10	0,0710	0,0552	0,1039	0,0848
15	0,0838	0,0876	0,0694	0,0686
20	0,0760	0,0787	0,0768	0,0808
25	0,1056	0,0674	0,1133	0,1440
30	0,0853	0,0900	0,1274	0,1517
35	0,0954	0,0931	0,1185	0,1128
40	0,0902	0,1132	0,0843	0,0788
45	0,0641	0,0866	0,0561	0,0495
50	0,0766	0,0659	0,0388	0,0289
55	0,0403	0,0432	0,0207	0,0206
60	0,0242	0,0310	0,0158	0,0138
65	0,0041	0,0183	0,0083	0,0119
70	0,0015	0,0179	0,0068	0,0079
75	0,0034	0,0139	0,0034	0,0062
80	0,0090	0,0091	0,0045	0,0096

Source: IPUMS U.S. Census microdata <https://usa.ipums.org/usa/>, Argentinean (1991, 2001) and Venezuelan (1990, 2001) Censuses

Annexes B: Migration estimations, table B.3: Inter-census mortality rates by country sex, age group and census round

Males											
Age	1990-2000							2000-2010			
	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela	Brazil	Ecuador	Mexico	Venezuela
5	0,0004	0,0002	0,0004	0,0007	0,0005	0,0010	0,0004	0,0003	0,0005	0,0003	0,0003
10	0,0004	0,0002	0,0003	0,0006	0,0004	0,0007	0,0004	0,0004	0,0006	0,0003	0,0003
15	0,0007	0,0003	0,0006	0,0010	0,0005	0,0009	0,0006	0,0006	0,0009	0,0003	0,0006
20	0,0010	0,0004	0,0008	0,0012	0,0007	0,0011	0,0008	0,0008	0,0010	0,0004	0,0007
25	0,0013	0,0004	0,0009	0,0015	0,0009	0,0014	0,0009	0,0010	0,0011	0,0006	0,0008
30	0,0017	0,0005	0,0011	0,0018	0,0011	0,0018	0,0012	0,0014	0,0014	0,0008	0,0010
35	0,0023	0,0008	0,0015	0,0022	0,0015	0,0023	0,0016	0,0020	0,0018	0,0011	0,0015
40	0,0034	0,0012	0,0021	0,0030	0,0023	0,0031	0,0024	0,0029	0,0024	0,0018	0,0022
45	0,0050	0,0020	0,0031	0,0040	0,0034	0,0044	0,0036	0,0043	0,0034	0,0027	0,0032
50	0,0073	0,0033	0,0049	0,0054	0,0053	0,0061	0,0054	0,0062	0,0045	0,0043	0,0050
55	0,0103	0,0052	0,0079	0,0081	0,0081	0,0092	0,0086	0,0091	0,0066	0,0068	0,0076
60	0,0152	0,0083	0,0119	0,0119	0,0125	0,0144	0,0131	0,0136	0,0089	0,0107	0,0118
65	0,0226	0,0134	0,0194	0,0186	0,0193	0,0234	0,0206	0,0200	0,0128	0,0168	0,0186
70	0,0366	0,0217	0,0308	0,0285	0,0297	0,0371	0,0320	0,0307	0,0201	0,0262	0,0296
75	0,0572	0,0355	0,0493	0,0457	0,0455	0,0544	0,0535	0,0473	0,0312	0,0408	0,0487
80	0,1225	0,1035	0,1233	0,1188	0,1194	0,1337	0,1315	0,1044	0,1133	0,1171	0,1269

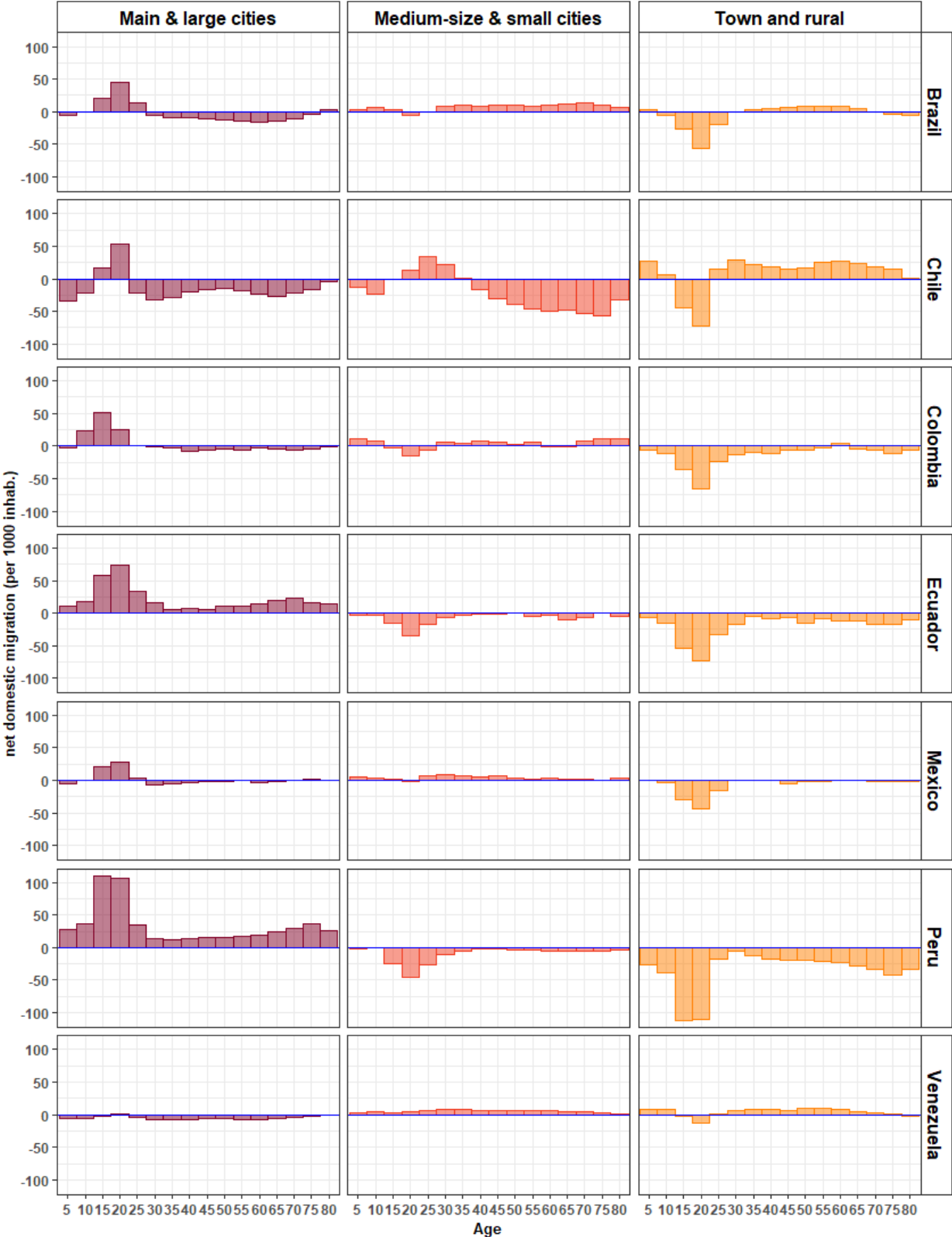
  

Females											
Age	1990-2000							2000-2010			
	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela	Brazil	Ecuador	Mexico	Venezuela
5	0,0006	0,0002	0,0005	0,0009	0,0006	0,0013	0,0005	0,0005	0,0007	0,0005	0,0005
10	0,0007	0,0003	0,0006	0,0009	0,0006	0,0009	0,0006	0,0005	0,0007	0,0005	0,0005
15	0,0021	0,0008	0,0027	0,0015	0,0013	0,0014	0,0018	0,0019	0,0017	0,0009	0,0021
20	0,0034	0,0012	0,0047	0,0022	0,0021	0,0021	0,0027	0,0031	0,0028	0,0015	0,0035
25	0,0039	0,0014	0,0047	0,0028	0,0027	0,0025	0,0027	0,0035	0,0033	0,0020	0,0033
30	0,0046	0,0016	0,0044	0,0032	0,0032	0,0029	0,0029	0,0040	0,0034	0,0025	0,0031
35	0,0056	0,0020	0,0047	0,0039	0,0037	0,0036	0,0031	0,0047	0,0039	0,0030	0,0031
40	0,0070	0,0026	0,0048	0,0049	0,0046	0,0047	0,0040	0,0061	0,0044	0,0038	0,0036
45	0,0094	0,0039	0,0054	0,0063	0,0062	0,0065	0,0057	0,0082	0,0059	0,0050	0,0051
50	0,0128	0,0061	0,0075	0,0082	0,0086	0,0092	0,0088	0,0109	0,0068	0,0069	0,0078
55	0,0179	0,0095	0,0115	0,0116	0,0123	0,0138	0,0136	0,0155	0,0094	0,0099	0,0117
60	0,0241	0,0147	0,0166	0,0160	0,0179	0,0206	0,0201	0,0215	0,0133	0,0145	0,0174
65	0,0333	0,0231	0,0269	0,0239	0,0261	0,0320	0,0311	0,0303	0,0189	0,0216	0,0272
70	0,0502	0,0357	0,0401	0,0378	0,0380	0,0481	0,0448	0,0445	0,0274	0,0324	0,0388
75	0,0726	0,0555	0,0620	0,0585	0,0553	0,0706	0,0667	0,0637	0,0390	0,0485	0,0562
80	0,1344	0,1220	0,1412	0,1324	0,1321	0,1481	0,1491	0,1146	0,1240	0,1313	0,1418

Source: Palloni, Pinto-Aguirre et al, 2014. Latin American Mortality Database LAMBDA. Inter-census adjusted mortality rates

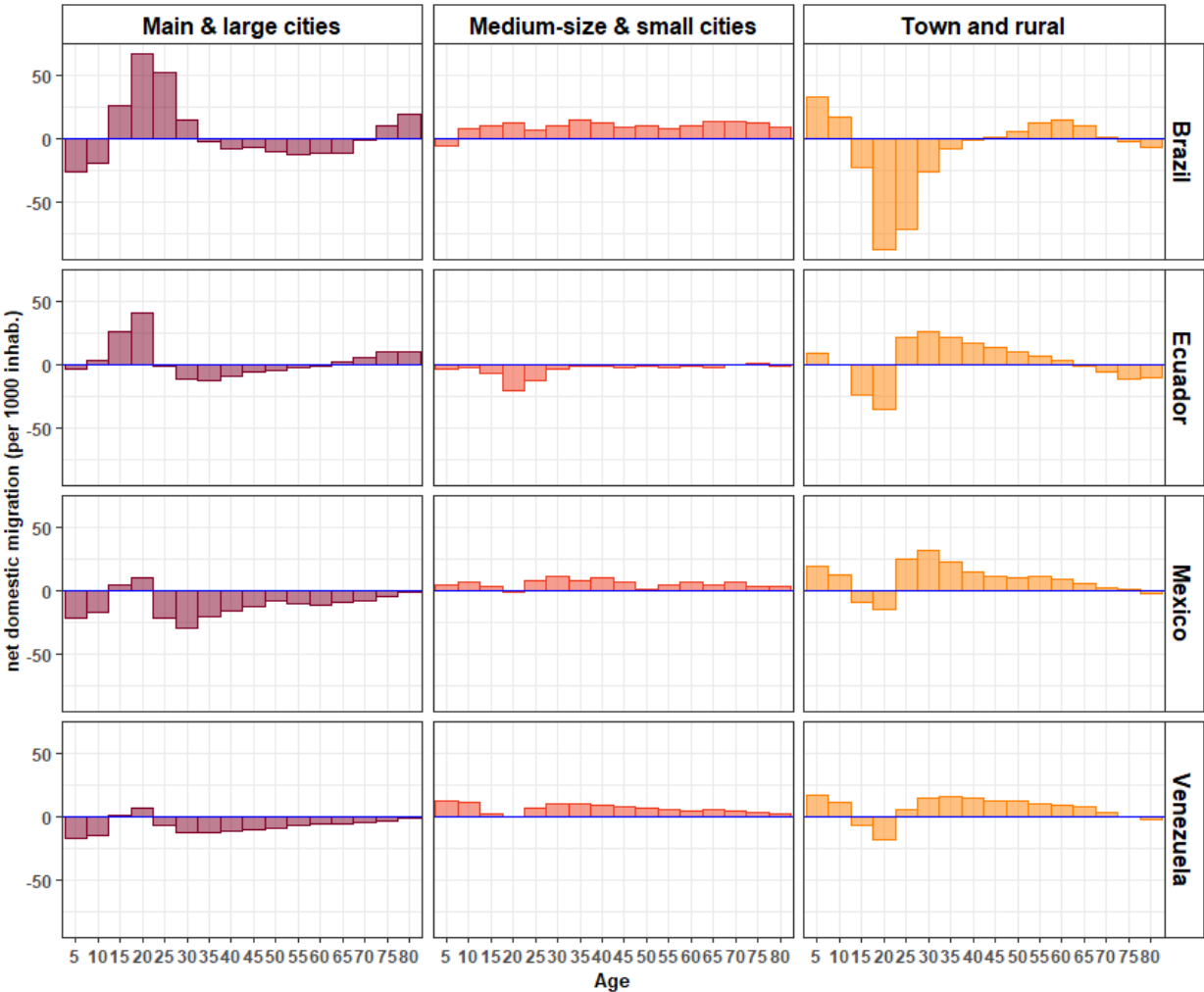
Annexes B: Migration estimations, Figure B.4: Male domestic net migration (per 1000 inhabitants) by spatial group

Period 1990-2000



Source: Census round 2000's in all countries

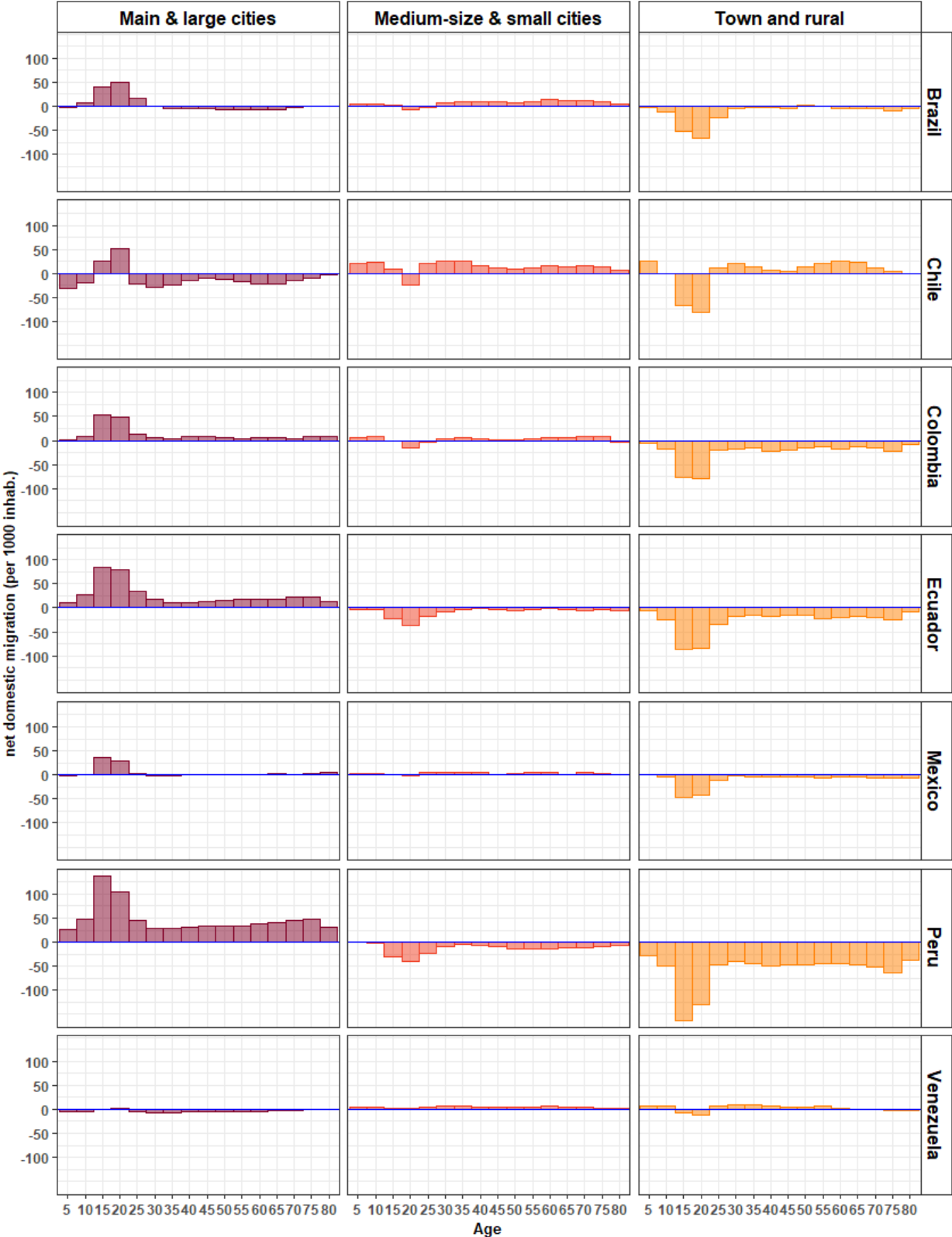
Period 2000-2010



Source: Census round 2010's in all countries

Annexes B: Migration estimations, Figure B.5: Female domestic net migration (per 1000 inhabitants) by spatial group

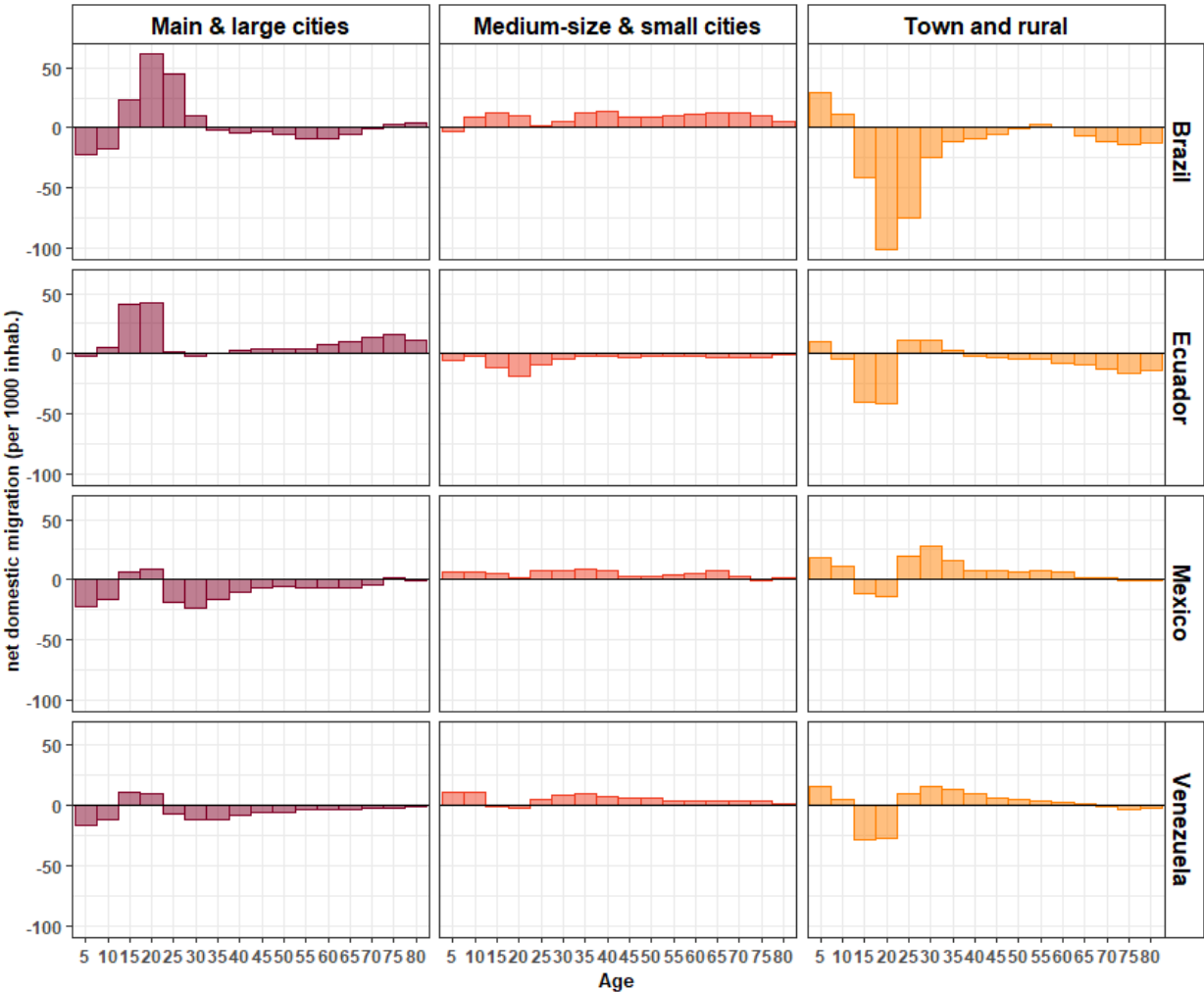
Period 1990-2000



Source: Census round 2000's in all countries



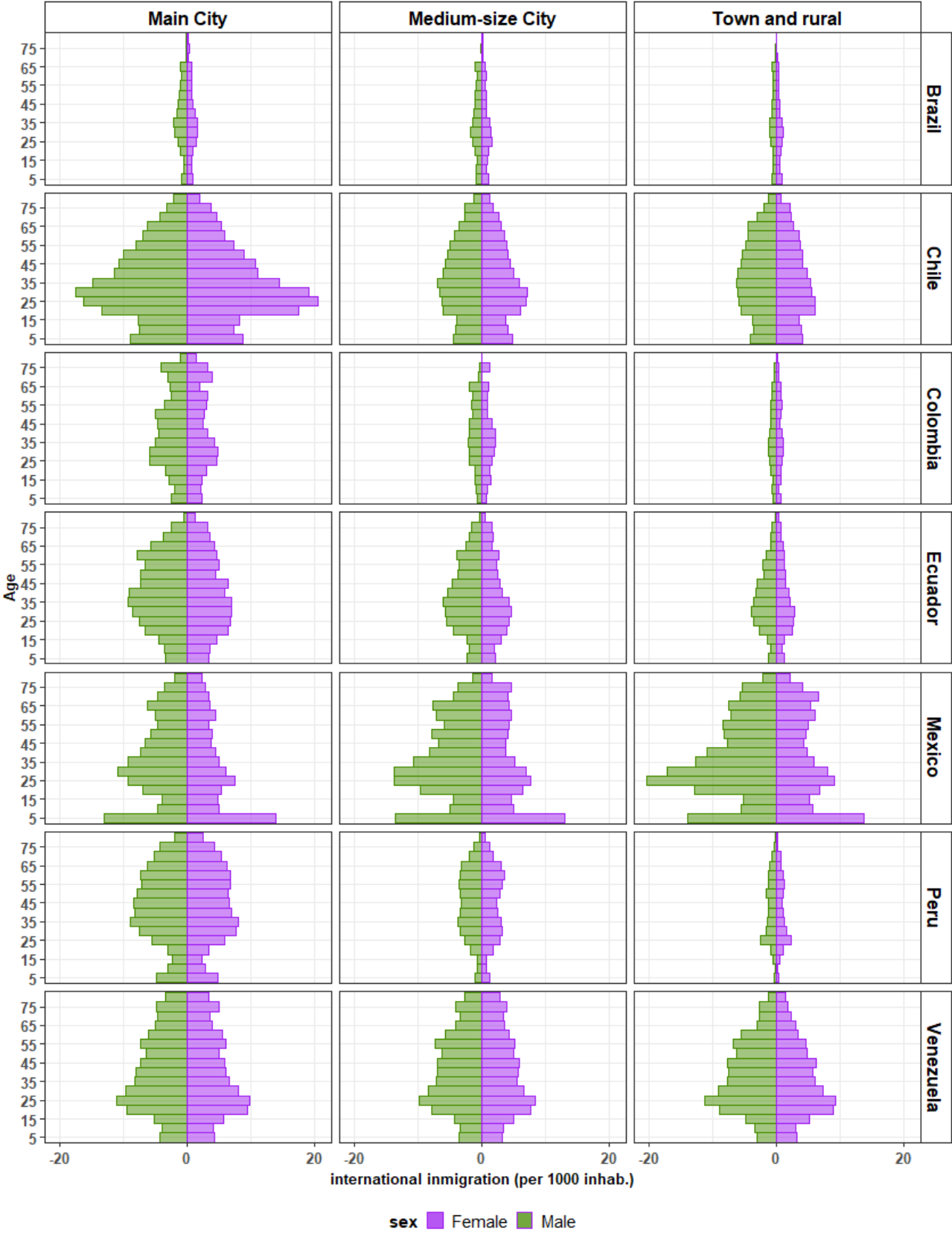
Period 2000-2010



Source: Census round 2000's in all countries

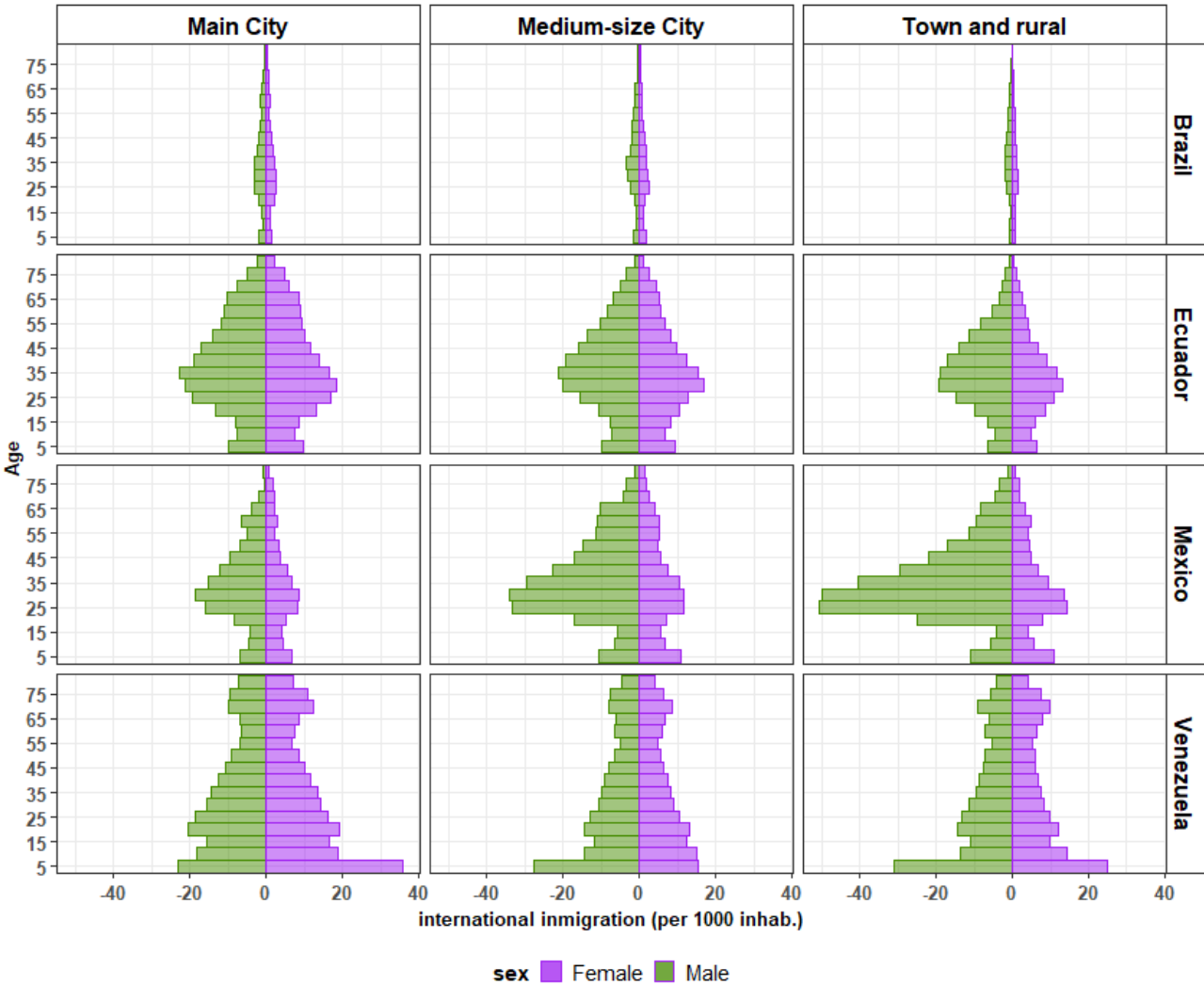
Annexes B: Migration estimations, Figure B.6: international immigration (per 1000 inhabitants) by spatial group

Period 1990-2000



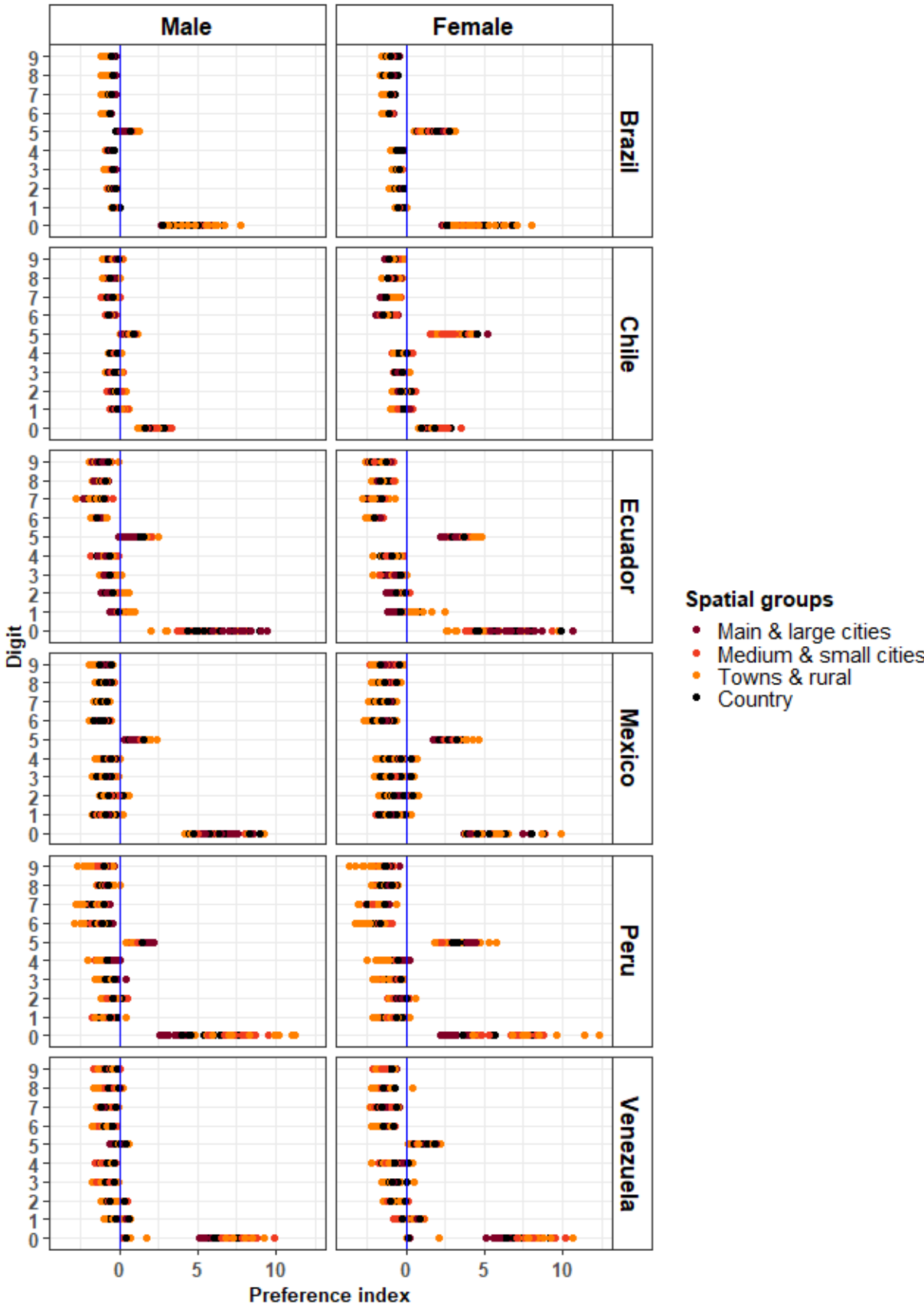
Source: Census round 2000's in all countries

Period 2000-2010



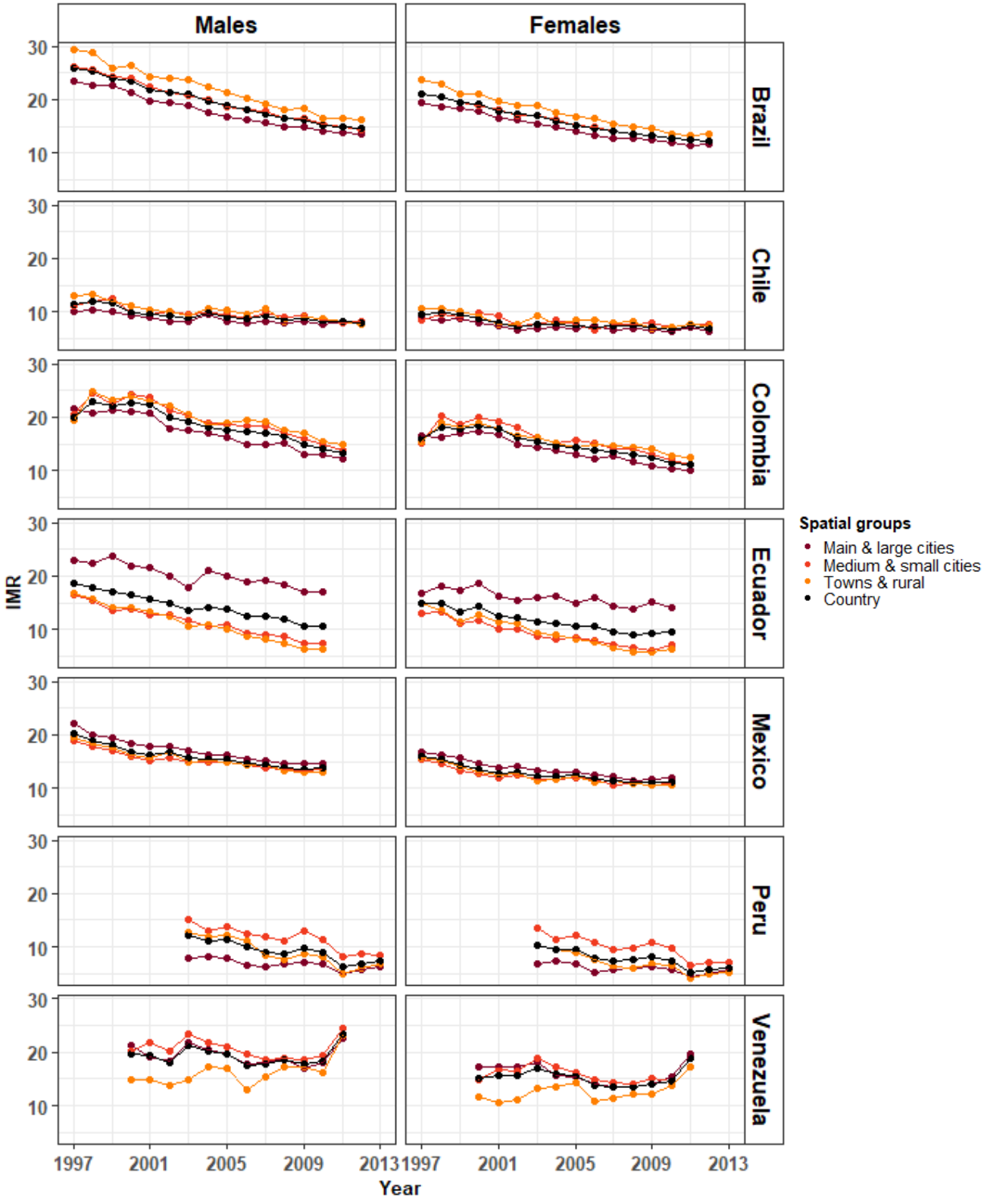
Source: Census round 2010's in all countries

Annexes C: age and sex preference in declaration, Figure C.1 Annual Myers preferences index by digit, sex, spatial group and country.



Source: Registered death database in all countries.

Annexes D: Infant mortality coverage, Figure D.1 Infant mortality rates by sex using unadjusted registry data.



Source: Unadjusted registered death and birth counts in all the countries.

Annexes D: Infant mortality coverage, Table D.2 Spatial group' gap linear regression model by country.

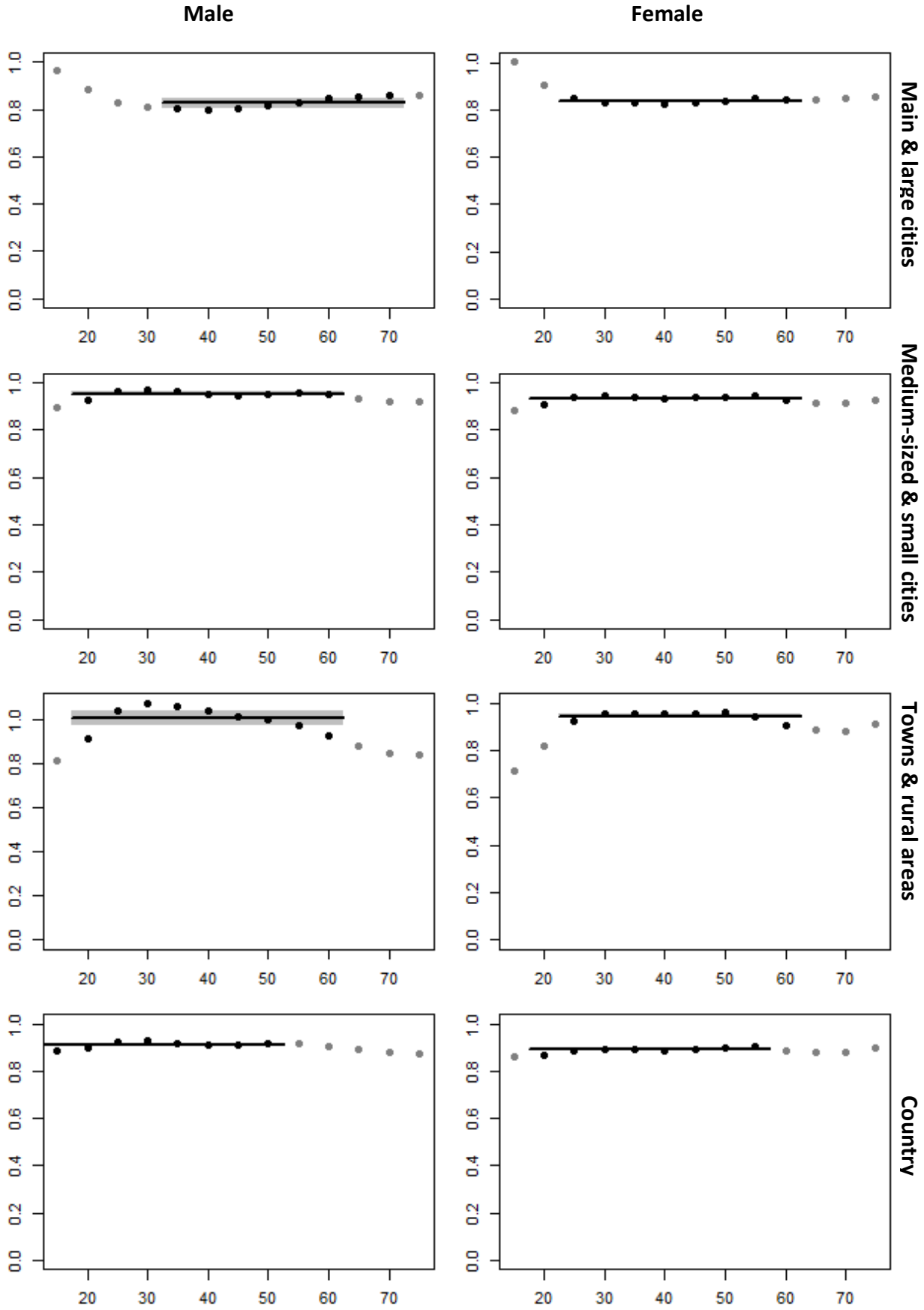
Country	Spatial groups	b1	b2	p-value	Standar Error	R-squared
Brazil	Main & large	8.43	-0.0038	0.3269	0.0035	0.159
	Medium-sized	2.124	-0.0005	0.8854	0.0038	0.003
	Town & Rural	4.979	-0.0017	0.9414	0.0233	0
Chile	Main & large	-17.394	0.0092	0.0331	0.0024	0.824
	Medium-sized	0.732	0.0001	0.9454	0.0016	0.001
	Town & Rural	10.609	-0.0525	0.124	0.0247	0.599
Colombia	Main & large	-1.374	0.0011	0.5552	0.0013	0.413
	Medium-sized	-9.083	0.005	0.0493	0.0003	0.994
	Town & Rural	11.66	-0.0052	0.1256	0.001	0.961
Ecuador	Main & large	-26.835	0.0138	0.0131	0.0051	0.259
	Medium-sized	12.64	-0.0058	0.0671	0.003	0.15
	Town & Rural	36.746	-0.0176	0.0893	0.0099	0.131
Mexico	Main & large	-8.619	0.0047	0.704	0.0121	0.012
	Medium-sized	16.549	-0.0077	0.5991	0.0143	0.023
	Town & Rural	32.81	-0.0157	0.4088	0.0183	0.057
Peru	Main & large	-13.335	0.0069	0.1221	0.0026	0.77
	Medium-sized	2.699	-0.0008	0.5436	0.0011	0.208
	Town & Rural	-8.125	0.0047	0.2366	0.0028	0.582
Venezuela	Main & large	-11.41	0.0061	0.003	0.0009	0.865
	Medium-sized	5.439	-0.0022	0,0000	0.0002	0.935
	Town & Rural	21.057	-0.0099	0.3732	0.0104	0.114

Annexes D: Infant mortality coverage, Table D.3 Percentage of coverage of registered IMR by sex and spatial group

Country	sex	Spatial groups	Coverage		
			Mean	Min	Max
Brazil	Male	Main & large	97	86	100
		Medium-sized	90	78	100
		Town & Rural	70	60	78
	Female	Main & large	98	87	100
		Medium-sized	89	77	99
		Town & Rural	69	60	76
Country			84	67	96
Chile	Male	Main & large	100	100	100
		Medium-sized	100	100	100
		Town & Rural	100	100	100
	Female	Main & large	100	100	100
		Medium-sized	100	100	100
		Town & Rural	100	100	100
Country			100	100	100
Colombia	Male	Main & large	97	89	100
		Medium-sized	84	74	95
		Town & Rural	89	71	95
	Female	Main & large	97	90	100
		Medium-sized	85	71	96
		Town & Rural	87	71	93
Country			88	76	98
Ecuador	Male	Main & large	100	100	100
		Medium-sized	53	47	57
		Town & Rural	37	27	43
	Female	Main & large	100	99	100
		Medium-sized	52	47	58
		Town & Rural	39	28	48
Country			50	45	54
Mexico	Male	Main & large	100	98	100
		Medium-sized	80	70	94
		Town & Rural	59	52	67
	Female	Main & large	99	97	100
		Medium-sized	80	71	93
		Town & Rural	60	52	67
Country			77	70	86
Peru	Male	Main & large	84	67	96
		Medium-sized	79	73	87
		Town & Rural	43	33	49
	Female	Main & large	90	76	100
		Medium-sized	81	74	89
		Town & Rural	40	33	46
Country			45	36	52
Venezuela	Male	Main & large	99	94	100
		Medium-sized	100	99	100
		Town & Rural	75	62	94
	Female	Main & large	100	97	100
		Medium-sized	100	94	100
		Town & Rural	72	42	87
Country			100	95	100

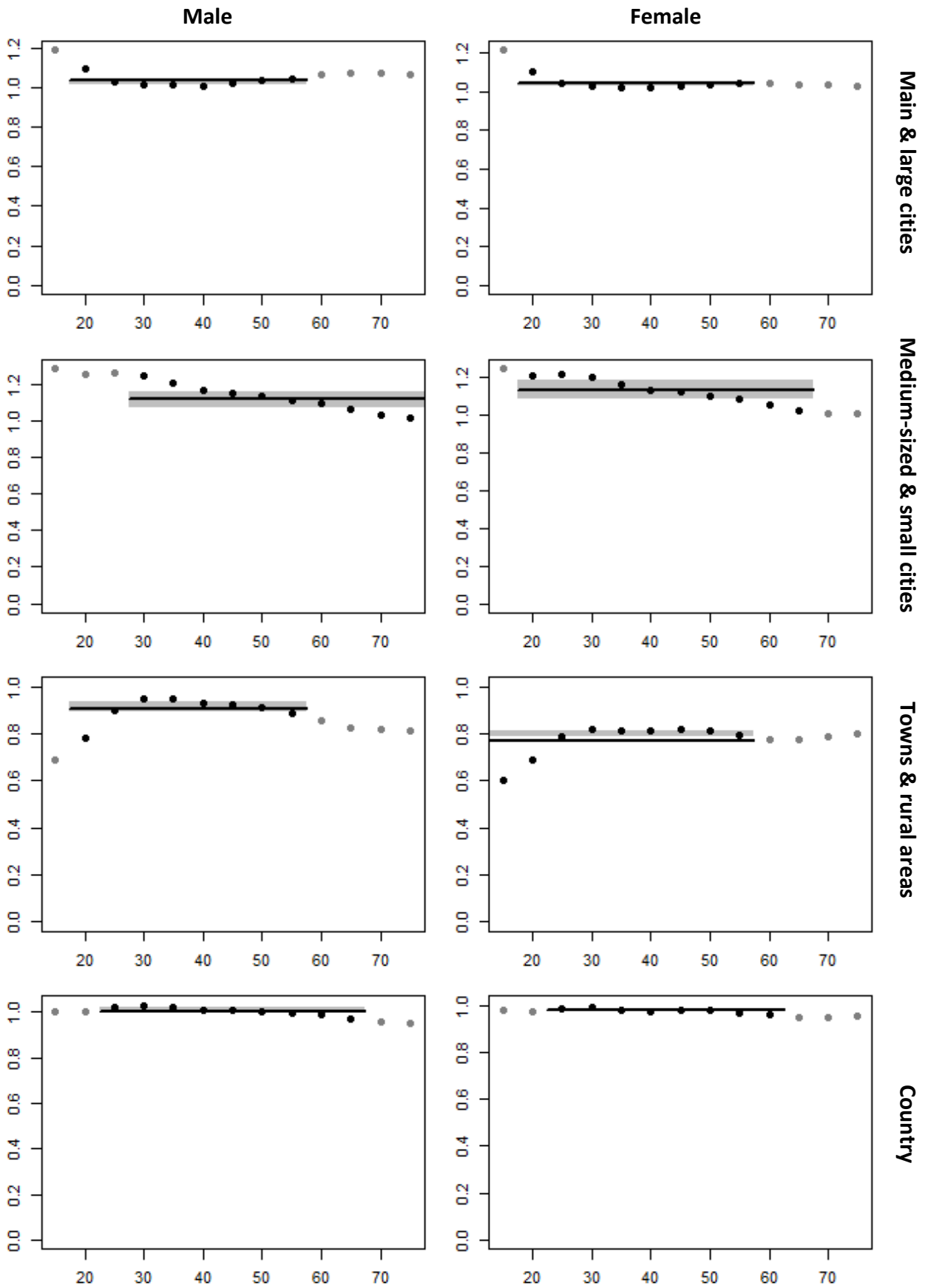
Annexes E: adult mortality coverage, Figure E.1. GGB-SEG age-pattern of coverage estimates with census data.

**Brazil 1990-2000**

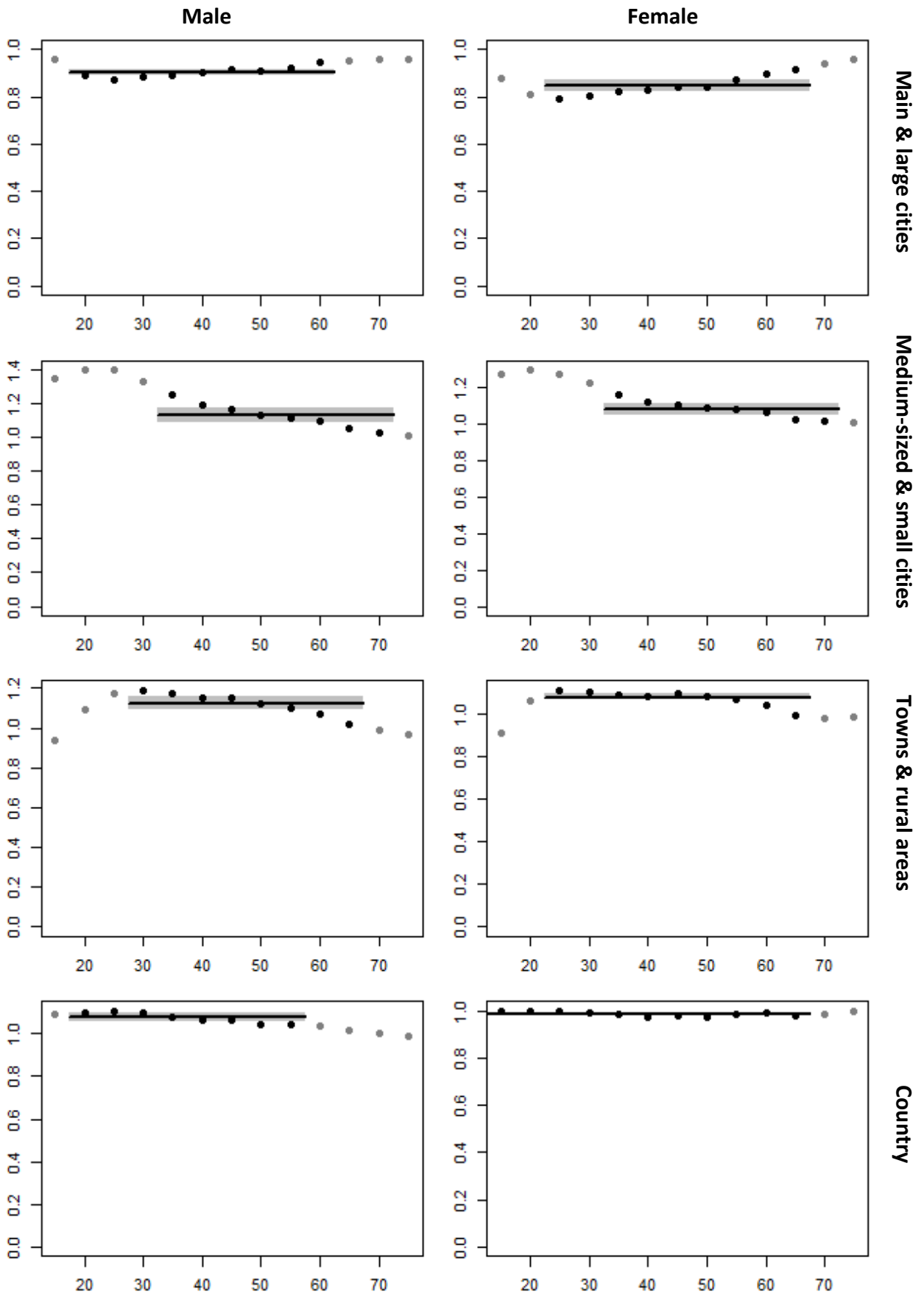




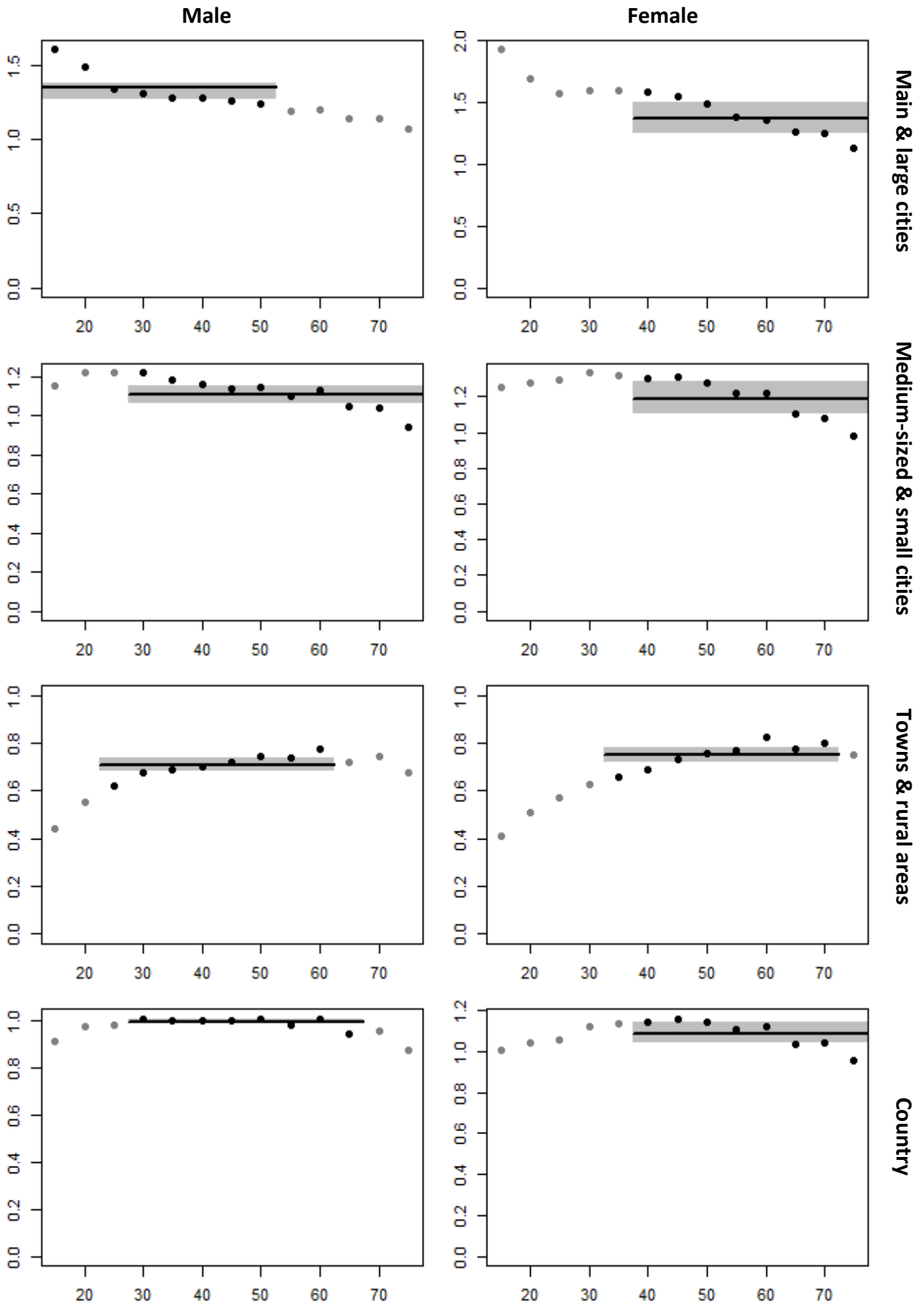
**Brazil 2000-2010**



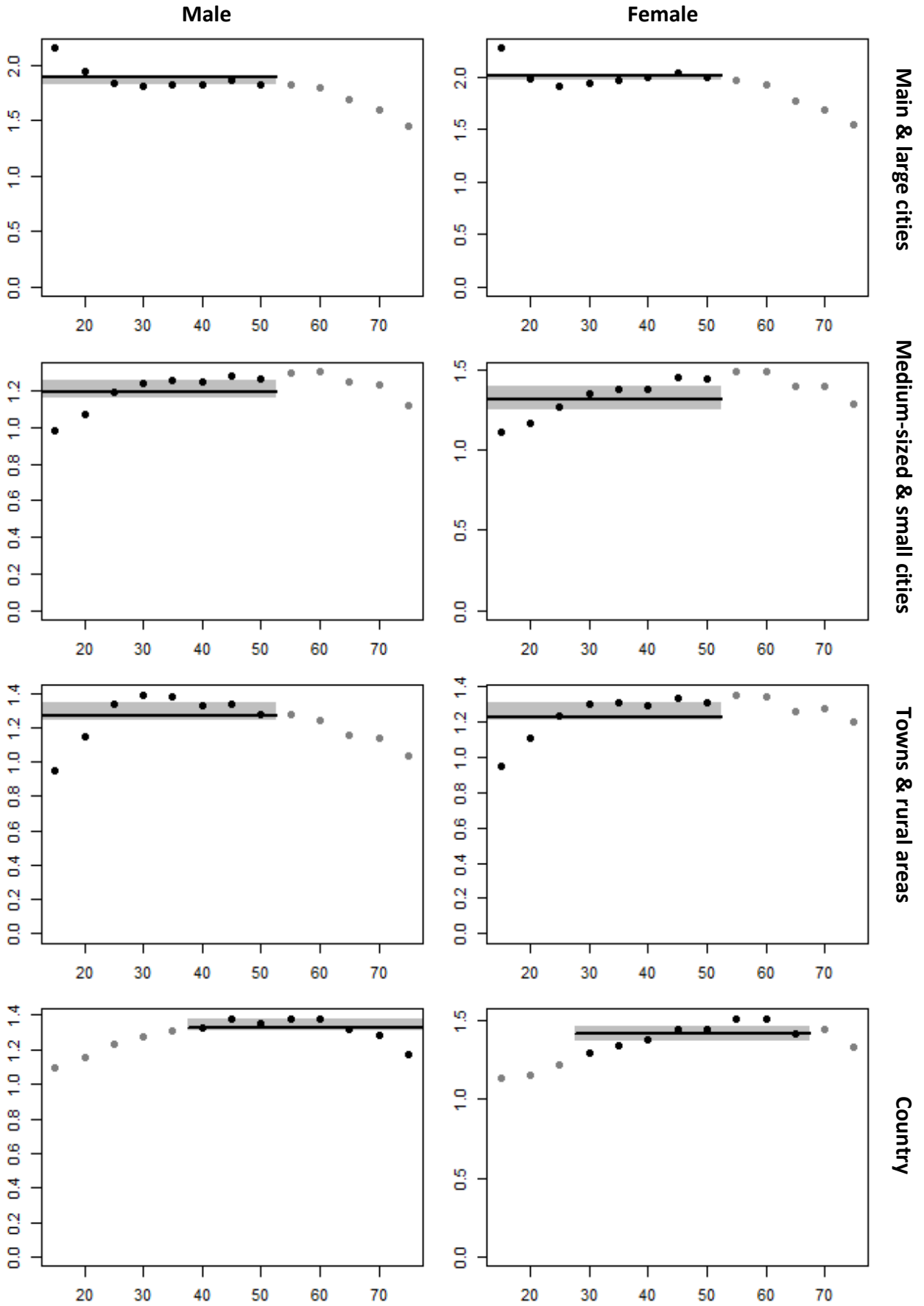
**Chile 1992-2002**



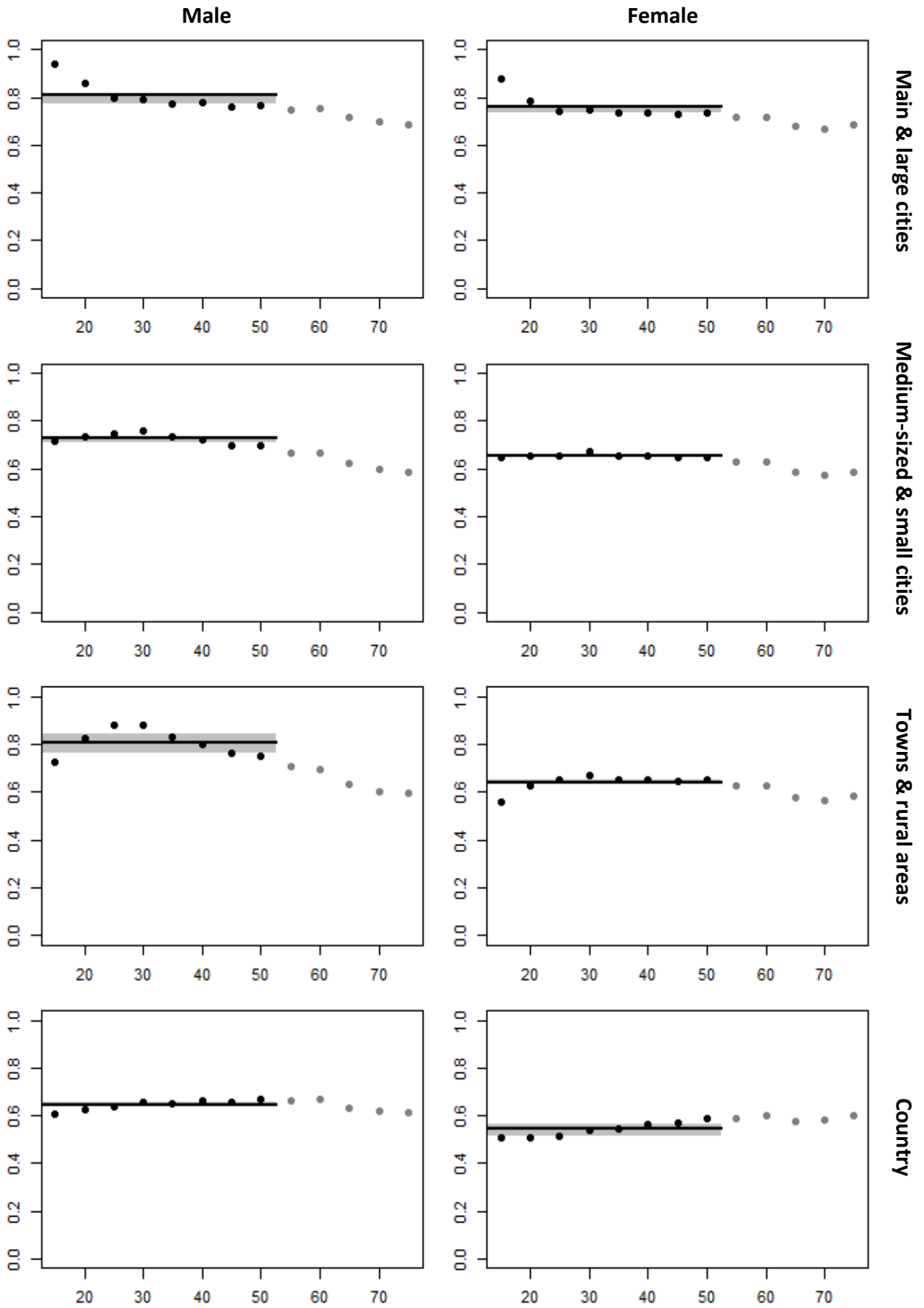
Colombia 1993-2005



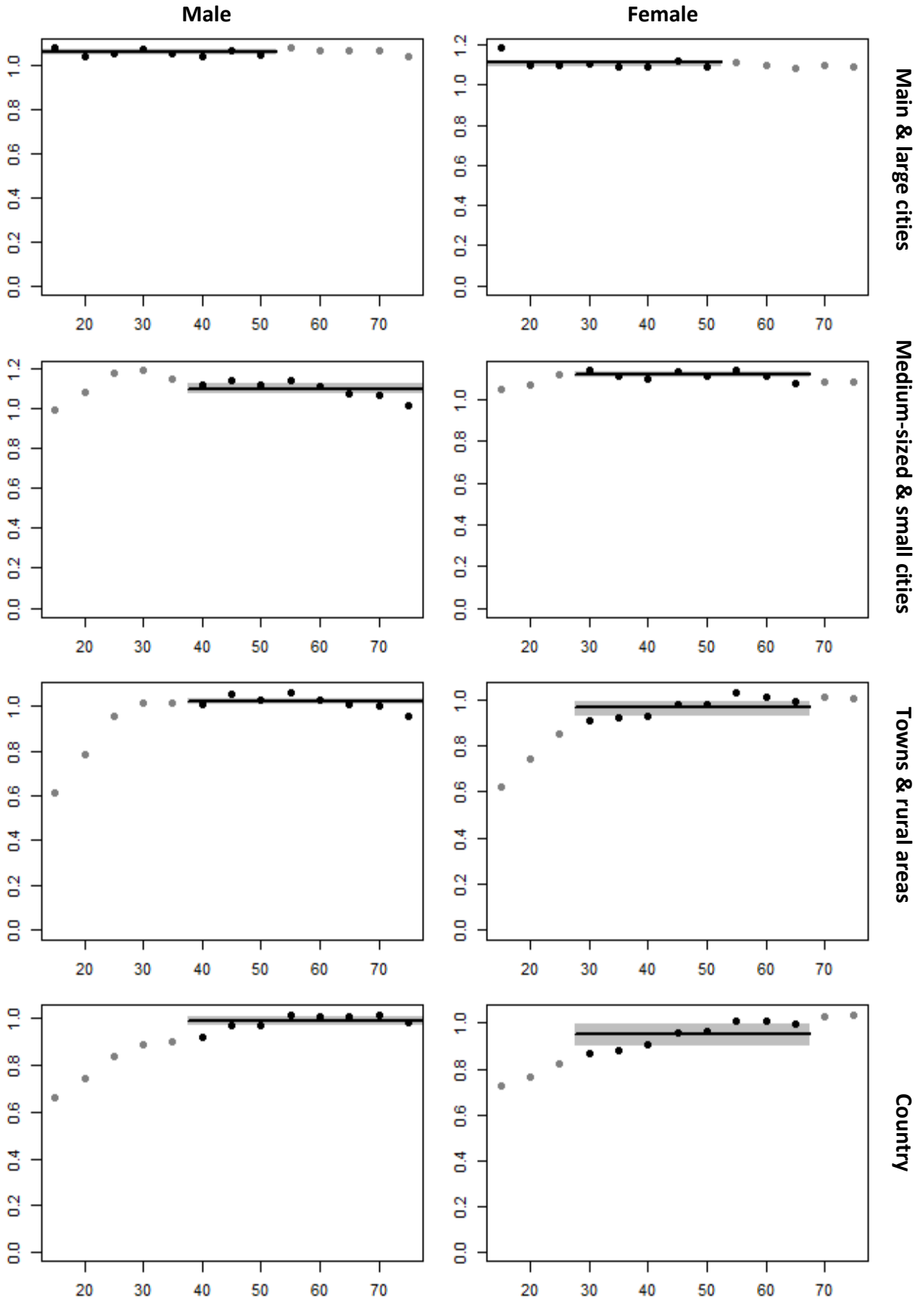
Ecuador 1991-2000



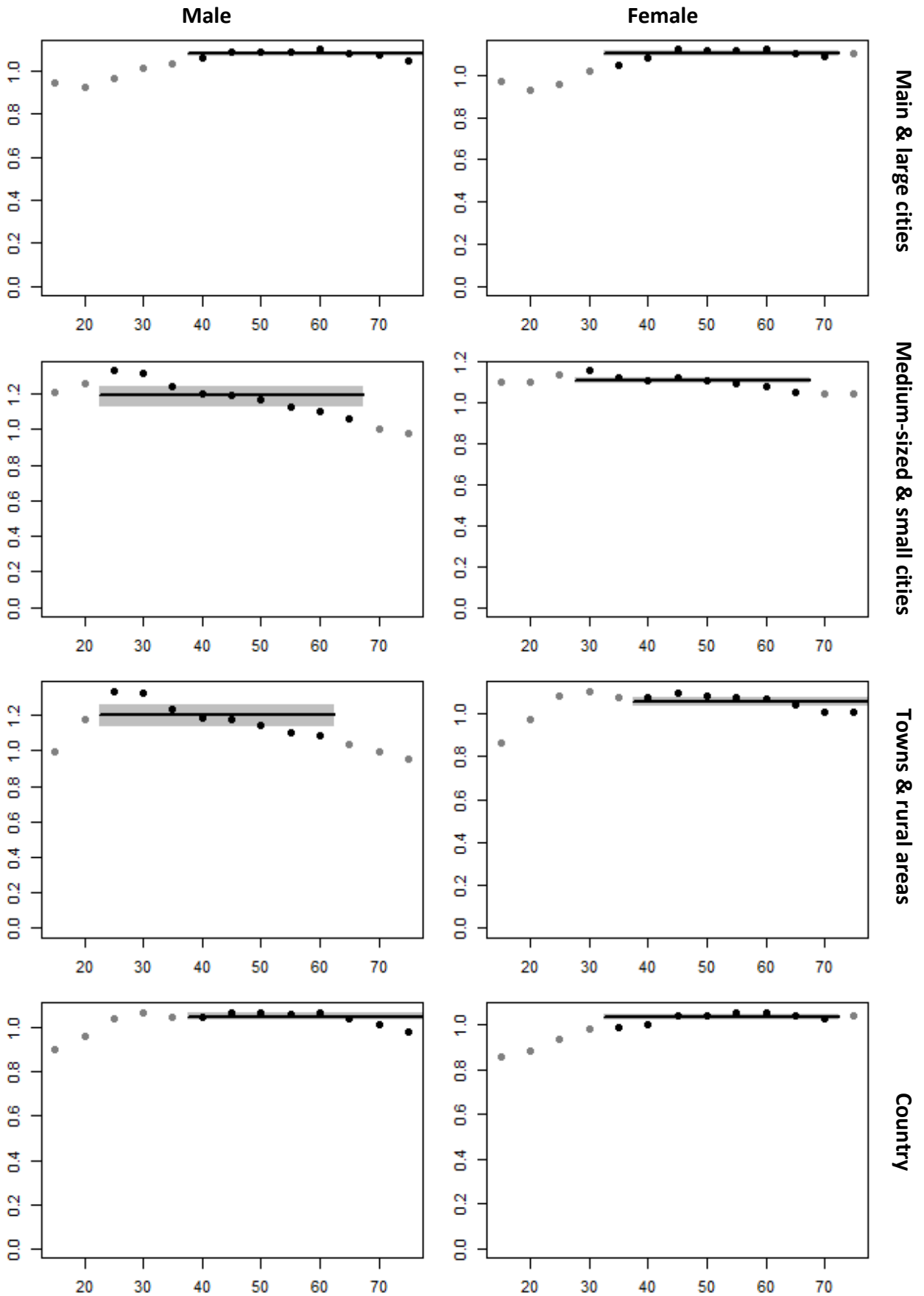
Ecuador 2000-2010



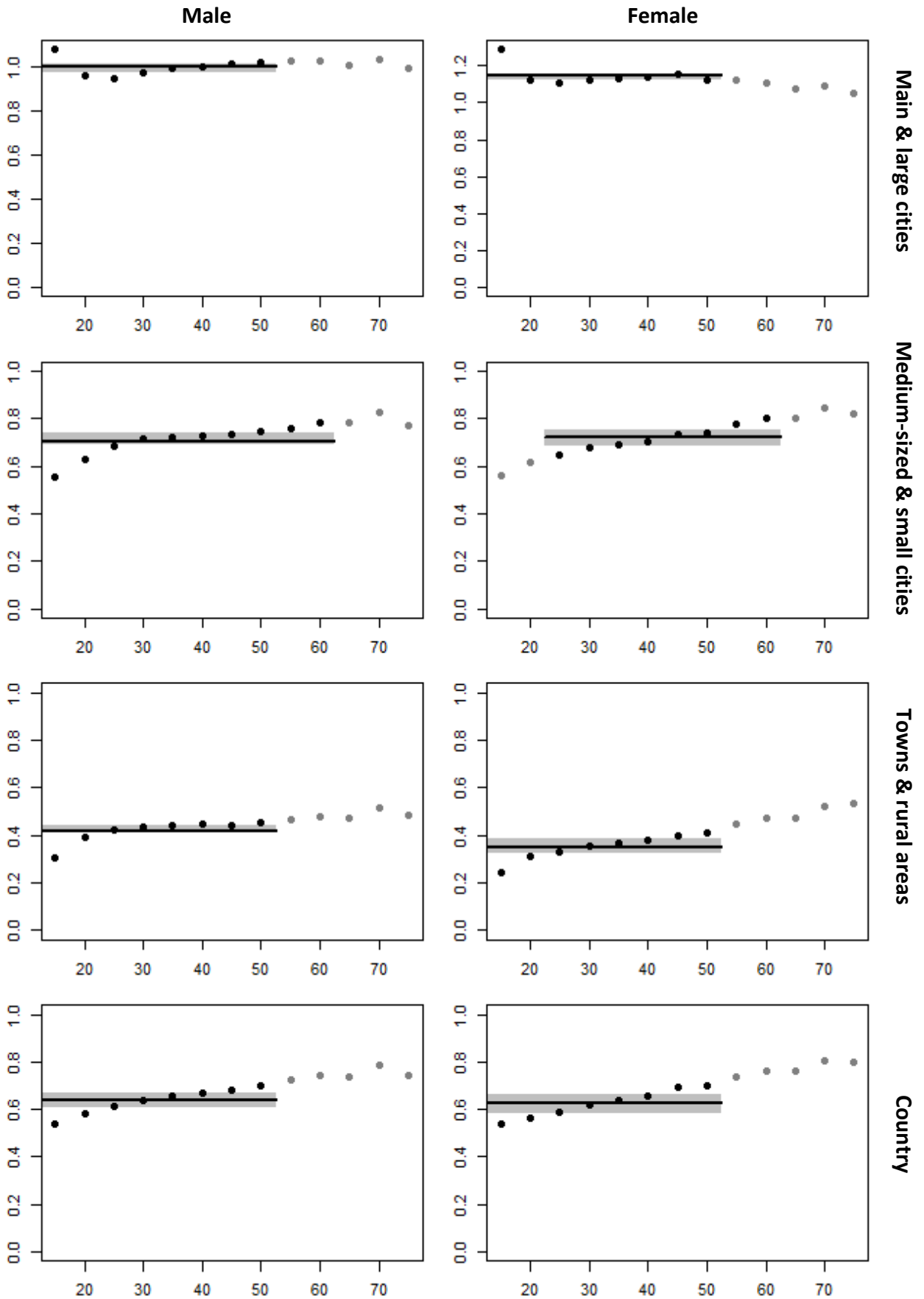
Mexico 1990-2000



Mexico 2000-2010

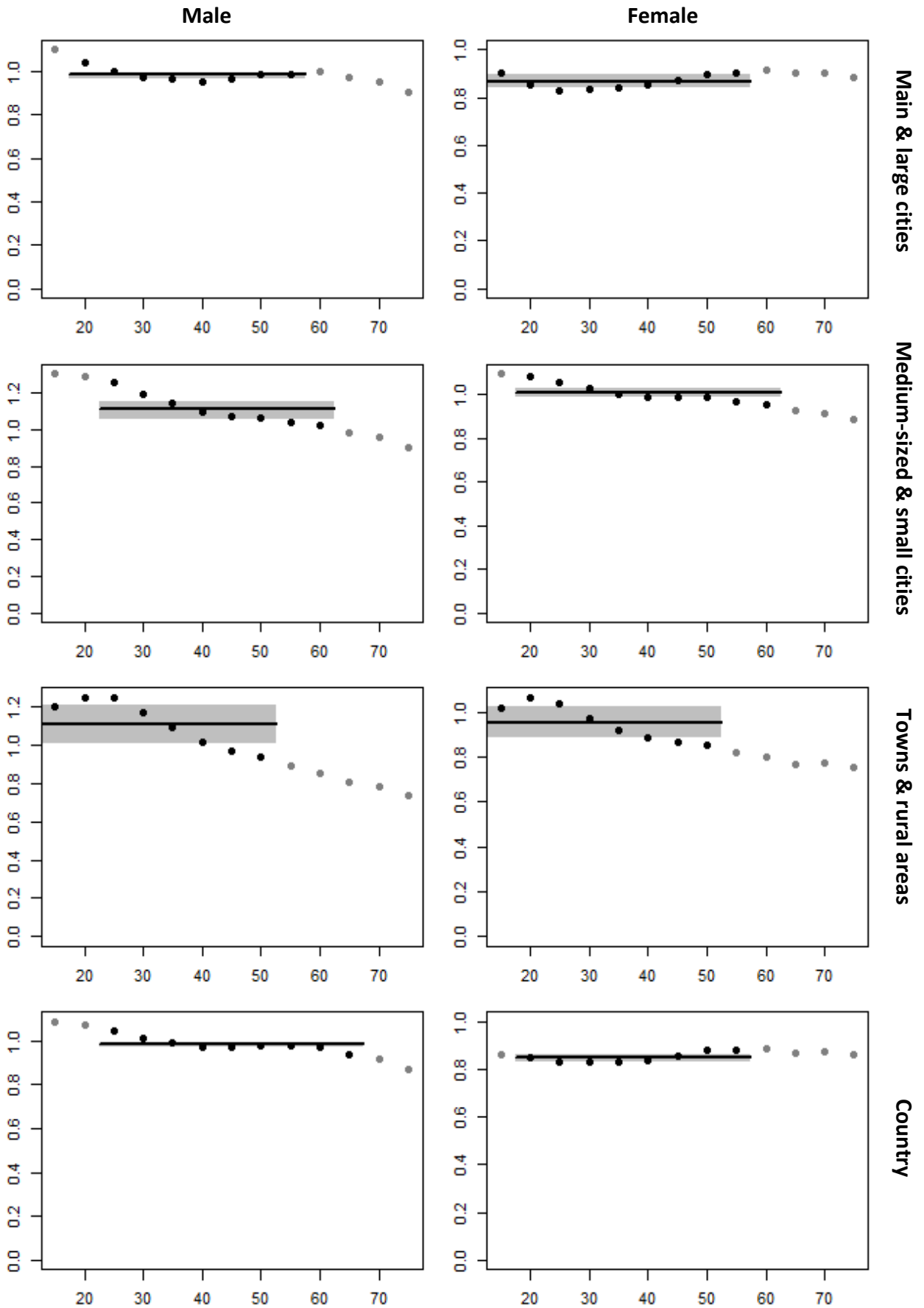


Peru 1993-2007





Venezuela 2001-2011

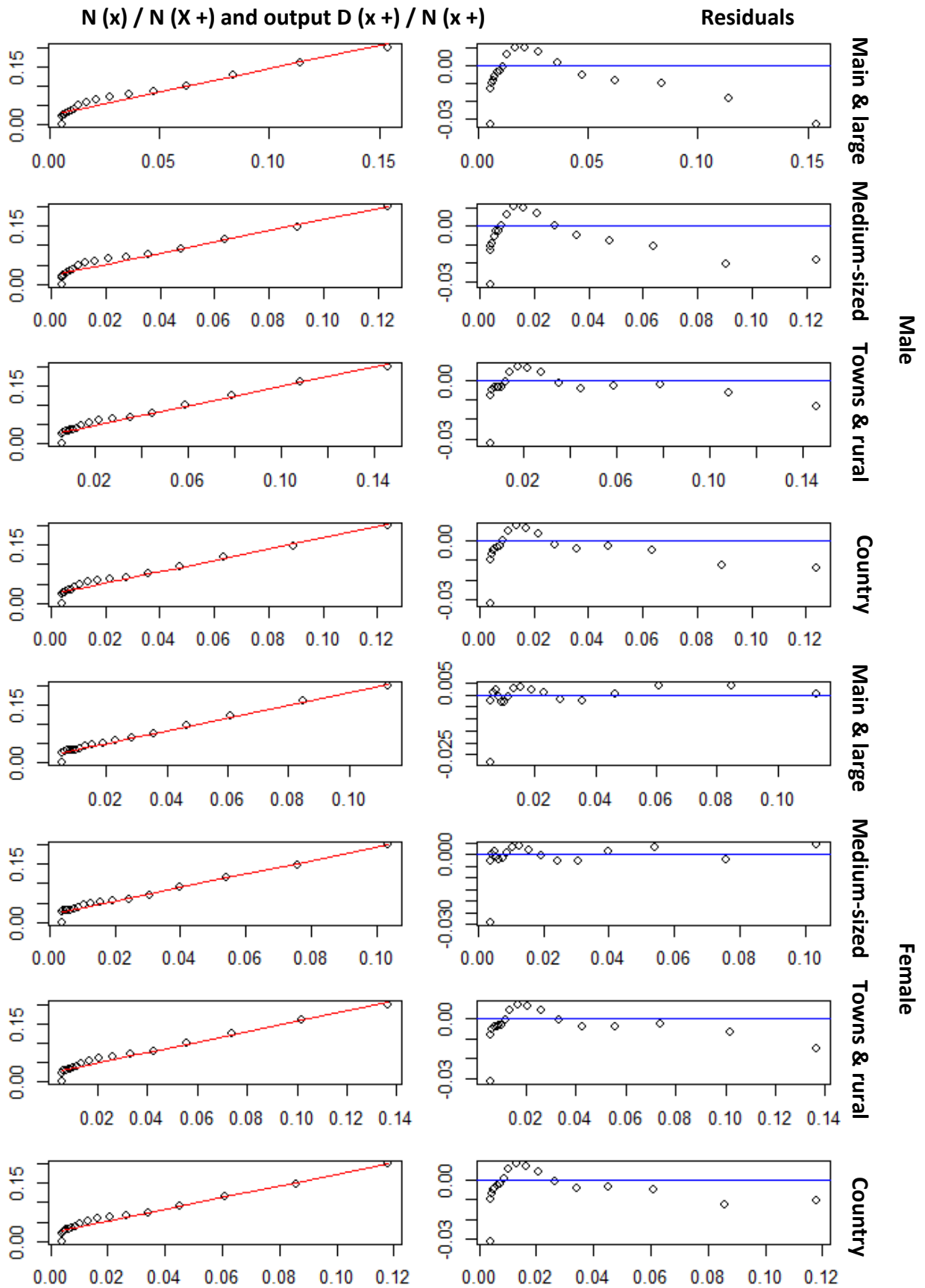


Annexes E: adult mortality coverage, Table E.2 Percentage of coverage of adult mortality with one census method into 2000's census data for Peru and Colombia.

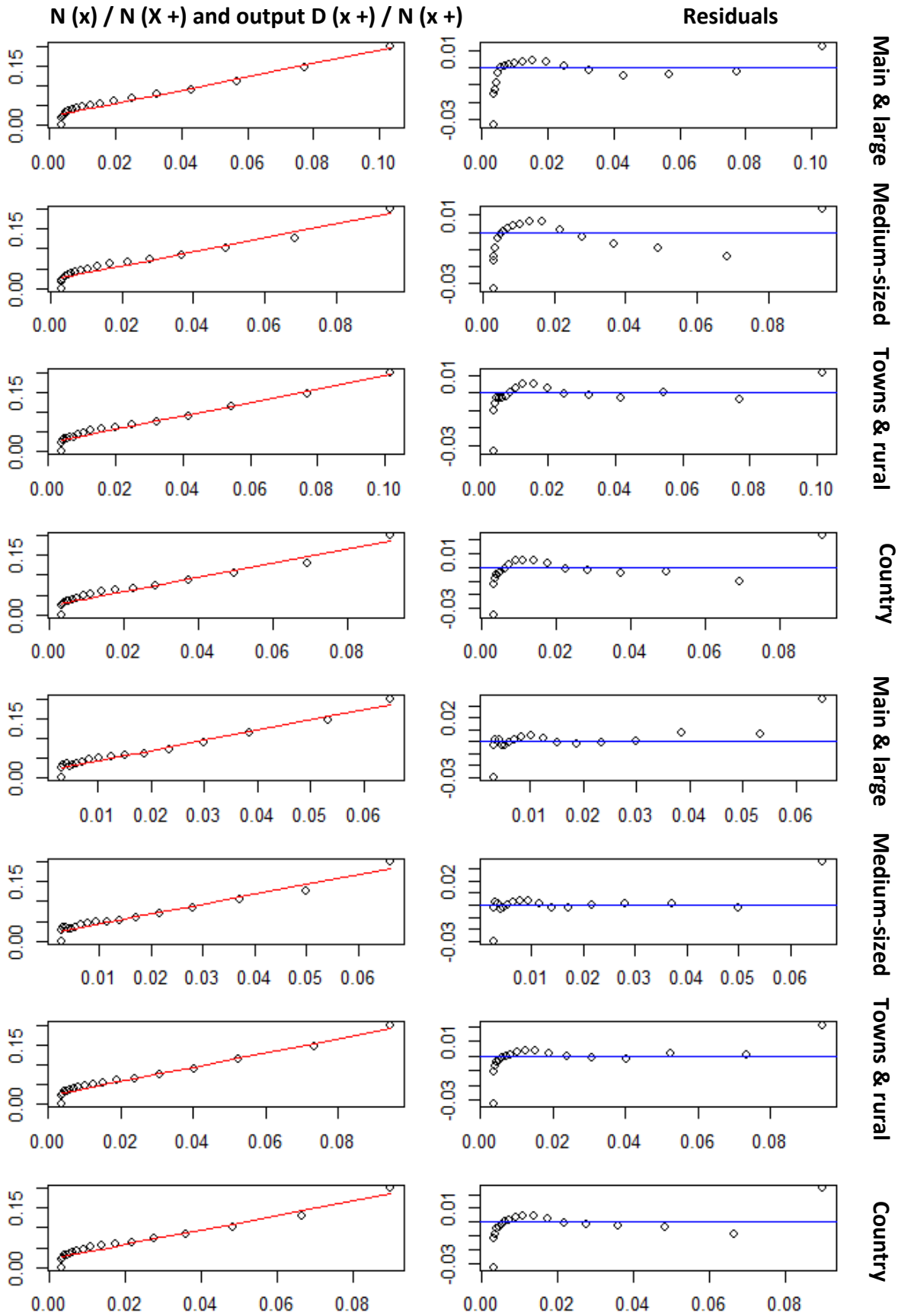
Country	sex	City-size group	Brass Growth Balance	Preston & Coale SEG
PER	Male	Main	65	54
		Medium-sized	63	36
		Small & Rural	46	25
		Country	63	36
	Female	Main	60	52
		Medium-sized	62	33
		Small & Rural	47	22
		Country	61	33
COL	Male	Main	75	56
		Medium-sized	78	53
		Small & Rural	63	29
		Country	72	43
	Female	Main	64	44
		Medium-sized	66	40
		Small & Rural	60	22
		Country	64	33

Annexes E: adult mortality coverage, Figure E.3. BGB method entry rates  $N(x)/N(X+)$  and output  $D(x+)/N(x+)$  with census data census data by sex, groups of cities and country.

**Colombia 2005**



Peru 2007

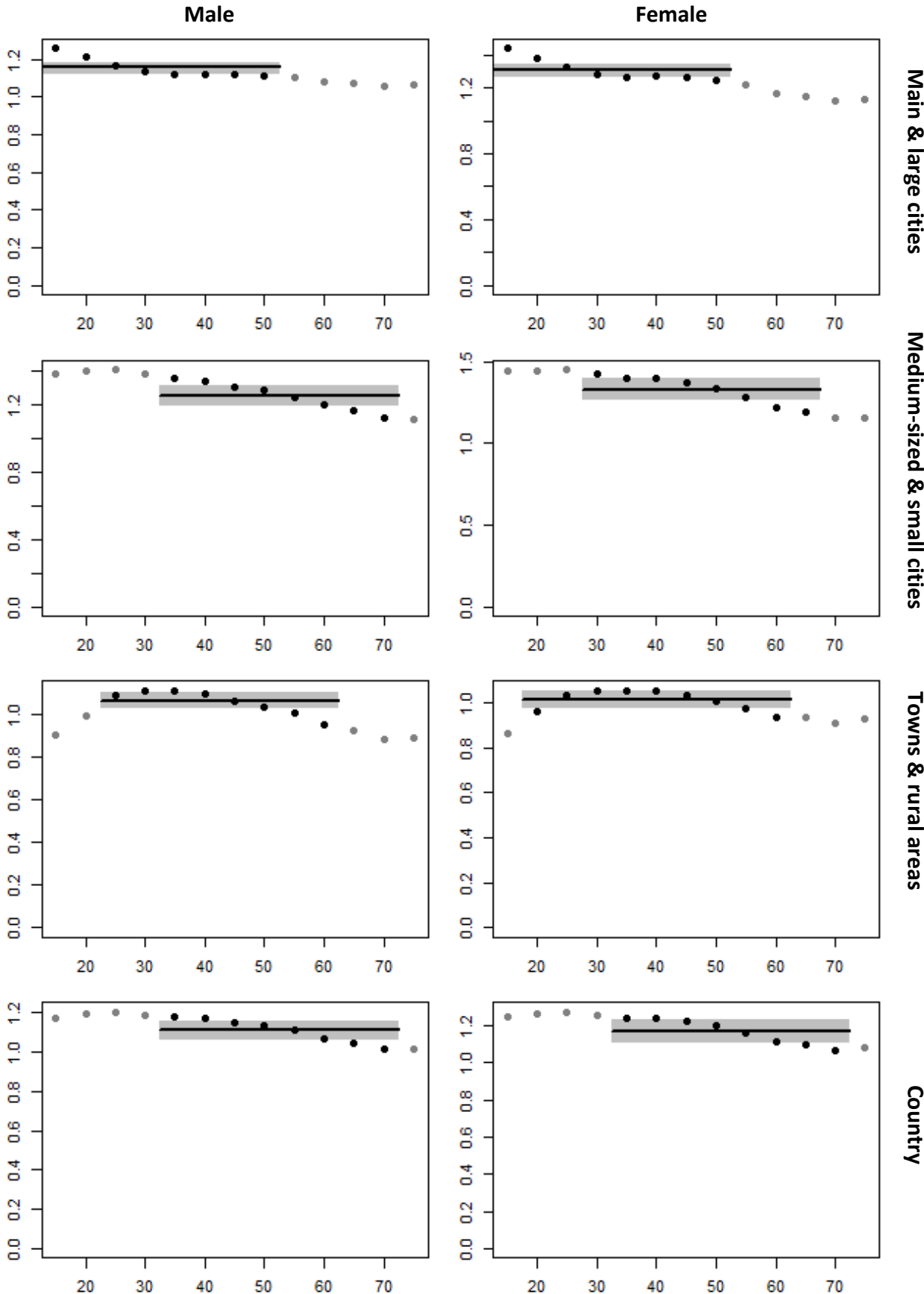


Annexes E: adult mortality coverage, Table E.4 Percentage of coverage of adult mortality with population estimations, sex and spatial group.

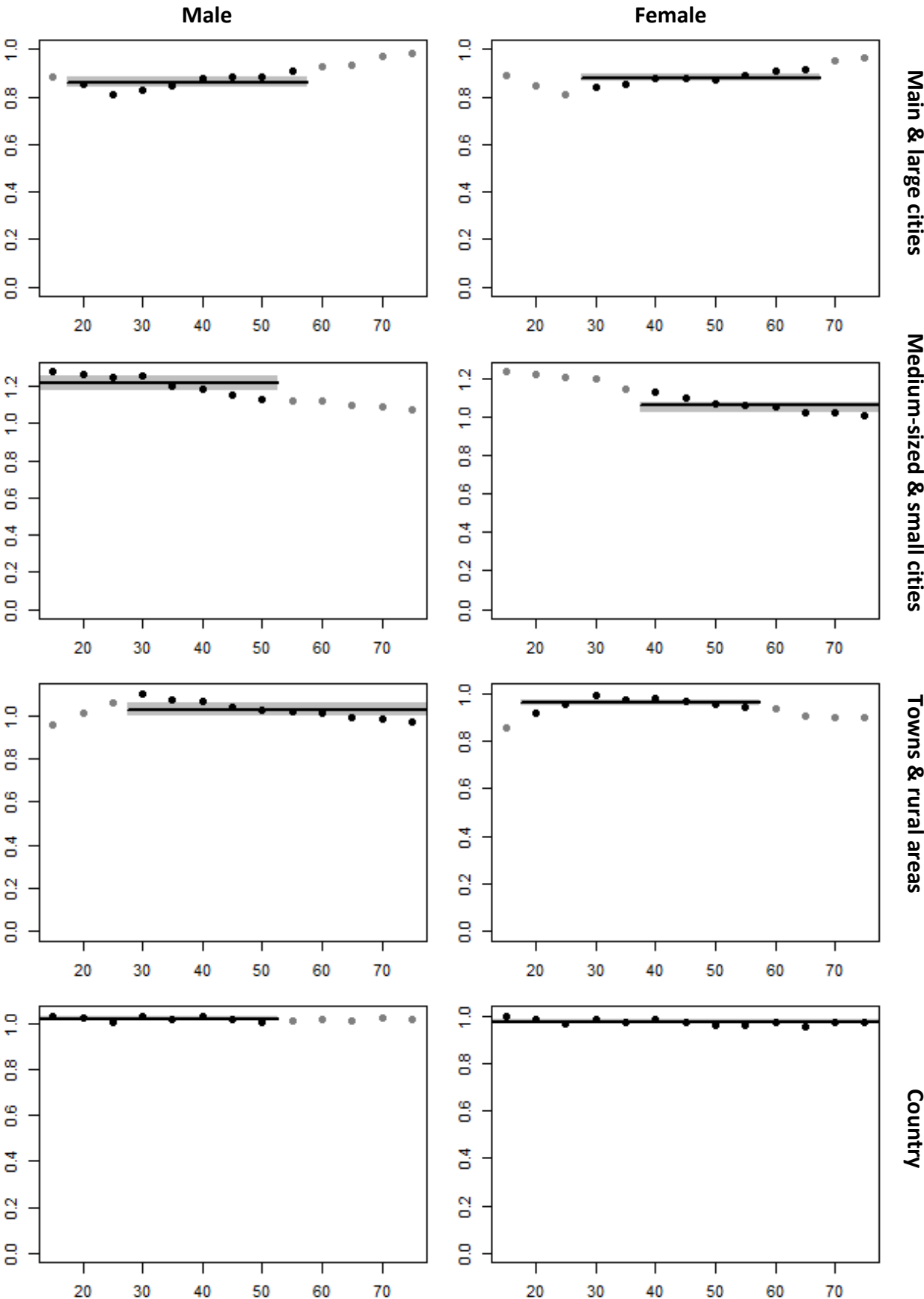
Country	sex	Spatial group	Method DDM/ Population estimations			Coverage		
			Period	ggb	seg	ggbseg	min	max
BRA	Male	Main & large	1997-2010	100	108	97	97	108
		Medium-sized		110	121	100	100	121
		Town & Rural		99	98	91	91	99
		Country		100	105	93	93	105
	Female	Main & large		106	119	99	99	119
		Medium-sized		109	120	99	99	120
		Town & Rural		95	93	89	89	95
		Country		102	108	95	95	108
CHI	Male	Main & large	1997-2010	103	89	103	89	103
		Medium-sized		101	121	98	98	121
		Town & Rural		105	106	98	98	106
		Country		107	101	103	101	107
	Female	Main & large		100	88	98	88	100
		Medium-sized		92	115	92	92	115
		Town & Rural		93	99	91	91	99
		Country		96	98	94	94	98
COL	Male	Main & large	1993-2005	90	79	78	78	90
		Medium-sized		86	76	76	76	86
		Town & Rural		99	56	82	56	99
		Country		96	71	82	71	96
	Female	Main & large		87	76	72	72	87
		Medium-sized		77	66	65	65	77
		Town & Rural		99	47	75	47	99
		Country		99	64	77	64	99
ECU	Male	Main & large	1997-2010	90	53	89	53	90
		Medium-sized		47	43	46	43	47
		Town & Rural		56	40	48	40	56
		Country		44	43	44	43	44
	Female	Main & large		90	49	89	49	90
		Medium-sized		40	37	40	37	40
		Town & Rural		54	33	44	33	54
		Country		39	37	39	37	39
MEX	Male	Main & large	1997-2010	129	94	104	94	129
		Medium-sized		122	100	92	92	122
		Town & Rural		123	89	96	89	123
		Country		111	92	86	86	111
	Female	Main & large		136	104	108	104	136
		Medium-sized		120	102	95	95	120
		Town & Rural		117	92	94	92	117
		Country		123	99	97	97	123
PER	Male	Main & large	1993-2007	78	64	72	64	78
		Medium-sized		73	50	63	50	73
		Town & Rural		52	35	42	35	52
		Country		72	50	62	50	72
	Female	Main & large		79	64	67	64	79
		Medium-sized		73	47	59	47	73
		Town & Rural		68	31	46	31	68
		Country		77	48	61	48	77
VEN	Male	Main & large	2001-2011	82	100	93	82	100
		Medium-sized		92	99	100	92	100
		Town & Rural		97	94	95	94	97
		Country		87	98	95	87	98
	Female	Main & large		77	94	90	77	94
		Medium-sized		81	90	90	81	90
		Town & Rural		95	85	90	85	95
		Country		82	91	90	82	91

Annexes E: adult mortality coverage, Figure E.5. SEG age-pattern of coverage with population estimations.

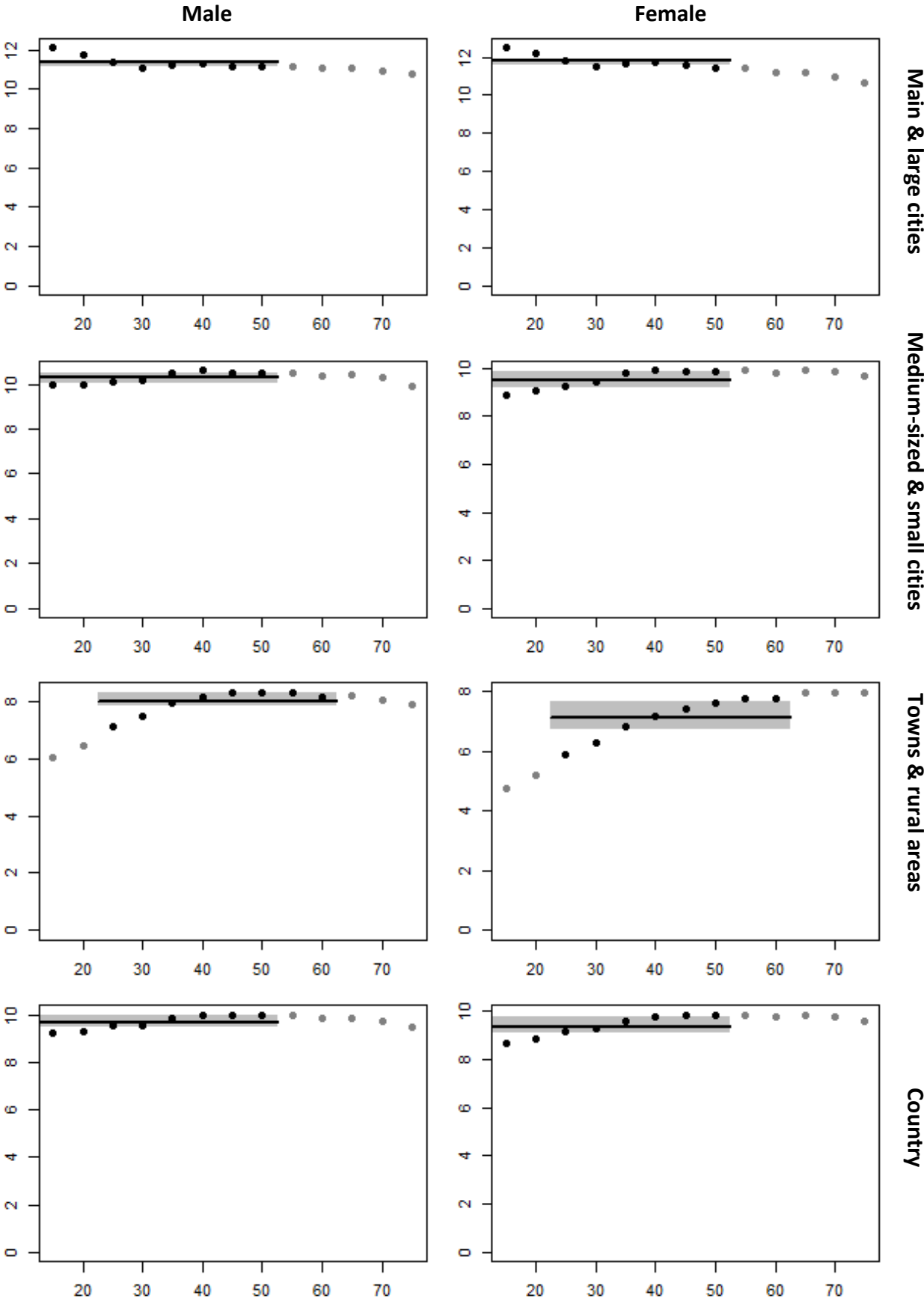
**Brazil 1997-2010**



Chile 1997-2010

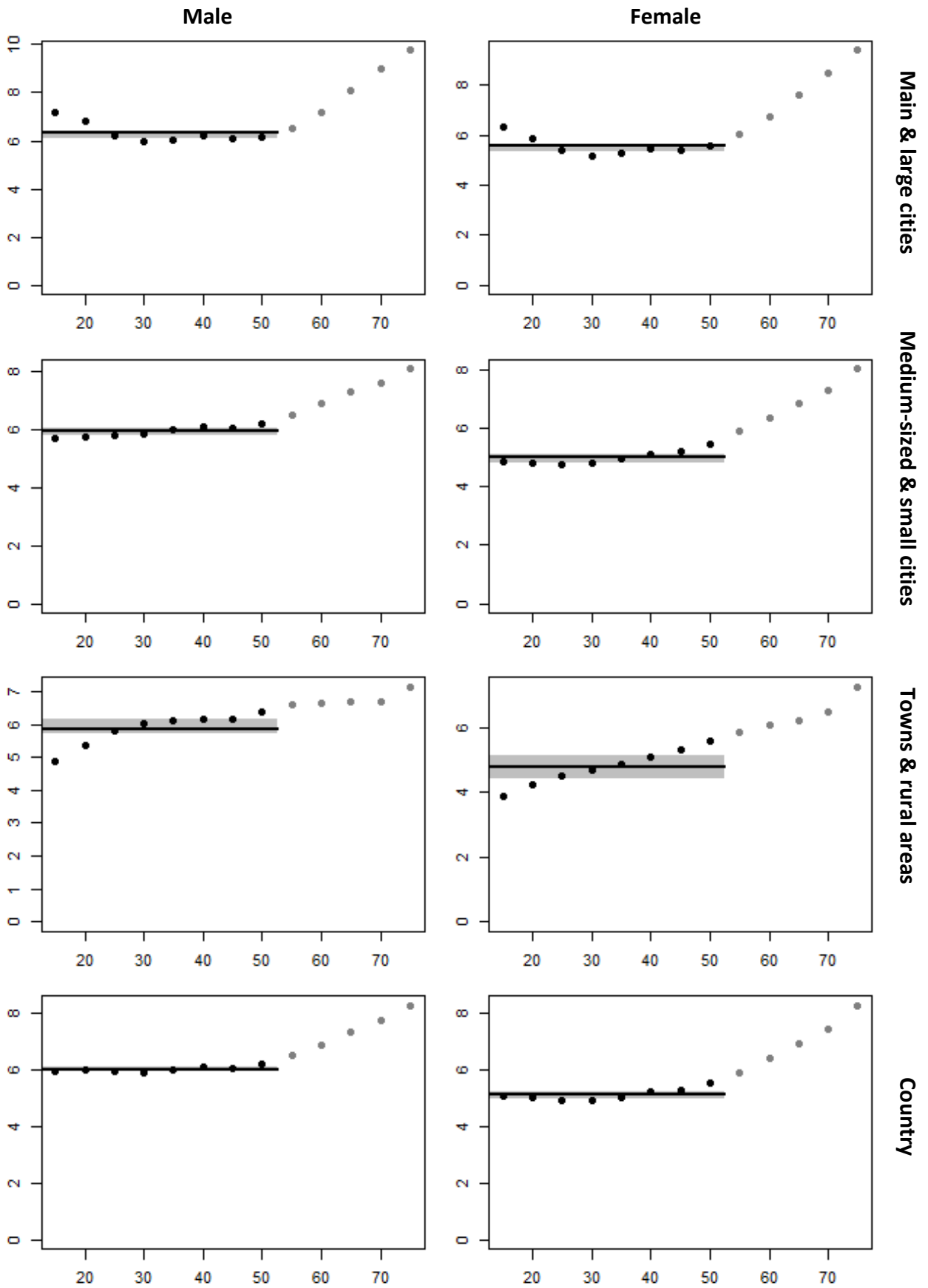


Colombia 1997-2010

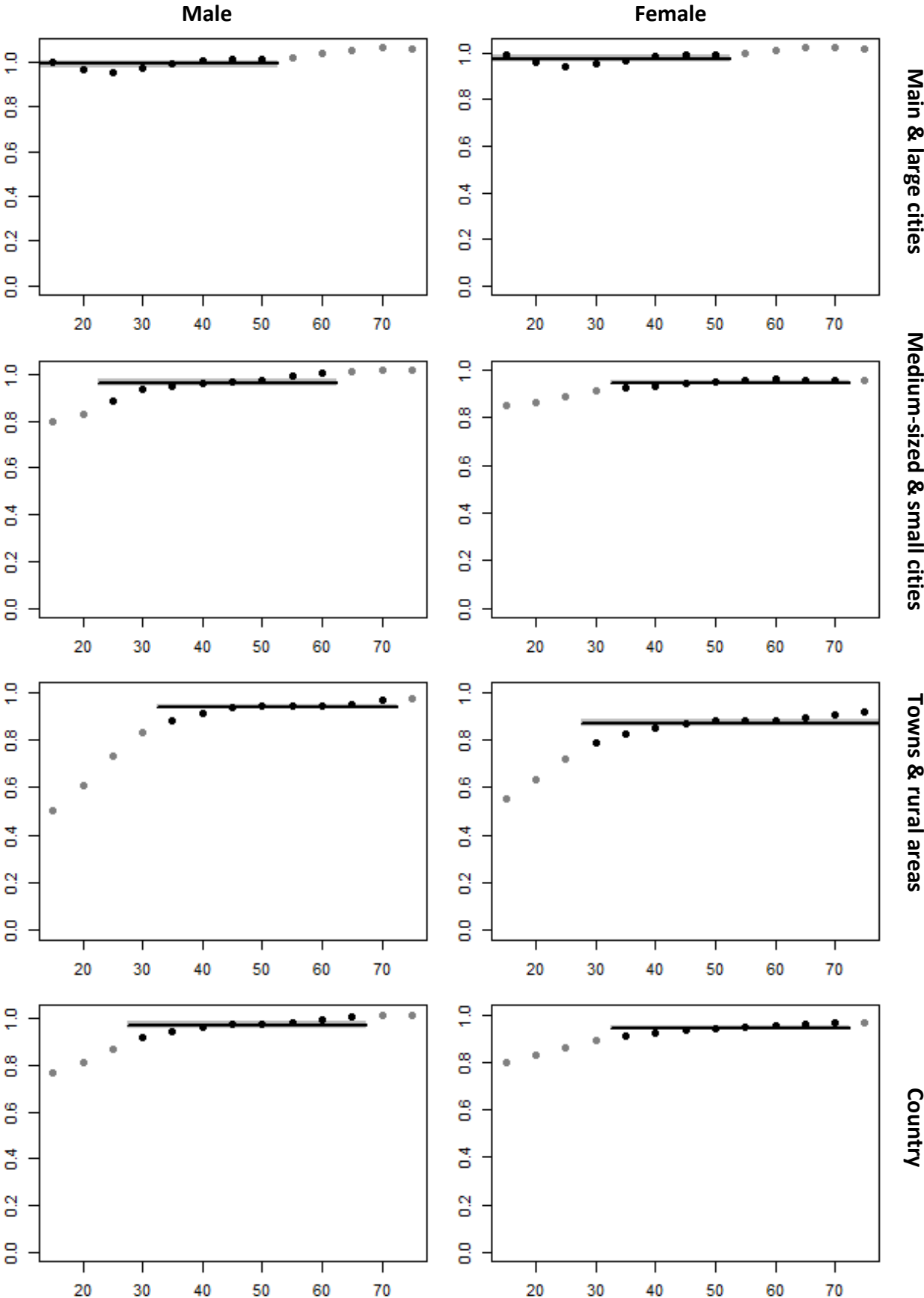




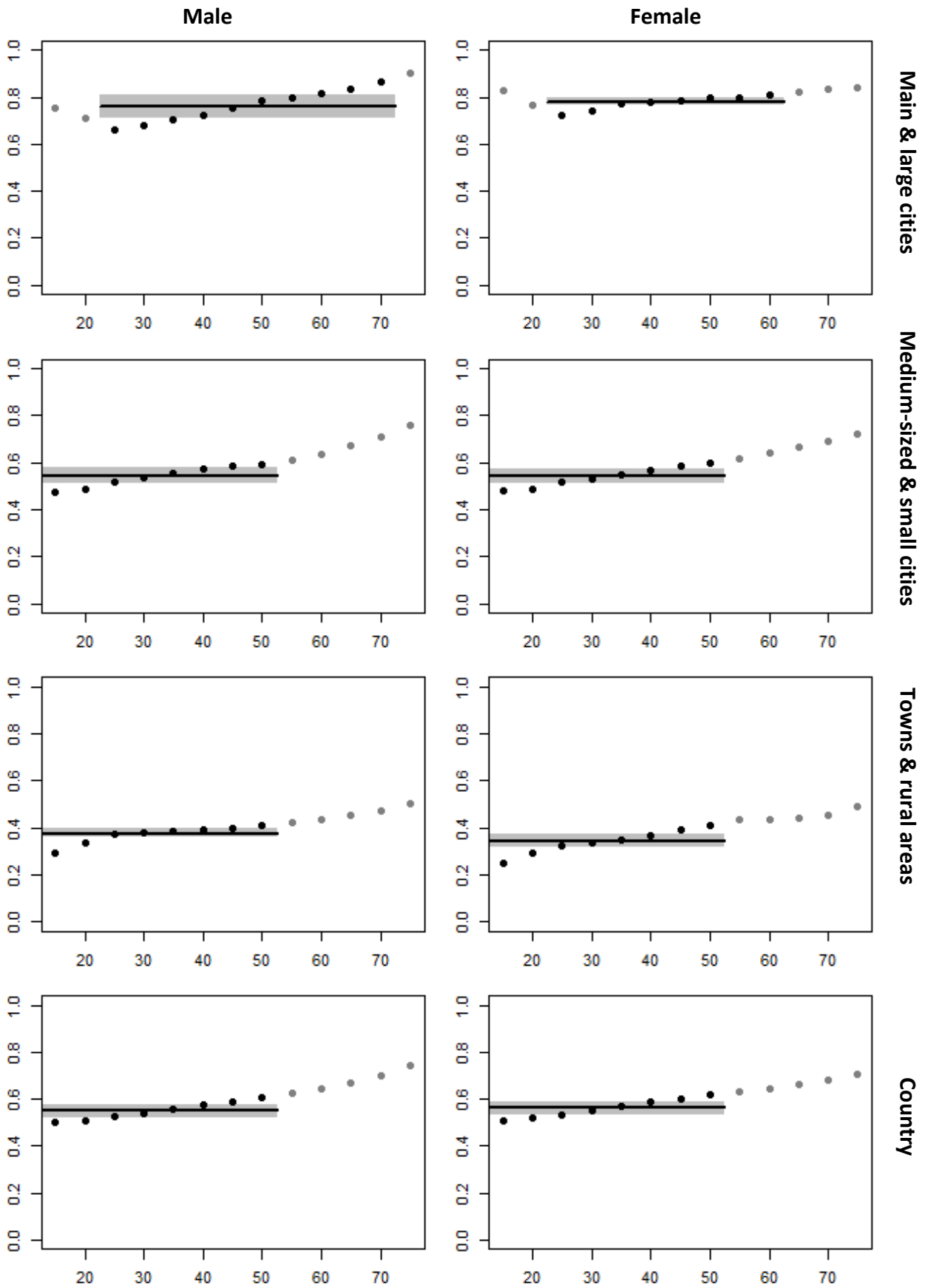
Ecuador 1997-2010



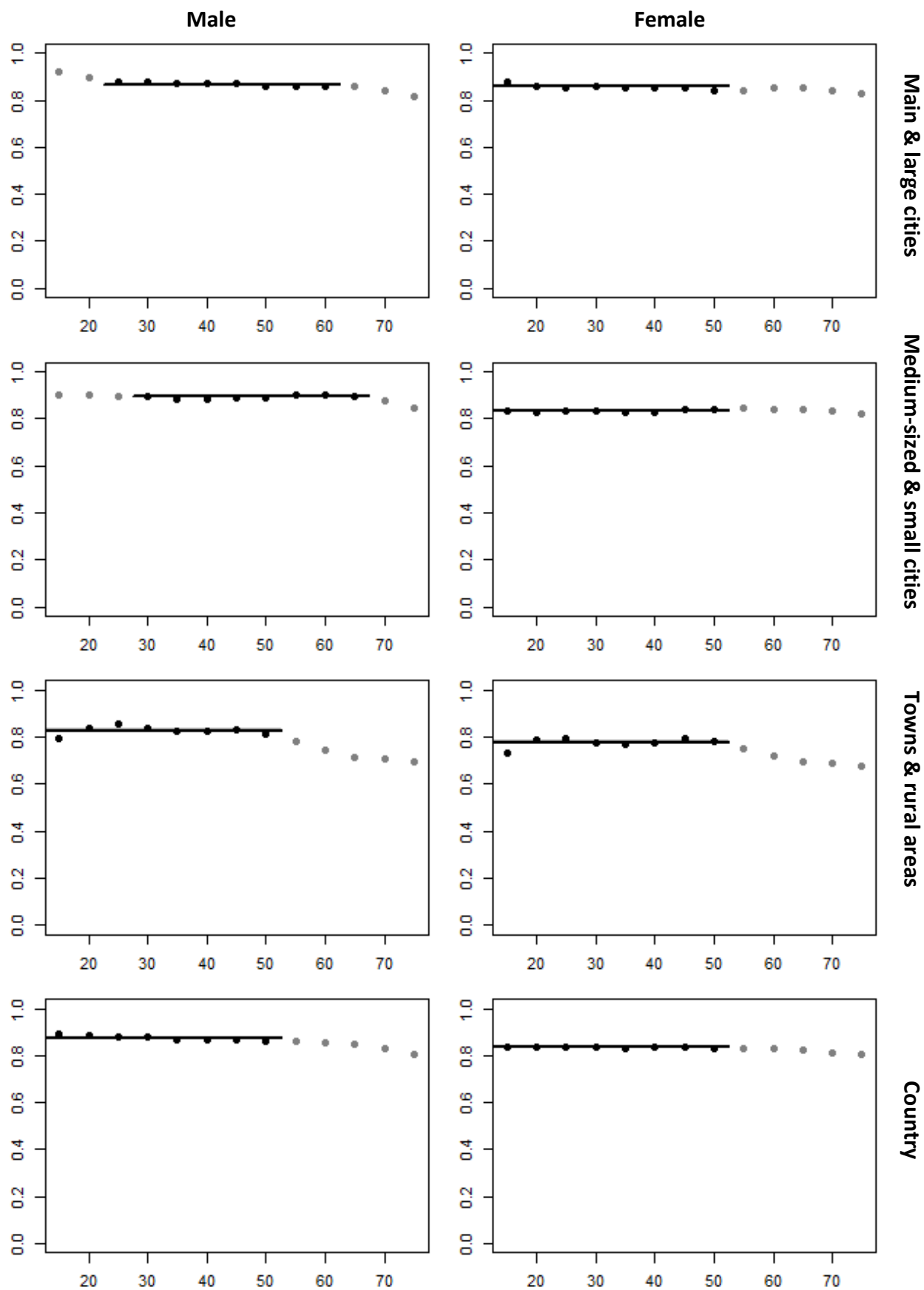
Mexico 1997-2010



Peru 2003-2013



Venezuela 2000-2011



Annexes F: Spatial group quality assessment, Table F.1 Statistical coefficients of the Principal component analysis on registered death's quality.

<b>Correlations test values</b>	<b>% Unknown cases</b>	<b>% Ill-defined causes</b>	<b>Digit preference</b>	<b>Age exaggeration</b>	<b>% Adult uncoverage</b>	<b>% Infant uncoverage</b>
% Unknown cases	1,000 99,990					
% Ill-defined causes	-0,109 -0,707	1,000 99,990				
Digit preference	0,158 0,955	0,193 1,172	1,000 99,990			
Age exaggeration	-0,011 -0,072	0,376 2,559	0,479 3,132	1,000 99,990		
% Adult uncoverage	0,153 1,003	0,193 1,266	0,654 4,694	0,490 3,476	1,000 99,990	
% Infant uncoverage	-0,087 -0,566	0,442 3,076	0,581 3,982	0,639 4,905	0,784 6,836	1,000 99,990
<b>Eigen values</b>						
<b>Factor</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Eigen values</b>	3,009	1,185	0,769	0,492	0,408	0,138
<b>% accumulated</b>	50,1	69,9	82,7	90,9	97,7	100,0
<b>Coordonnées des variables actives</b>						
<b>variable</b>	<b>Axe 1</b>	<b>Axe 2</b>	<b>Axe 3</b>	<b>Axe 4</b>	<b>Axe 5</b>	<b>Axe 6</b>
% Unknown cases	0,055	<b>0,846</b>	0,517	0,047	-0,092	0,055
% Ill-defined causes	0,499	<b>-0,528</b>	0,641	-0,229	0,074	-0,062
Digit preference	0,777	0,295	-0,160	-0,117	0,518	0,029
Age exaggeration	0,776	-0,141	0,077	0,608	0,006	-0,058
% Adult uncoverage	<b>0,850</b>	0,256	-0,216	-0,210	-0,260	-0,232
% Infant uncoverage	<b>0,910</b>	-0,134	-0,110	-0,099	-0,240	0,271
<b>Correlations between variables actives and factors</b>						
<b>variable</b>	<b>Axe 1</b>	<b>Axe 2</b>	<b>Axe 3</b>	<b>Axe 4</b>	<b>Axe 5</b>	<b>Axe 6</b>
% Unknown cases	0,055	0,846	0,517	0,047	-0,092	0,055
% Ill-defined causes	0,499	-0,528	0,641	-0,229	0,074	-0,062
Digit preference	0,777	0,295	-0,160	-0,117	0,518	0,029
Age exaggeration	0,776	-0,141	0,077	0,608	0,006	-0,058
% Adult uncoverage	0,850	0,256	-0,216	-0,210	-0,260	-0,232
% Infant uncoverage	0,910	-0,134	-0,110	-0,099	-0,240	0,271
<b>Anciens axes unitaires</b>						
<b>variable</b>	<b>Axe 1</b>	<b>Axe 2</b>	<b>Axe 3</b>	<b>Axe 4</b>	<b>Axe 5</b>	<b>Axe 6</b>
% Unknown cases	0,032	<b>0,777</b>	0,589	0,068	-0,145	0,148
% Ill-defined causes	0,287	<b>-0,485</b>	0,732	-0,326	0,116	-0,165
Digit preference	0,448	0,271	-0,183	-0,167	0,811	0,078
Age exaggeration	0,447	-0,129	0,088	0,867	0,010	-0,156
% Adult uncoverage	0,490	0,235	-0,247	-0,300	-0,407	-0,623
% Infant uncoverage	0,525	-0,123	-0,125	-0,141	-0,376	0,730

Annexes F: Spatial group quality assessment, Table F.2 T-values of illustrative variables.

Countries	Distance à l'origine	Axe 1	Axe 2	Axe 3	Axe 4	Axe 5	Axe 6
BRA	2,882	-0,810	-0,936	0,968	-0,535	0,239	0,259
CHI	5,051	-1,961	-0,897	0,076	0,268	-0,549	-0,145
COL	3,881	-0,533	1,751	0,594	-0,332	-0,210	-0,159
ECU	9,075	2,913	-0,548	0,215	0,179	0,107	-0,447
MEX	1,975	0,510	0,630	-0,100	0,741	0,820	0,295
PER	3,189	1,019	0,093	-1,196	-0,242	-0,763	0,267
VEN	1,748	-1,137	-0,093	-0,557	-0,079	0,355	-0,070
<b>Spatial groups</b>							
Me	0,011	-0,023	0,083	-0,021	-0,020	0,051	-0,016
Mn	0,870	-0,864	-0,050	-0,235	0,231	0,106	-0,040
Sm	0,926	0,887	-0,033	0,256	-0,212	-0,156	0,056
To	0,000	0,000	0,000	0,000	0,000	0,000	0,000
<b>Sex</b>							
Fe	0,217	0,066	-0,071	-0,177	-0,331	0,256	-0,018
Ma	0,217	-0,066	0,071	0,177	0,331	-0,256	0,018

Annexes G: Causes of death classification. Table G.1 Amenable causes of death classification by Tobias and Jackson (detailed)

Conditions involved	ICD coding		Proportional weight			Final Group
	ICD 9	ICD 10	PAM	SAM	TAM	
Diarrhoeal diseases	001-999	A00-A09	0.7	0.1	0.2	PAM
Tuberculosis	010-018, 137	A15-A19, B90	0.6	0.35	0.05	PAM
Diphtheria	032	A36	0.9	0.05	0.05	PAM
whooping cough	033	A37	0.9	0.05	0.05	PAM
tetanus	037	A33-A35	0.9	0.05	0.05	PAM
Syphilis+ gonorrhoea	090-099	A50-A64	0.8	0.1	0.1	PAM
polio	045	A80, B91	0.9	0.05	0.05	PAM
measles	055	B05	0.9	0.05	0.05	PAM
rubella	056, 771.0, 771.4	B06, P35, P38	0.9	0.05	0.05	PAM
HIV/AIDS	042	B20-B24	0.9	0.05	0.05	PAM
Hepatitis A, B, C, D, E	070	B15-B19	0.7	0.1	0.2	PAM
primary liver cancer	155	C22	0.7	0.1	0.2	PAM
Lip cancer, melanoma, other skin cancer	140, 172, 173	C00, C43, C44	0.6	0.1	0.3	PAM
Malignant neoplasm mouth	141, 143-6	C01-C06	0.8	0.1	0.1	PAM
Malignant neoplasm pharynx	148-9	C10-C14	0.8	0.1	0.1	PAM
Malignant neoplasm larynx	161	C32	0.8	0.1	0.1	PAM
Malignant neoplasm trachea	162	C33	0.95	-	0.05	PAM
Malignant neoplasm bronchus AND lung	162	C34	1.95	-	1.05	PAM
Nutritional deficits including anaemia	260-9, 280, 281	E40-E64, D50-D53	1	-	-	PAM
Psychosis due to alcohol abuse	291, 303, 305.0	F10	0.9	-	0.1	PAM
Ischaemic heart disease	410-414	I20-125	0.5	0.25	0.25	PAM
Chronic bronchitis and emphysema	490-492, 496	J40-J44	0.8	0.1	0.1	PAM
Liver damage due to alcohol	571.0-5	K70	0.9	-	0.1	PAM
other STD	614.0-614.5, 614.7-616.9	N70-N77	0.8	0.1	0.1	PAM
ectopic pregnancy	633	O00	0.8	0.1	0.1	PAM
Prematurity, low birthweight, respiratory disease from prematurity	764-765, 769, 770.7	P05-P07, P27	0.5	0.1	0.4	PAM
Congenital anomalies of brain and spinal cord	740-742	Q00-Q06	0.6	0.2	0.2	PAM
Sudden infant death	798.0	R95	1	-	-	PAM
Road traffic injury	E810-829	V01-V89	0.6	-	0.4	PAM
Poisoning	E850-869	X40-X49	0.6	-	0.4	PAM
Swimming pool falls and drownings	E883.0, E910.5, E910.6	W67	0.8	-	0.2	PAM
Falls from playground equipment, sport injury	E884.0, E884.5, E886.0, EE917.0, E927	W02, W09	0.6	-	0.4	PAM
Burns and scalds	E890-899	X00-X09	0.8	-	0.2	PAM
Suicide	E950-959, E980-989	X60-X84	0.6	0.3	0.1	PAM
Colorectal cancer	153-154	C18-C21	0.4	0.5	0.1	SAM
Cervical cancer	180	C53	0.3	0.5	0.2	SAM
Congenital hypothyroidism	243	E00	-	0.8	0.2	SAM
Goitre, thyrotoxicosis, hypothyroidism	240-242, 244	E01-E05	0.1	0.7	0.2	SAM
Diabetes	250	E10-E14	0.3	0.5	0.1	SAM
CAH	255.2	E25	-	0.8	0.2	SAM
PKU	270.1	E70	-	0.8	0.2	SAM
galatosaemia	271.1	E74	-	0.8	0.2	SAM
Epilepsy	345	G40, G41	-	0.9	0.1	SAM
Otitis media and mastoiditis	381-383	H65-H95	0.1	0.7	0.2	SAM
Acute rheumatic fever, heart disease	390-398	I00-I09	0.3	0.6	0.1	SAM
Hypertensive disease	401-405, 437.2	I10-I16, I67	0.3	0.65	0.05	SAM
Intracerebral haemorrhage or occlusion	431, 433, 434, 436	I61-I66	0.3	0.5	0.2	SAM
Asthma	493	J45, J46	0.1	0.7	0.2	SAM
Gastric and duodenal ulcer	531-534	K25-K28	0.05	0.75	0.2	SAM
Skin, bone and joint infections	680-686, 711, 730	M00, L00-L08, M86	0.2	0.5	0.3	SAM
Complications of pregnancy	630-632, 634-676	O01-O99	0.2	0.5	0.3	SAM
Breast cancer	174	C50	0.15	0.35	0.5	TAM
Cancer of testis	186	C62	-	0.3	0.7	TAM
Eye cancer	190	C69	-	-	1	TAM
Thyroid cancer	193	C73	0.1	0.2	0.7	TAM
Hodgkin's disease	201	C81	-	0.1	0.9	TAM
Lymphoid leukaemia	204	C91	0.05	0.05	0.9	TAM
Benign cancers	210-234	D00-D36	-	-	1	TAM
Appendicitis	540-543	K35-K38	-	-	1	TAM
Intestinal obstruction and hernia	550-553, 560	K40-K46, K56	-	-	1	TAM
Gallbladder disease	574-576.9	K80-K83	0.2	-	0.8	TAM
Acute renal failure	584	N17	0.1	0.2	0.7	TAM

PAM=Primary Avoidable Mortality, SAM=Secondary Avoidable Mortality, TAM=Tertiary Avoidable Mortality.

Conditions involved	ICD coding		Proportional weight			Final Group
	ICD 9	ICD 10	PAM	SAM	TAM	
Other perinatal conditions: respiratory disease, haemolytic disease, jaundice, etc.	766, 769, 770.2-6, 770.8-9	P08, P22, P25, P26,P28	0.3	0.2	0.5	TAM
Congenital eye, ear, face, and cardiac malformations	743-744.9	Q10-Q19	0.1	0.2	0.7	TAM
Congenital cardiac malformations	745-747	Q20-Q28	0.1	0.2	0.7	TAM
Congenital respiratory system malformations	748-749	Q30-Q37	0.1	0.2	0.7	TAM
Congenital digestive anomalies	750-751	Q38-Q45	0.1	0.2	0.7	TAM
Congenital urinary system anomalies	752-753	Q50-Q64	0.1	0.2	0.7	TAM
Congenital muskuloskeletal AND OTHERS anomalies	754-759	Q65-Q99	0.1	0.2	0.7	TAM
Complications of treatment	E870-879	Y40-Y84	-	0.2	0.8	TAM
brucellosis	023-031	A23-A32	0.3	0.4	0.3	COM
streptococcus	034	A38	0.3	0.4	0.3	COM
meningitis	036, 320.1-9	A39, G00,G04	0.3	0.4	0.3	COM
Erysipelas	035	A46	0.3	0.4	0.3	COM
malaria	084	B50-B54	0.3	0.4	0.3	COM
Others transmissible diseases	041.5	B96, P35	0.9	0.05	0.05	COM
Stomach cancer	151	C16	0.4	0.2	0.4	COM
Cancer of uterus	179, 182	C54, C55	0.1	0.4	0.5	COM
Respiratory infections including pneumonia and influenza	460-466, 480-487	J00-J21	0.4	0.5	0.1	COM
Birth trauma and asphyxia	767-768, 770.1, 772.0, 772.3	P10-P21,P24, P50, P51	0.1	0.4	0.5	COM
congenital	771.1-2, 771.4-8, 770.0	P23, P36-P37, P39	0.3	0.4	0.3	COM

PAM=Primary Avoidable Mortality, SAM=Secondary Avoidable Mortality, TAM=Tertiary Avoidable Mortality.



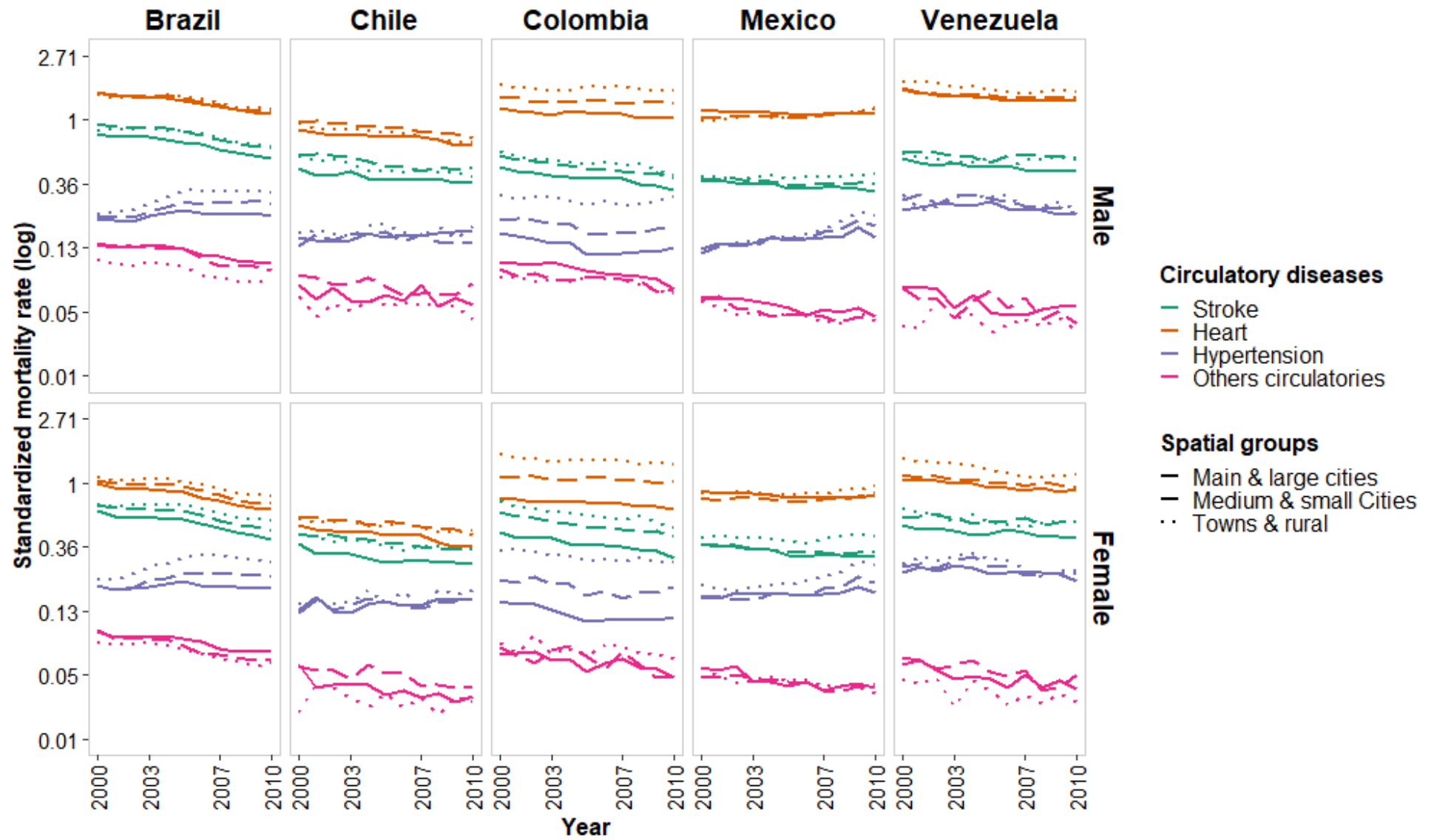
Annexes G: Causes of death classification. Table G.2. Primary avoidable mortality (PAM) added to Tobias and Jackson classification

Conditions involved	ICD 10
Viral infectious of the central nervous system (acute poliomyelitis, rabies, mosquito-borne viral encephalitis, tick-borne viral encephalitis, viral meningitis)	A81-A89
Arthropod-borne viral fevers and viral haemorrhagic fevers	A90-A99
Protozal diseases (Leishmaniasis, african trypanosomiasis, chagas, toxoplasmosis, pneumocystosis, other protozoal)	B55-B64
Viral infectious characterized by skin and ocous membrane lesions (herperviral, varicella, zoster, smallpox, monkeypox, rubella, viral warts, others)	B00-B04,B07-B09

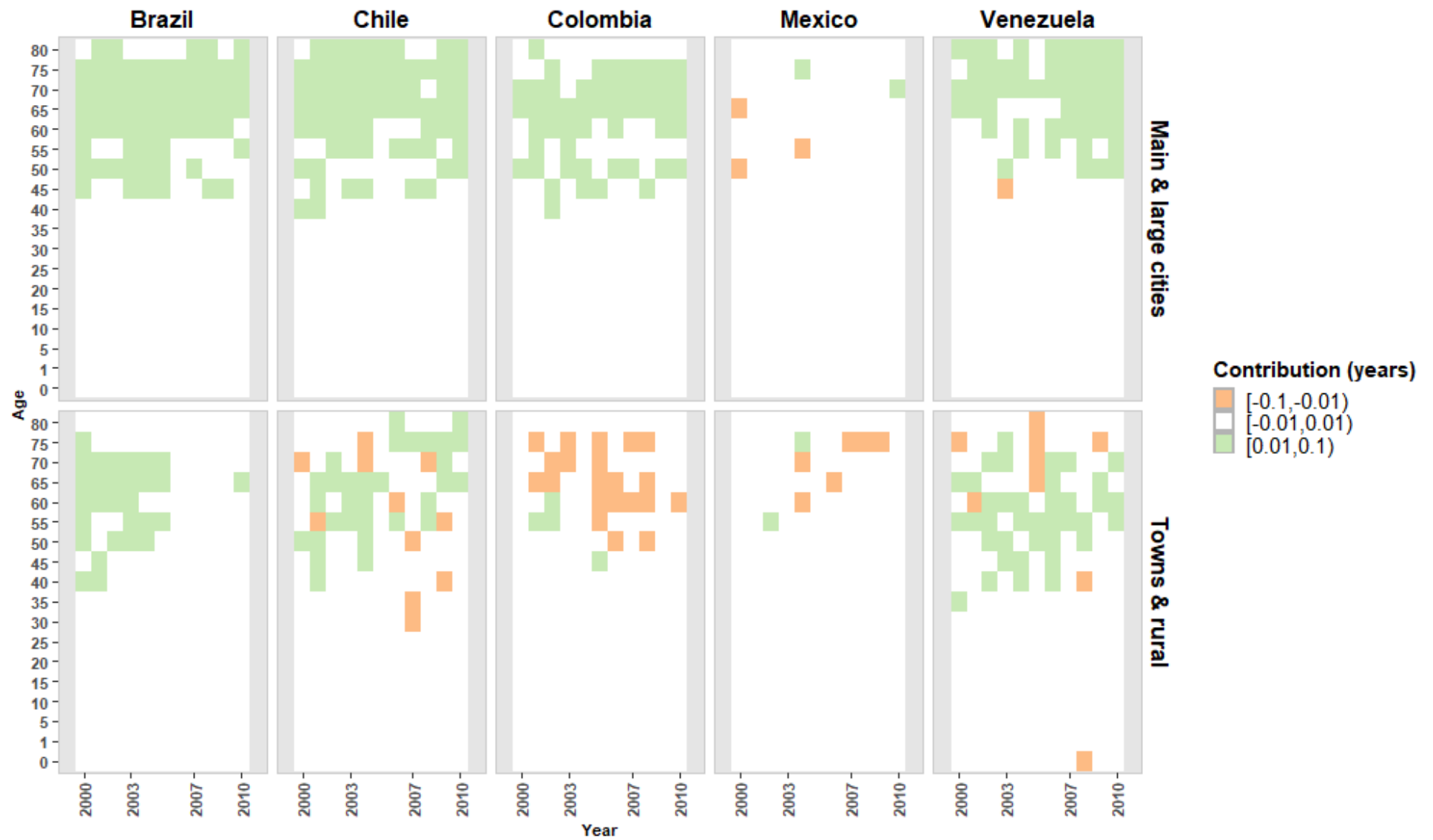
Annexes H: Subpopulation mortality patterns, Table H.1 Statistical coefficients of the Principal component analysis on mortality patterns in Subpopulations.

Correlations								
test values t-student	IMR in t1	30q15 in t1	30q45 in t1	e70 in t1	change in IMR	change in 30q15	change in 30q45	change in e70
IMR in t1	1,000 99,999							
30q15 in t1	0,584 4,197	1,000 99,999						
30q45 in t1	0,595 4,314	-0,071 7,937	1,000 99,999					
e70 in t1	-0,468 -3,086	-0,609 -4,480	<b>-0,833</b> -8,769	1,000 99,999				
Change in IMR	<b>0,867</b> 10,152	0,366 2,293	0,500 3,363	-0,336 -2,081	1,000 99,999			
Change in 30q15	0,108 0,631	0,586 4,218	0,302 1,847	-0,223 -1,331	0,095 0,557	1,000 99,999		
Change in 30q45	-0,388 -2,454	-0,071 -0,412	-0,059 -0,346	-0,050 -0,294	-0,294 2,410	0,382 -1,794	1,000 99,999	
Change in e70	0,334 2,069	0,162 0,956	0,130 0,764	0,062 0,360	0,282 -0,284	-0,049 -8,883	<b>-0,836</b> 1,712	1,000 99,999
Eigen values								
Factor	1	2	3	4	5	6	7	8
Eigen values	3,647	2,134	0,948	0,762	0,254	0,157	0,075	0,023
% accumulated	45,6	72,3	84,1	93,6	96,8	98,8	99,7	100,0
Active variables								
variable	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Representation quality in the first 5 axis (R <sup>2</sup> )		
IMR in t1	<b>-0,858</b>	-0,246	-0,219	0,304	-0,136	0,956		
30q15 in t1	<b>-0,839</b>	0,292	0,306	-0,102	<b>-0,317</b>	0,994		
30q45 in t1	<b>-0,884</b>	0,248	-0,092	-0,283	0,022	0,931		
e70 in t1	0,733	-0,358	0,266	<b>0,418</b>	-0,224	0,961		
change in IMR	-0,740	-0,254	-0,302	<b>0,505</b>	0,139	0,978		
change in 30q15	-0,361	0,578	<b>0,640</b>	0,303	0,146	0,988		
change in 30q45	0,295	<b>0,898</b>	-0,134	0,208	0,081	0,960		
change in e70	-0,351	<b>-0,771</b>	0,457	-0,118	0,192	0,977		
Actives variables contribution to the axis (%)								
variable	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Qualité de représentation par les 5 premiers axes (R <sup>2</sup> )		
IMR in t1	<b>20,2</b>	2,8	5,0	12,2	7,3	12,5		
30q15 in t1	<b>19,3</b>	4,0	9,9	1,4	<b>39,6</b>	12,5		
30q45 in t1	<b>21,4</b>	2,9	0,9	10,5	0,2	12,5		
e70 in t1	14,7	6,0	7,5	<b>22,9</b>	19,7	12,5		
change in IMR	15,0	3,0	9,6	<b>33,5</b>	7,6	12,5		
change in 30q15	3,6	15,6	<b>43,3</b>	12,1	8,5	12,5		
change in 30q45	2,4	<b>37,8</b>	1,9	5,7	2,6	12,5		
change in e70	3,4	<b>27,9</b>	22,0	1,8	14,5	12,5		

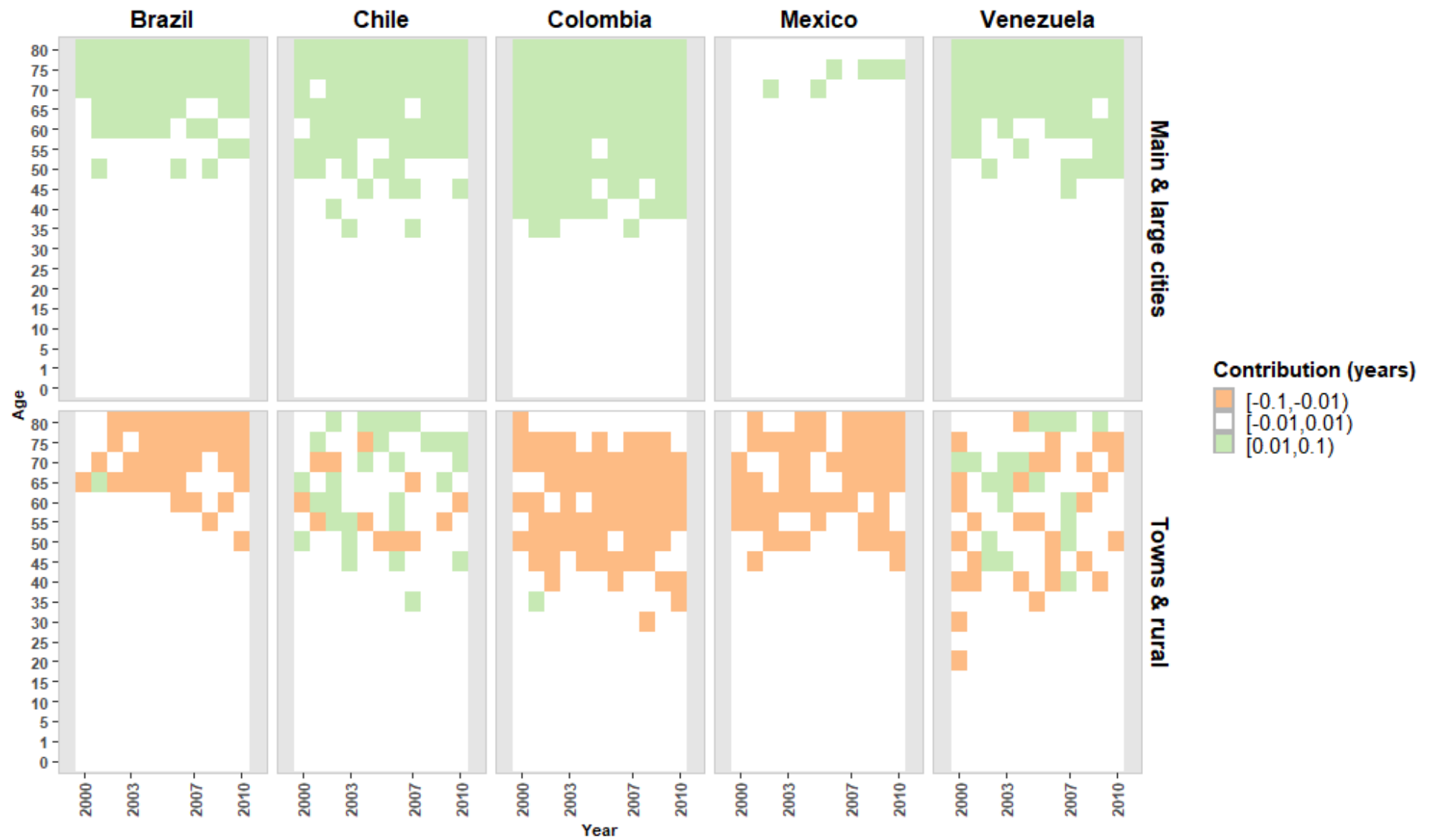
Annexes I: Causes of death analysis, Figure I.1 Circulatory diseases standardized mortality rate by sex, spatial group and country.



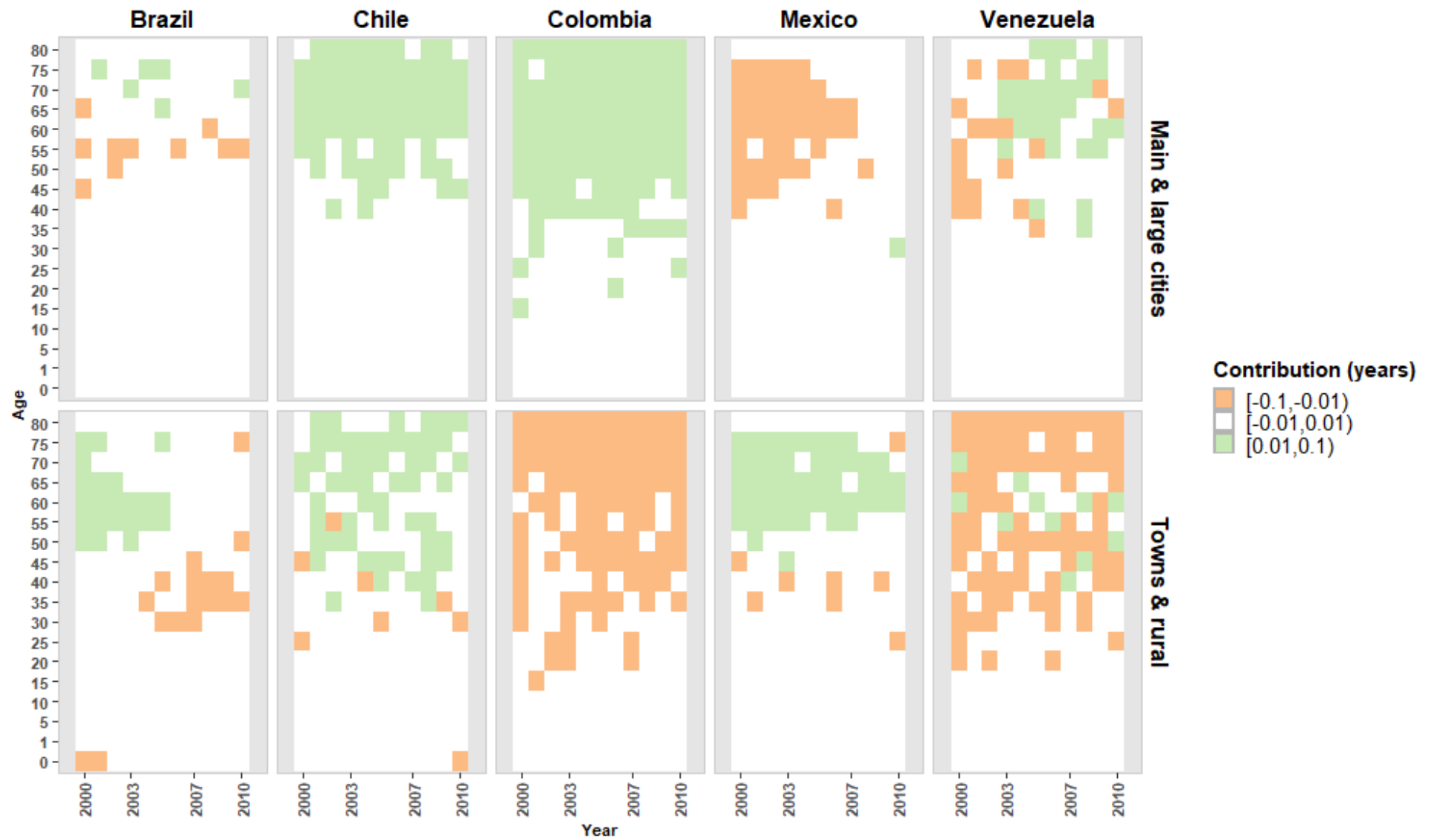
Annexes I: Causes of death analysis, Figure I.2A Contributions (in years) of strokes to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



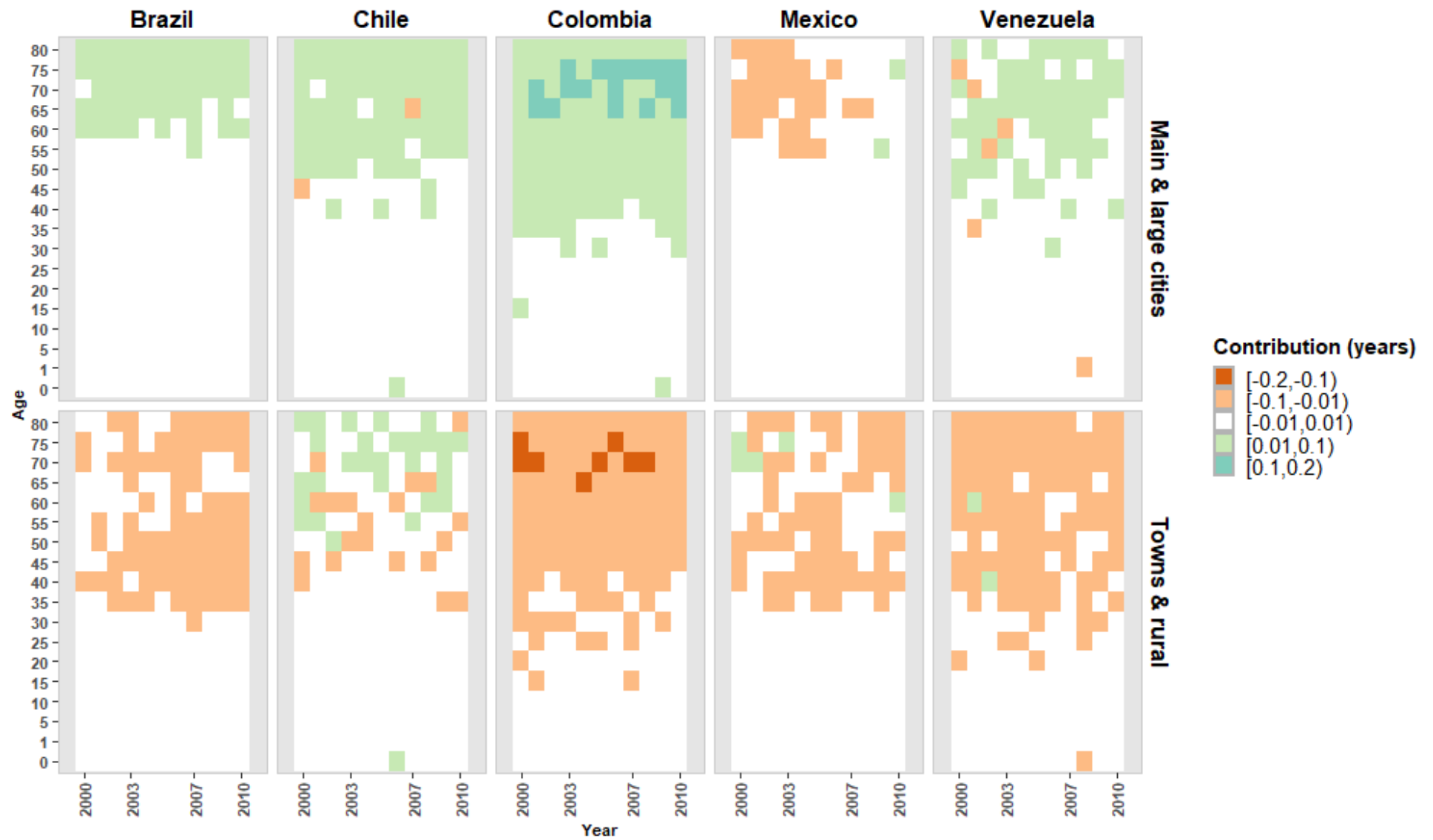
Annexes I: Causes of death analysis, Figure I.2B Contributions (in years) of strokes to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



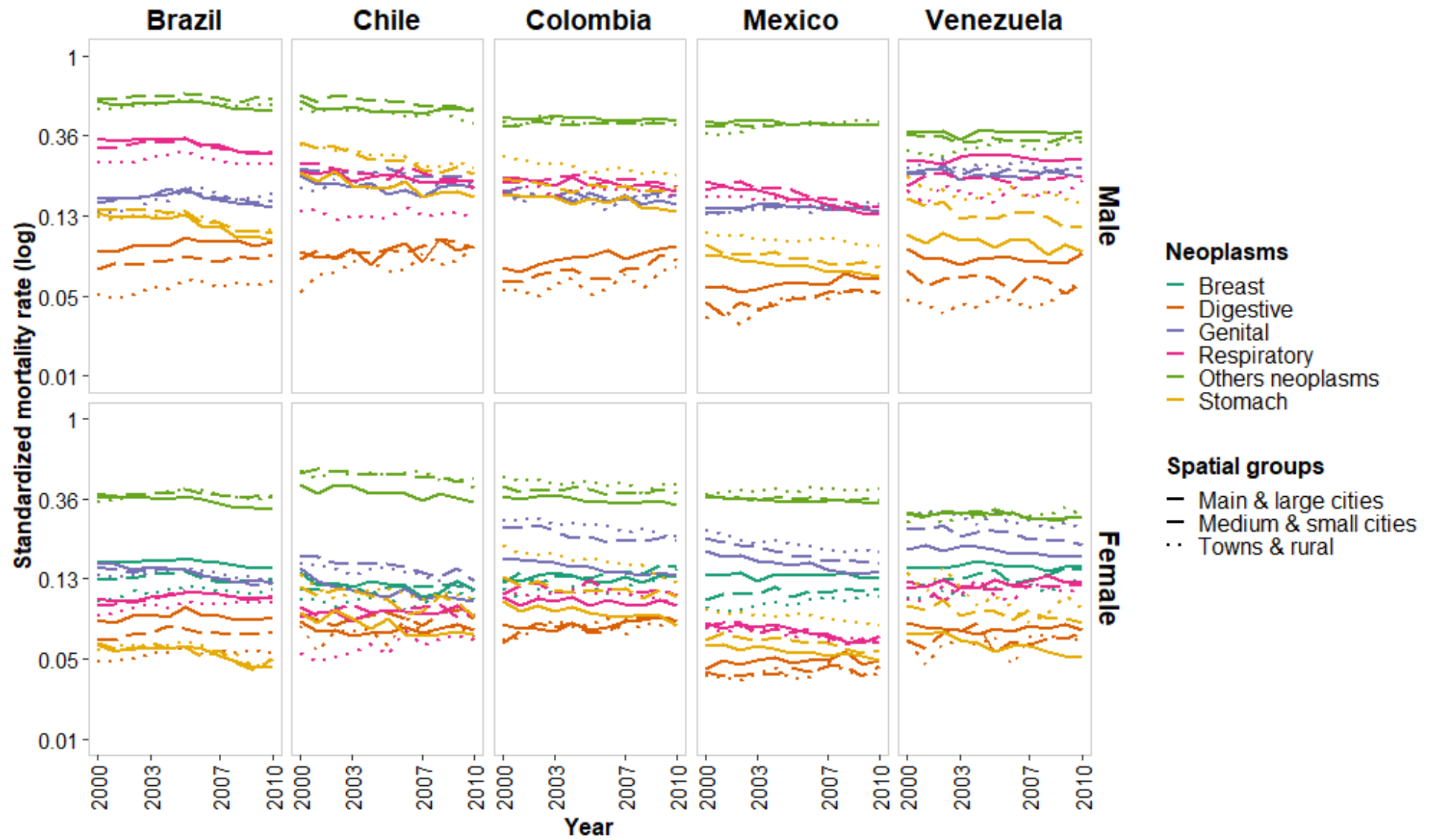
Annexes I: Causes of death analysis, Figure I.3A Contributions (in years) of heart diseases to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



Annexes I: Causes of death analysis, Figure I.3B Contributions (in years) of heart diseases to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).

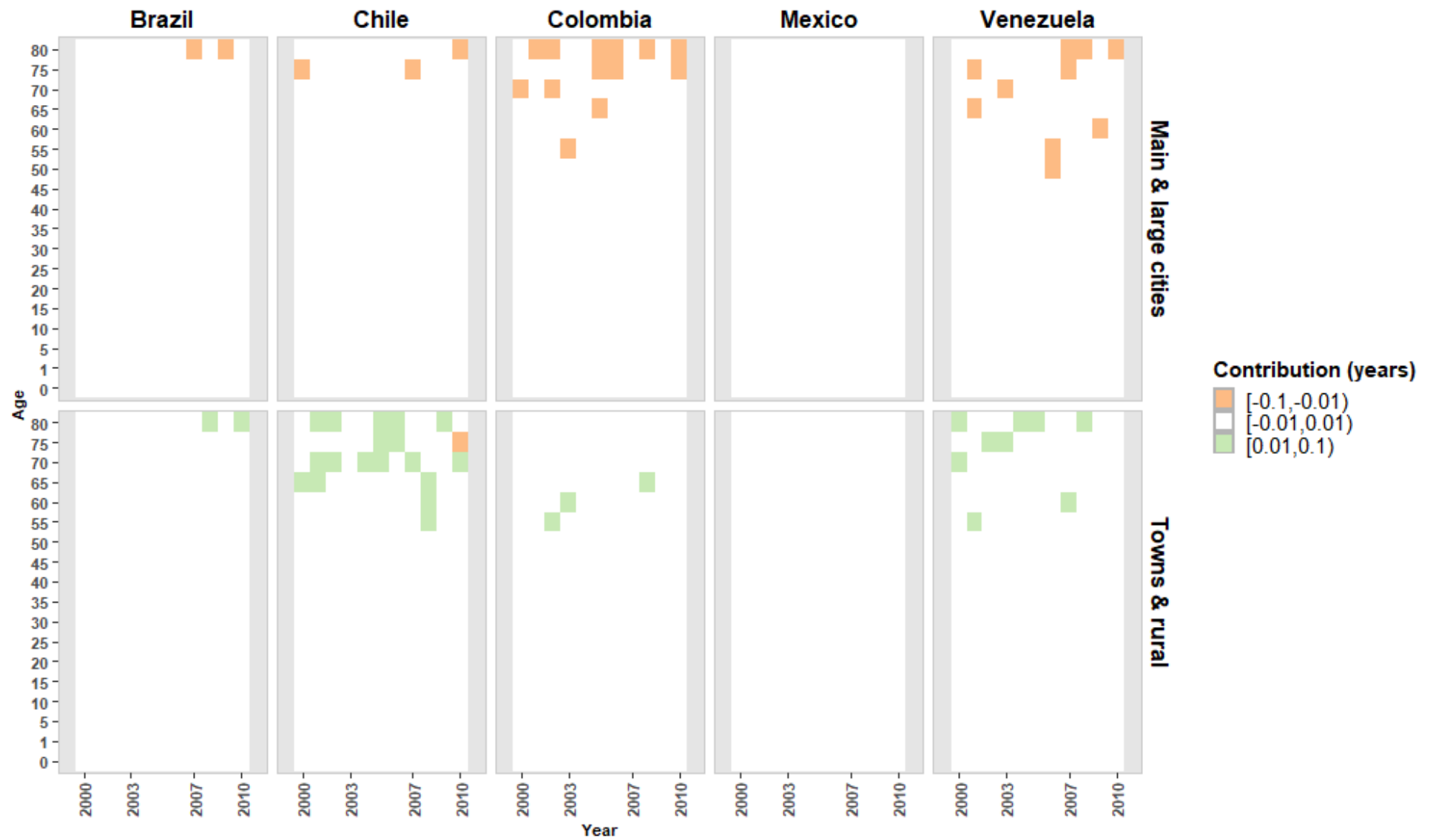


Annexes I: Causes of death analysis, Figure I.4 Neoplasms standardized rate by sex, spatial group and country.





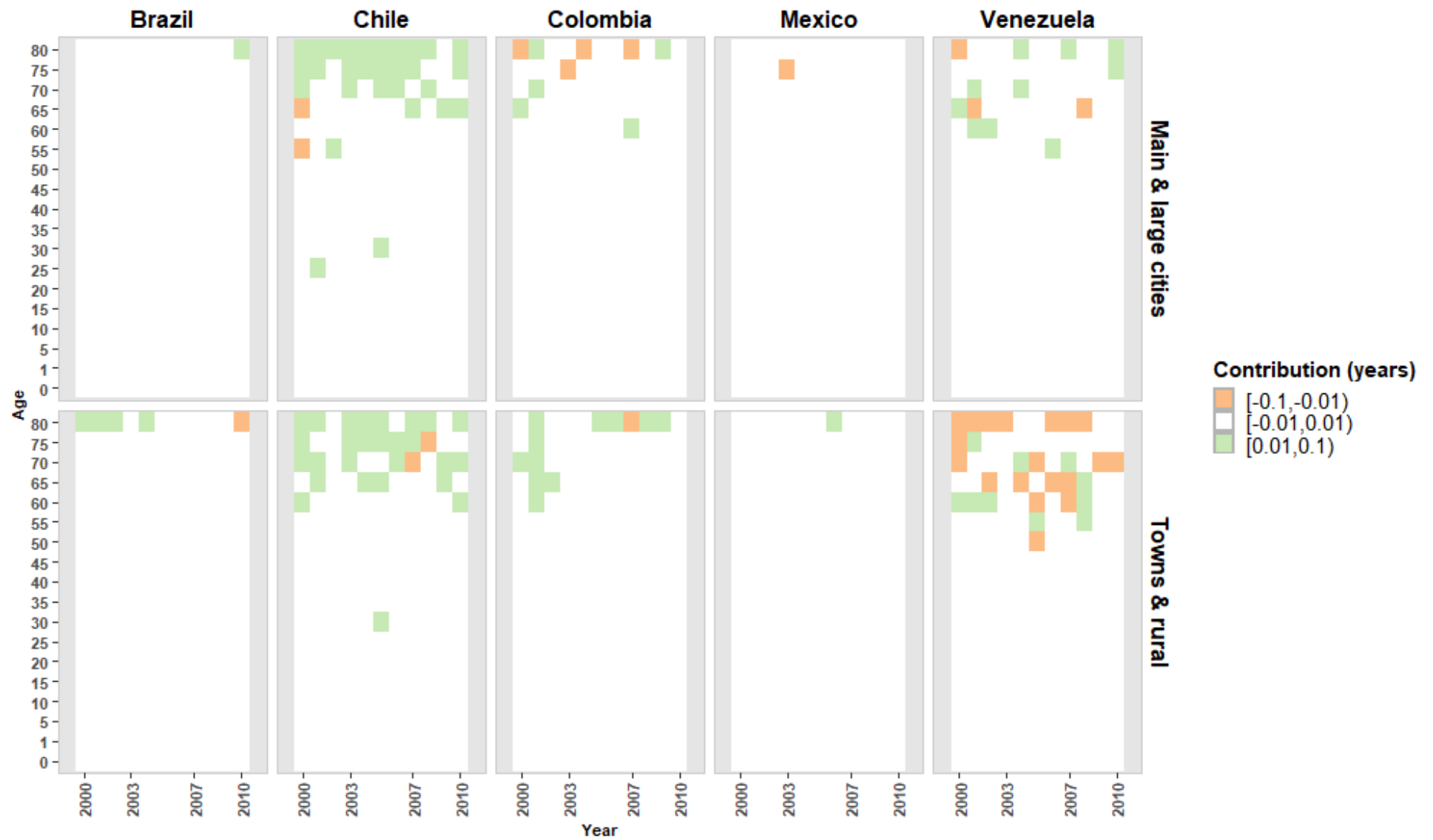
Annexes I: Causes of death analysis, Figure I.5A Contributions (in years) of neoplasm in the digestive system to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



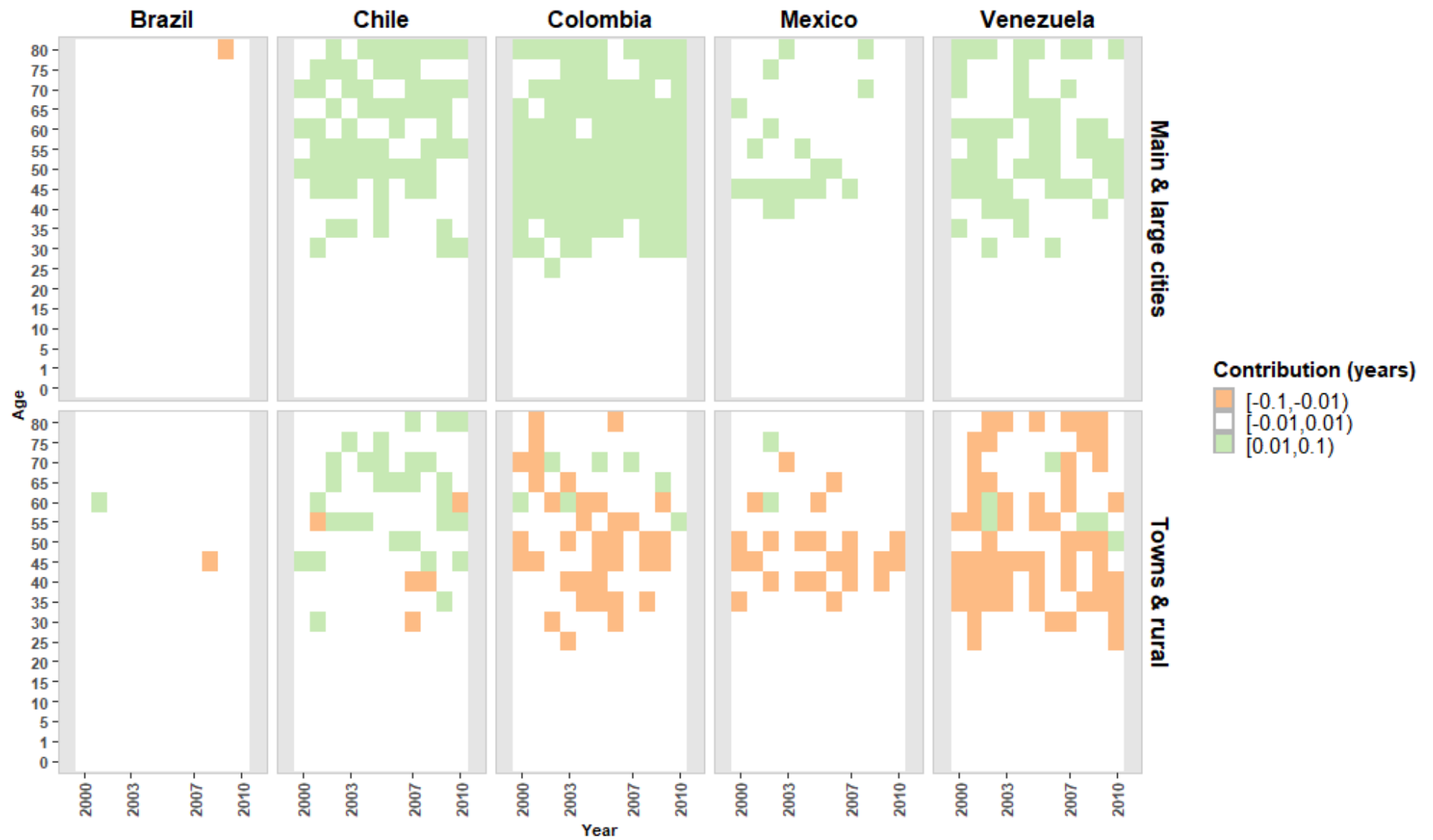
Annexes I: Causes of death analysis, Figure I.5B Contributions (in years) of neoplasm in the digestive system to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



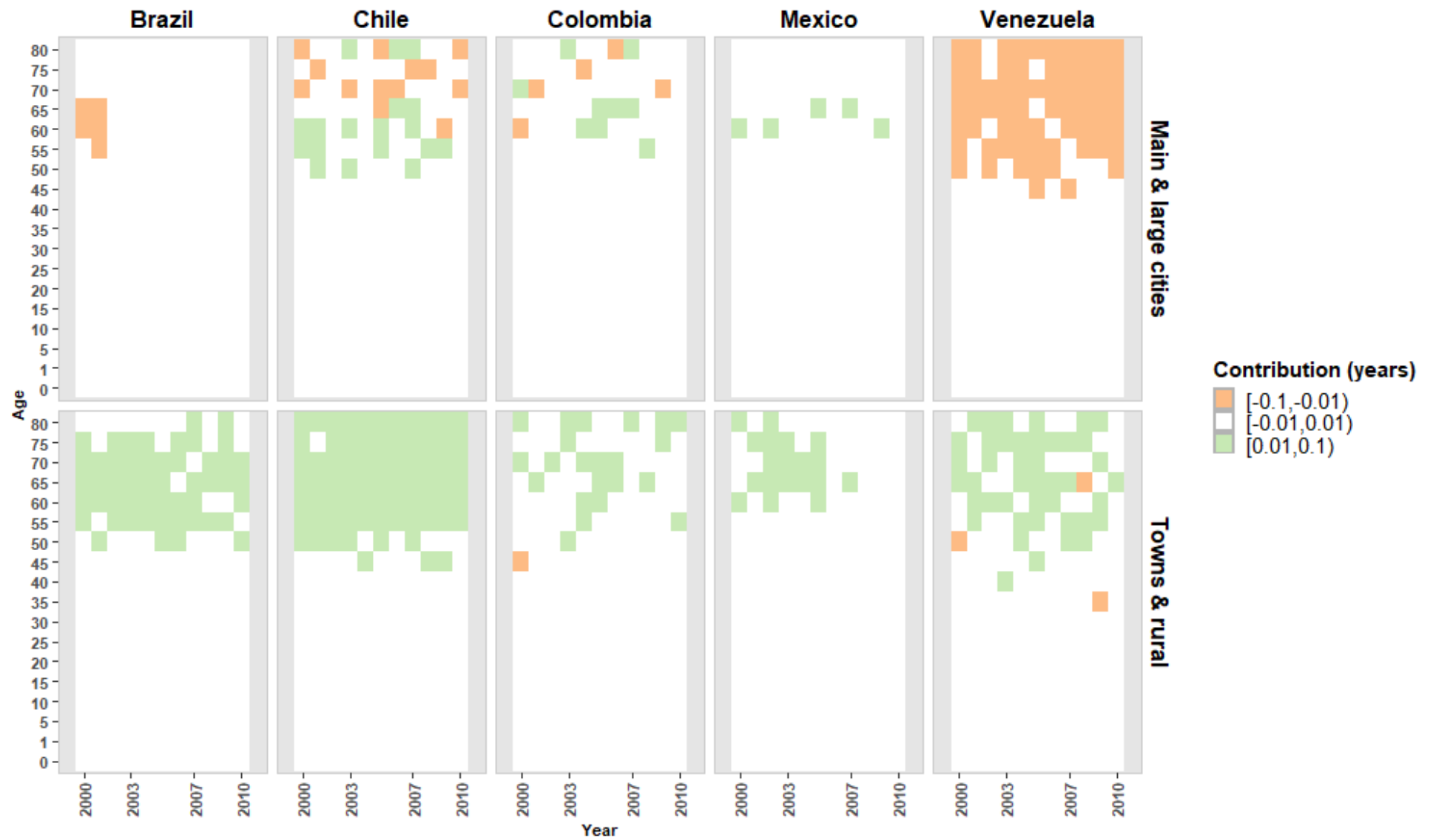
Annexes I: Causes of death analysis, Figure I.6A Contributions (in years) of neoplasm in the genital system to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



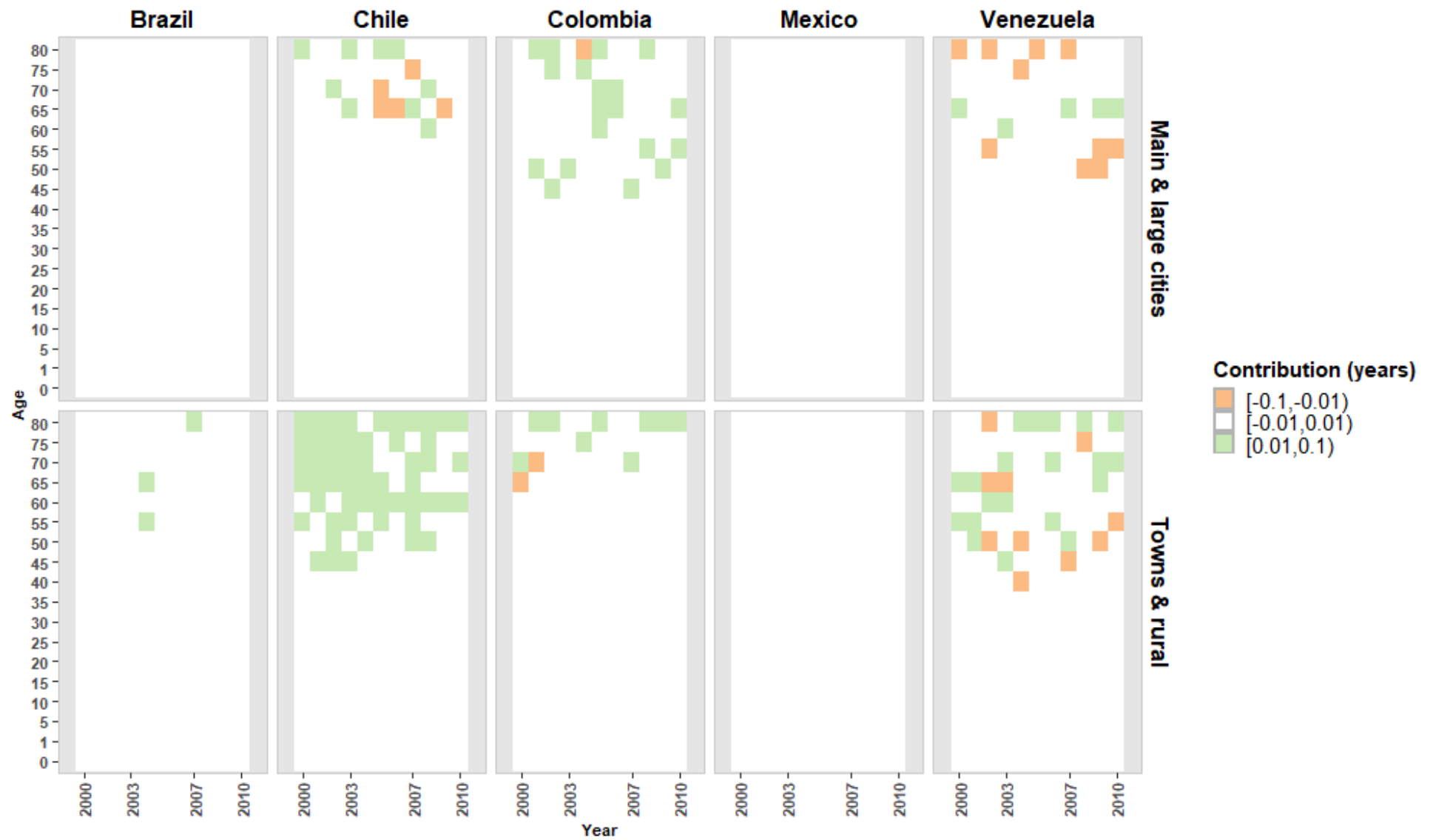
Annexes I: Causes of death analysis, Figure I.6B Contributions (in years) of neoplasm in the genital system to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



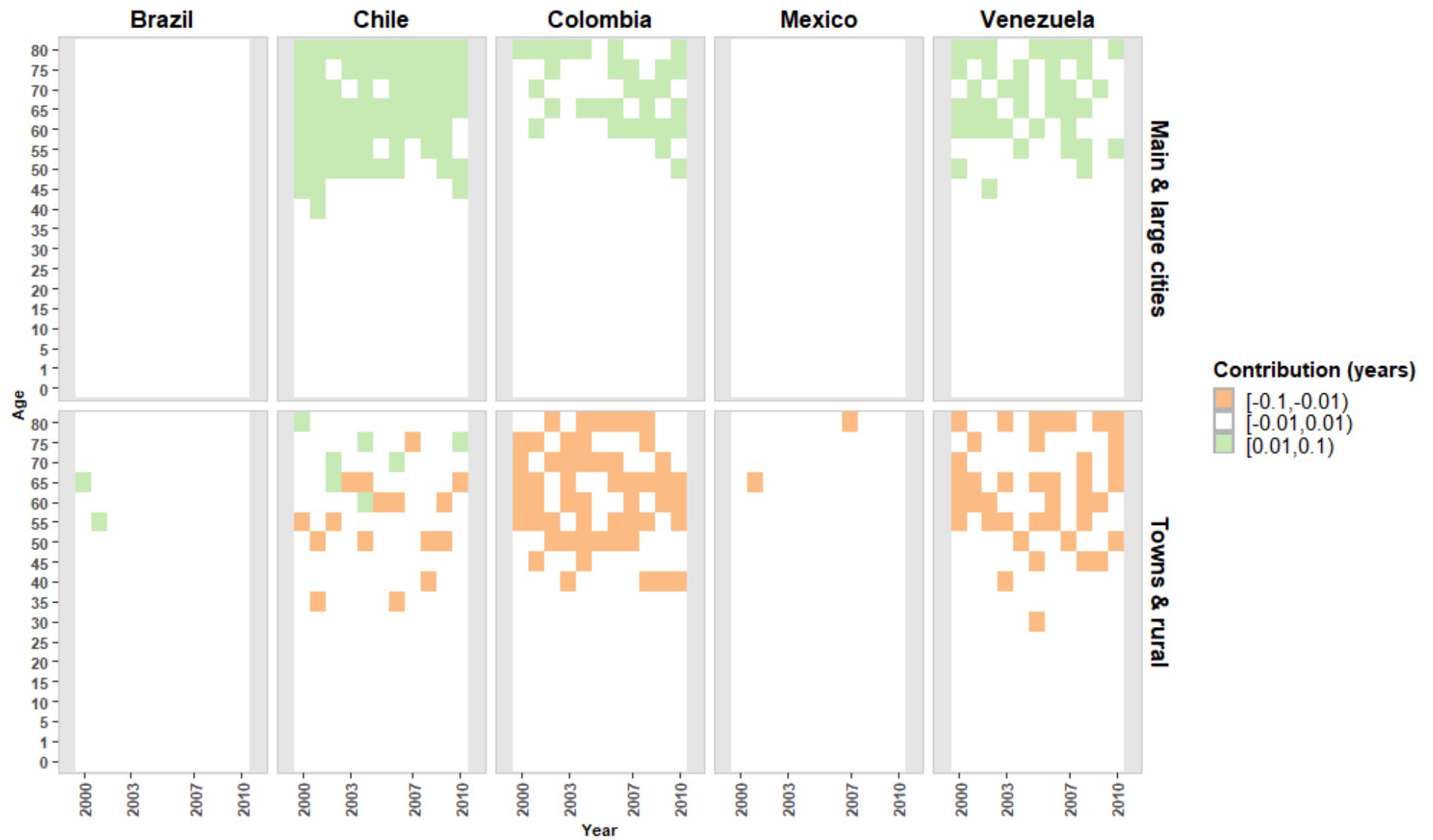
Annexes I: Causes of death analysis, Figure I.7A Contributions (in years) of neoplasm in the respiratory system to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



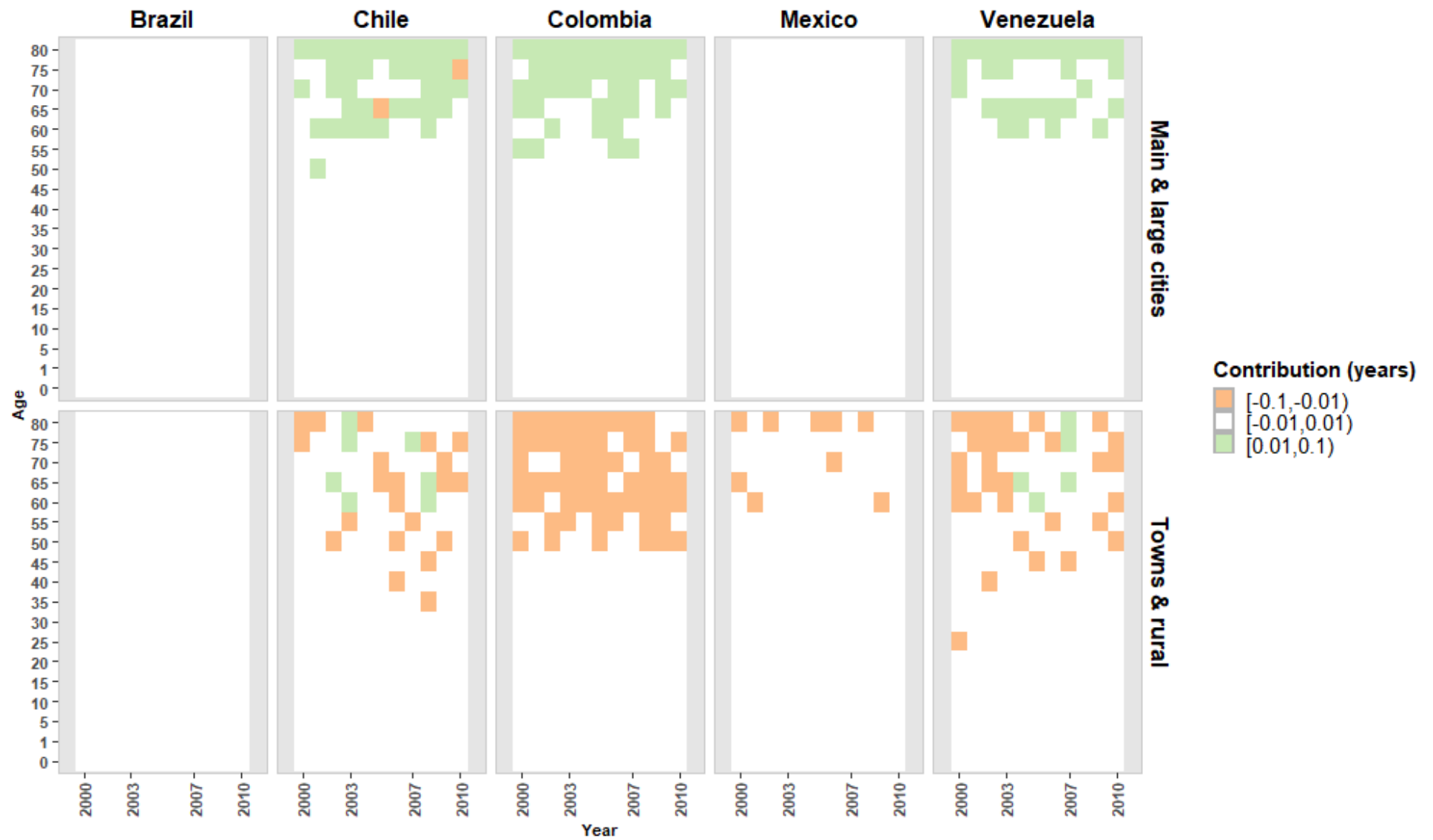
Annexes I: Causes of death analysis, Figure I.7B Contributions (in years) of neoplasm in the respiratory system to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



Annexes I: Causes of death analysis, Figure I.8A Contributions (in years) of stomach neoplasm to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



Annexes I: Causes of death analysis, Figure I.8B Contributions (in years) of stomach neoplasm to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).

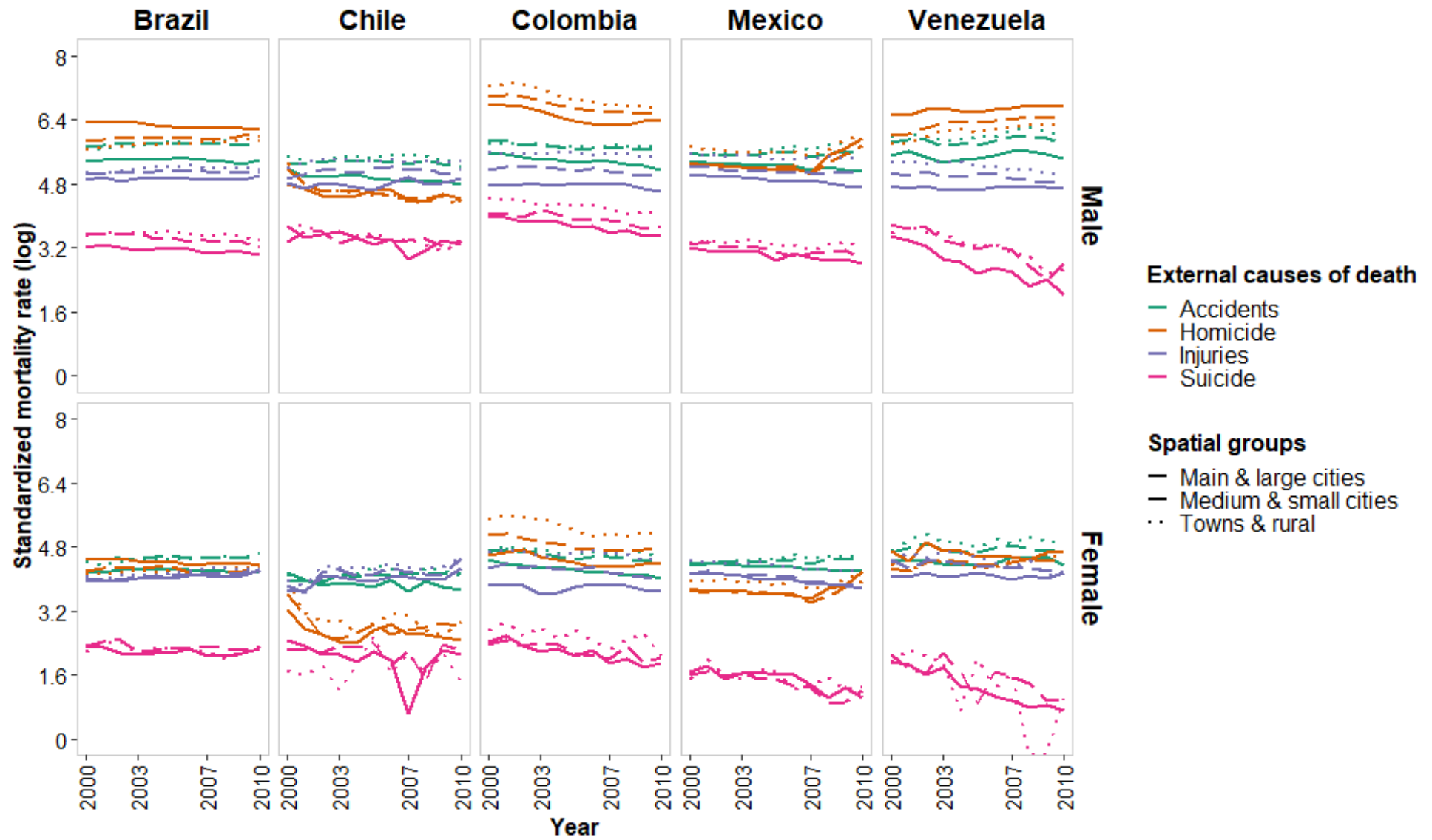




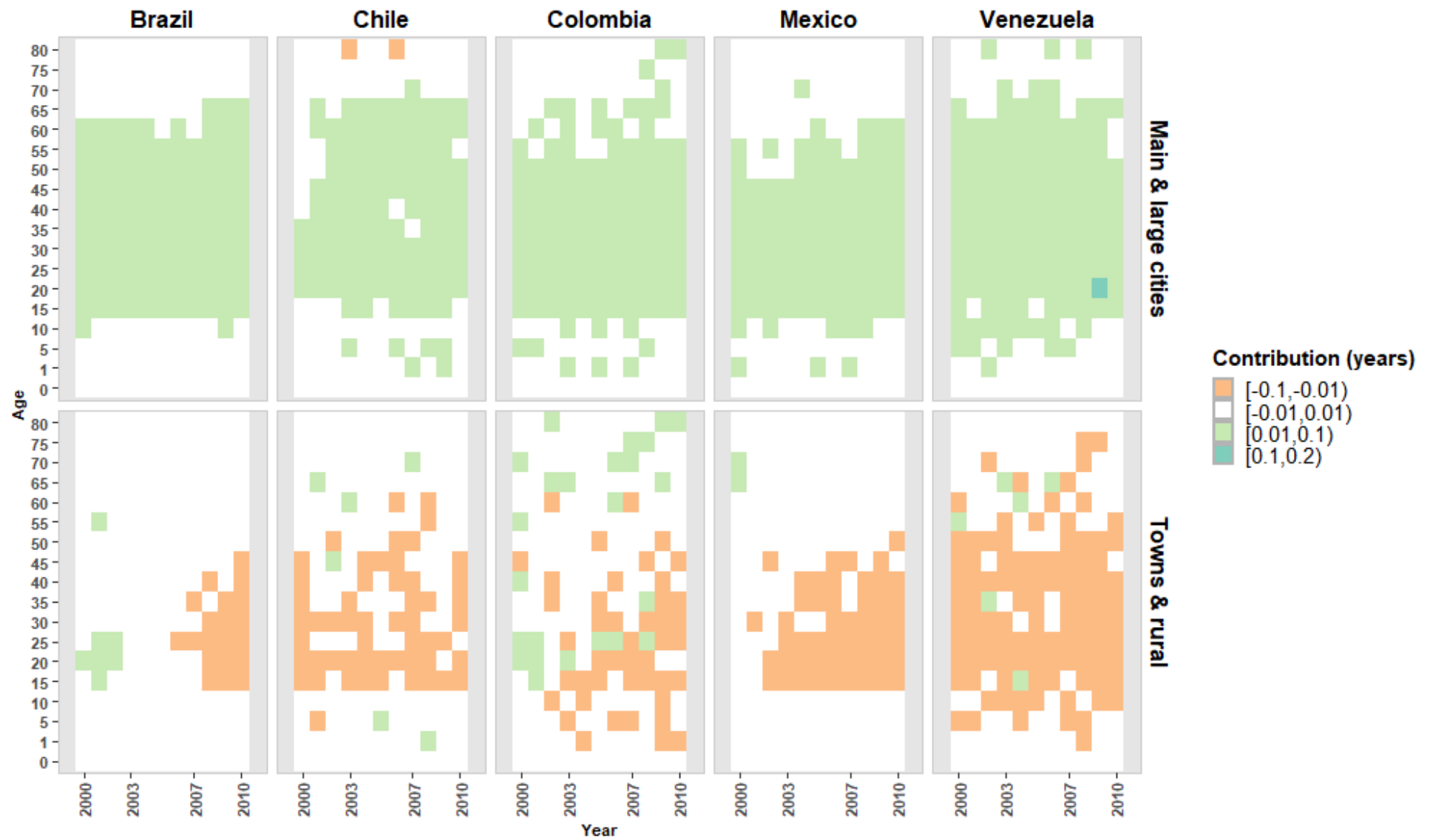
Annexes I: Causes of death analysis, Figure I.9 Contributions (in years) of breast neoplasm to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



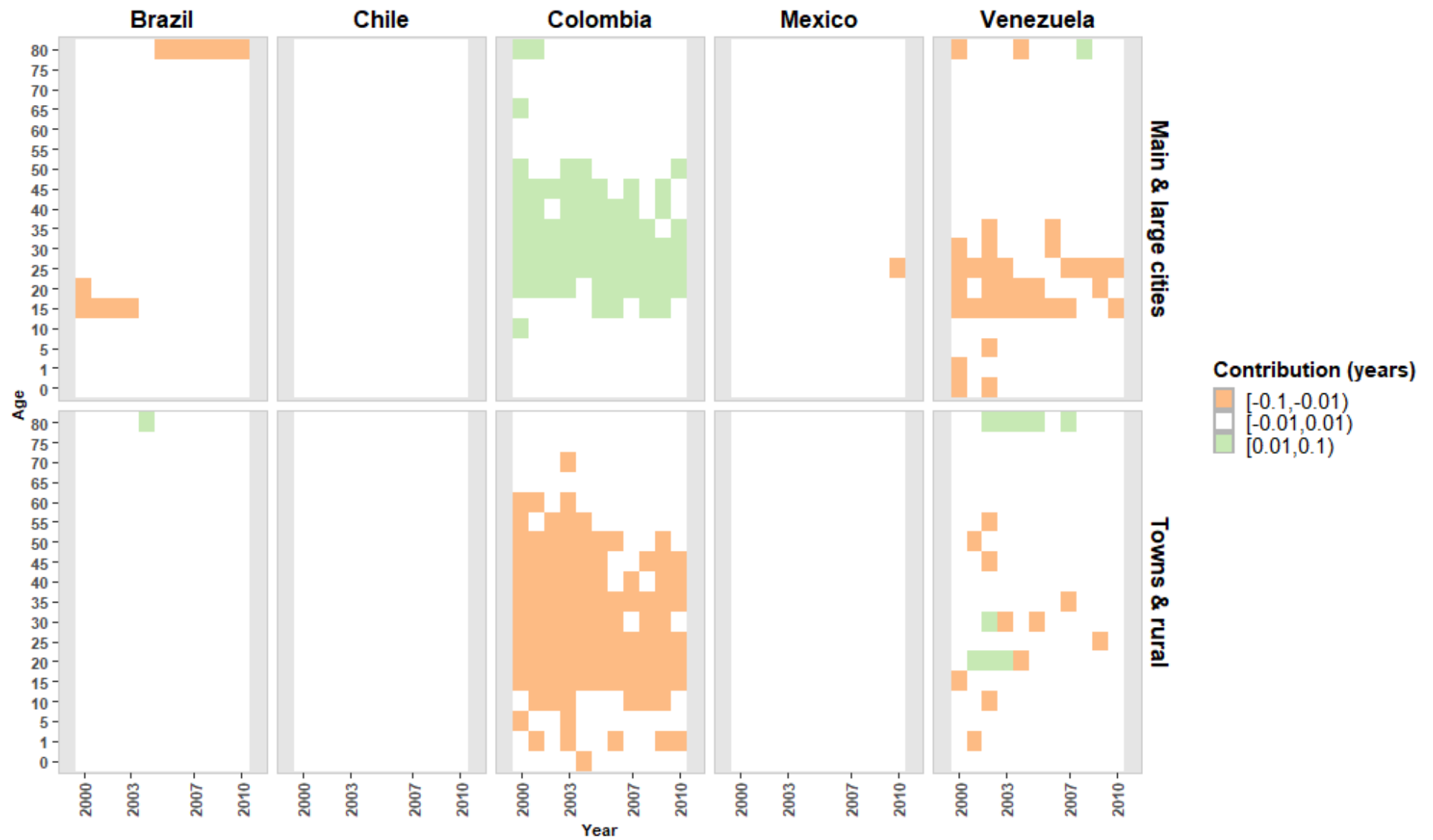
Annexes I: Causes of death analysis, Figure I.10 External causes of death standardized rate by sex, spatial group and country.



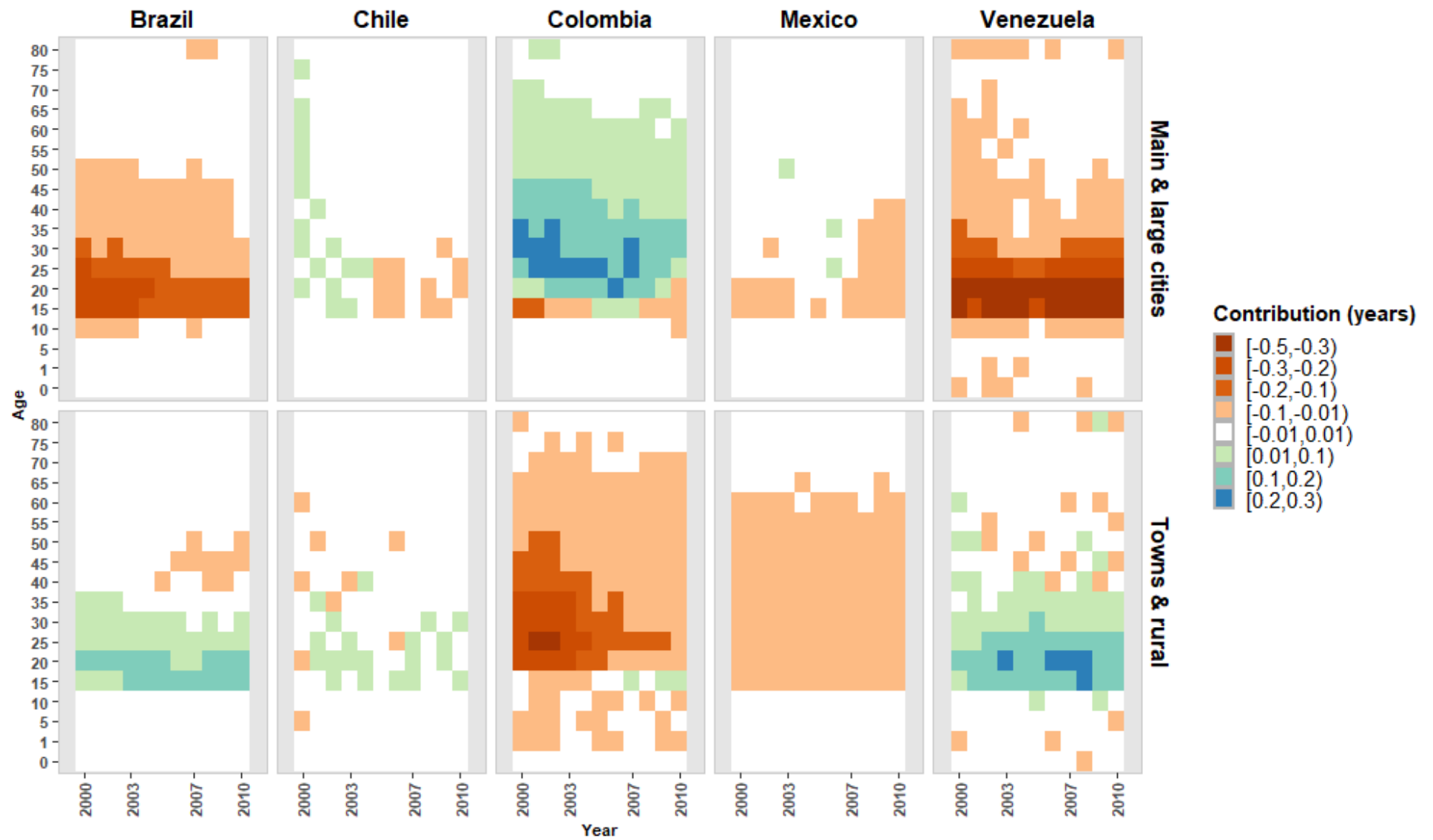
Annexes I: Causes of death analysis, Figure I.11A Contributions (in years) of transport accidents to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



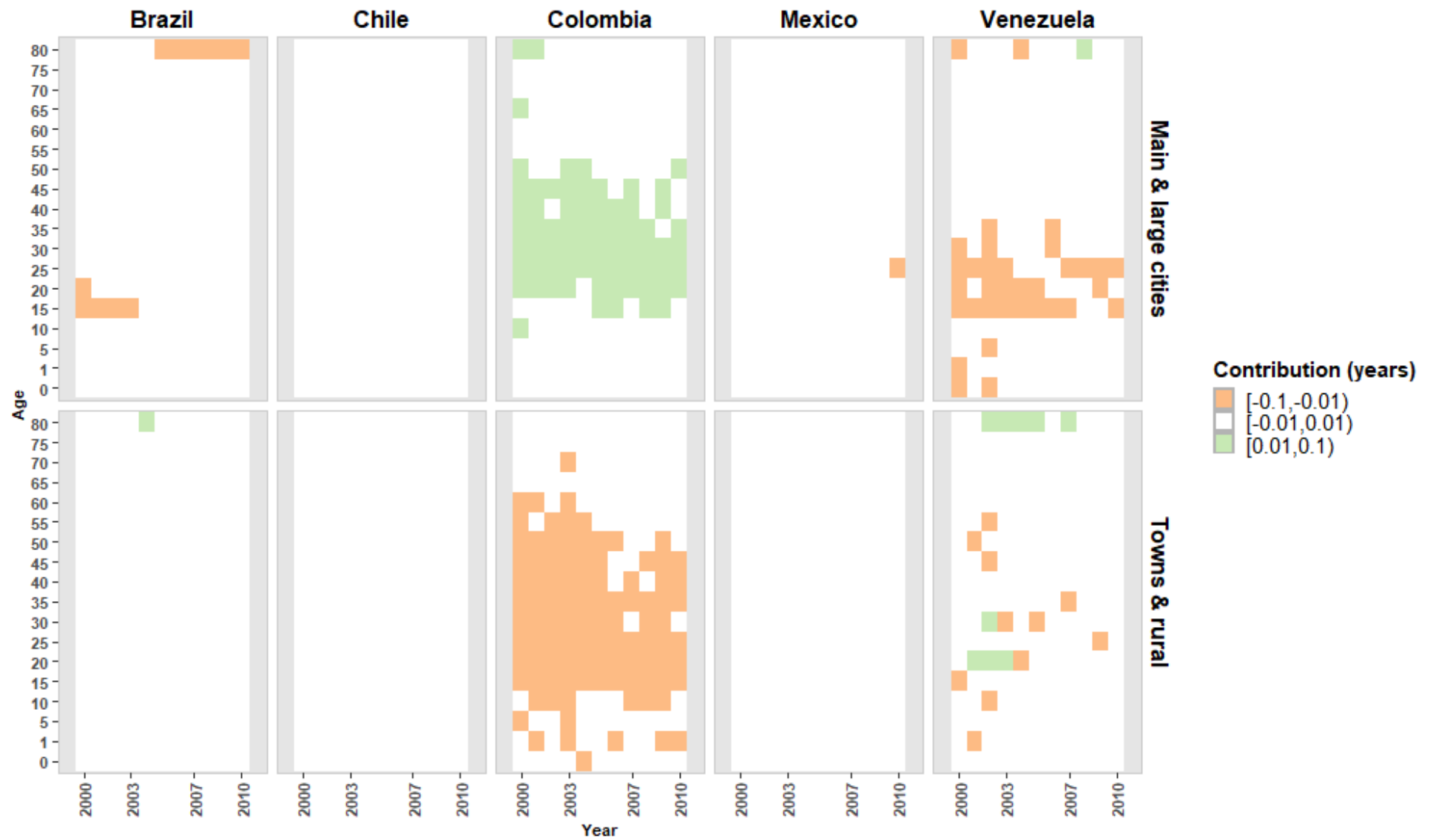
Annexes I: Causes of death analysis, Figure I.11B Contributions (in years) of transport accidents to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



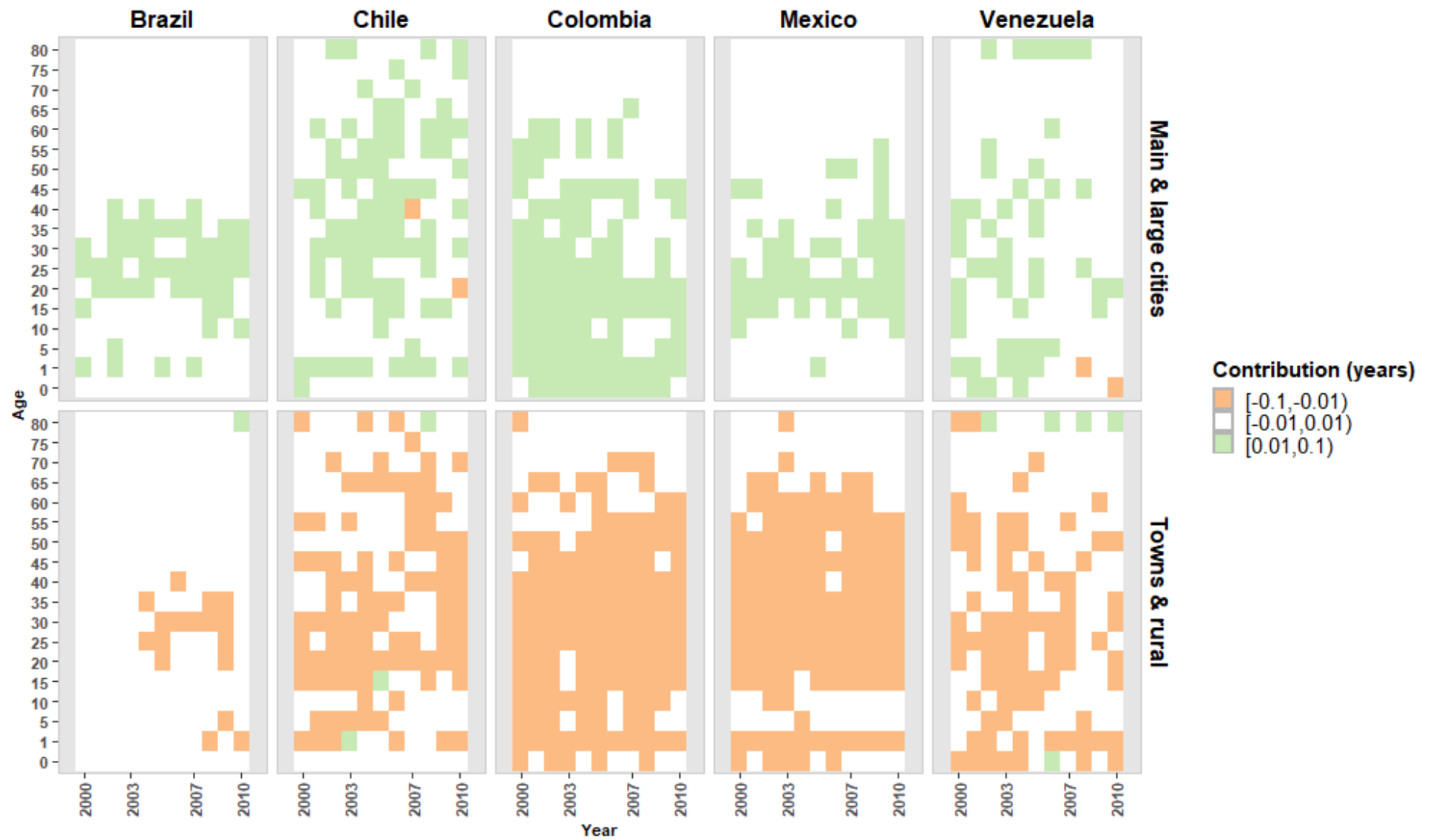
Annexes I: Causes of death analysis, Figure I.12A Contributions (in years) of homicides to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



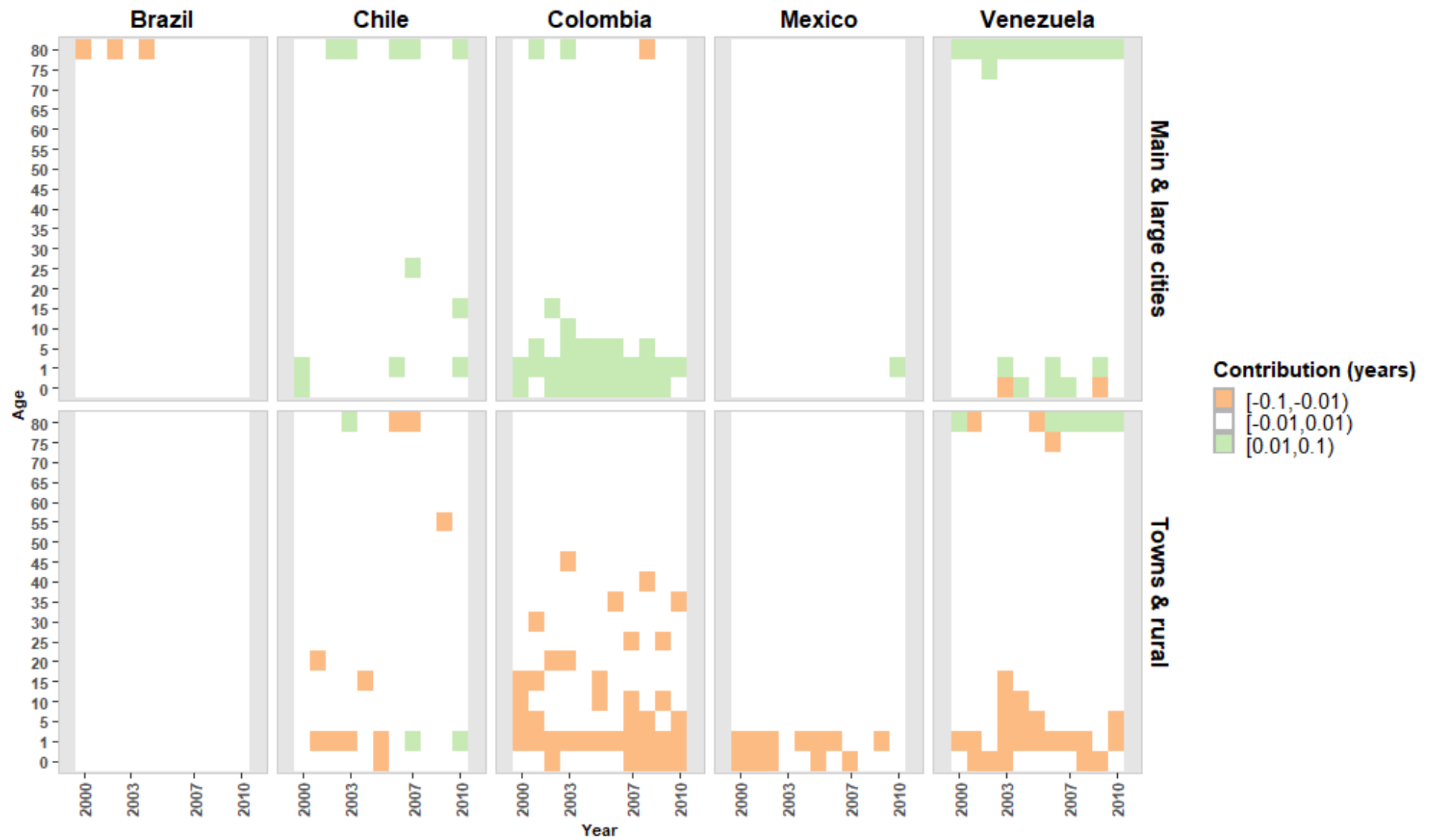
Annexes I: Causes of death analysis, Figure I.12B Contributions (in years) of homicides to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



Annexes I: Causes of death analysis, Figure I.13A Contributions (in years) of others accidents to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).

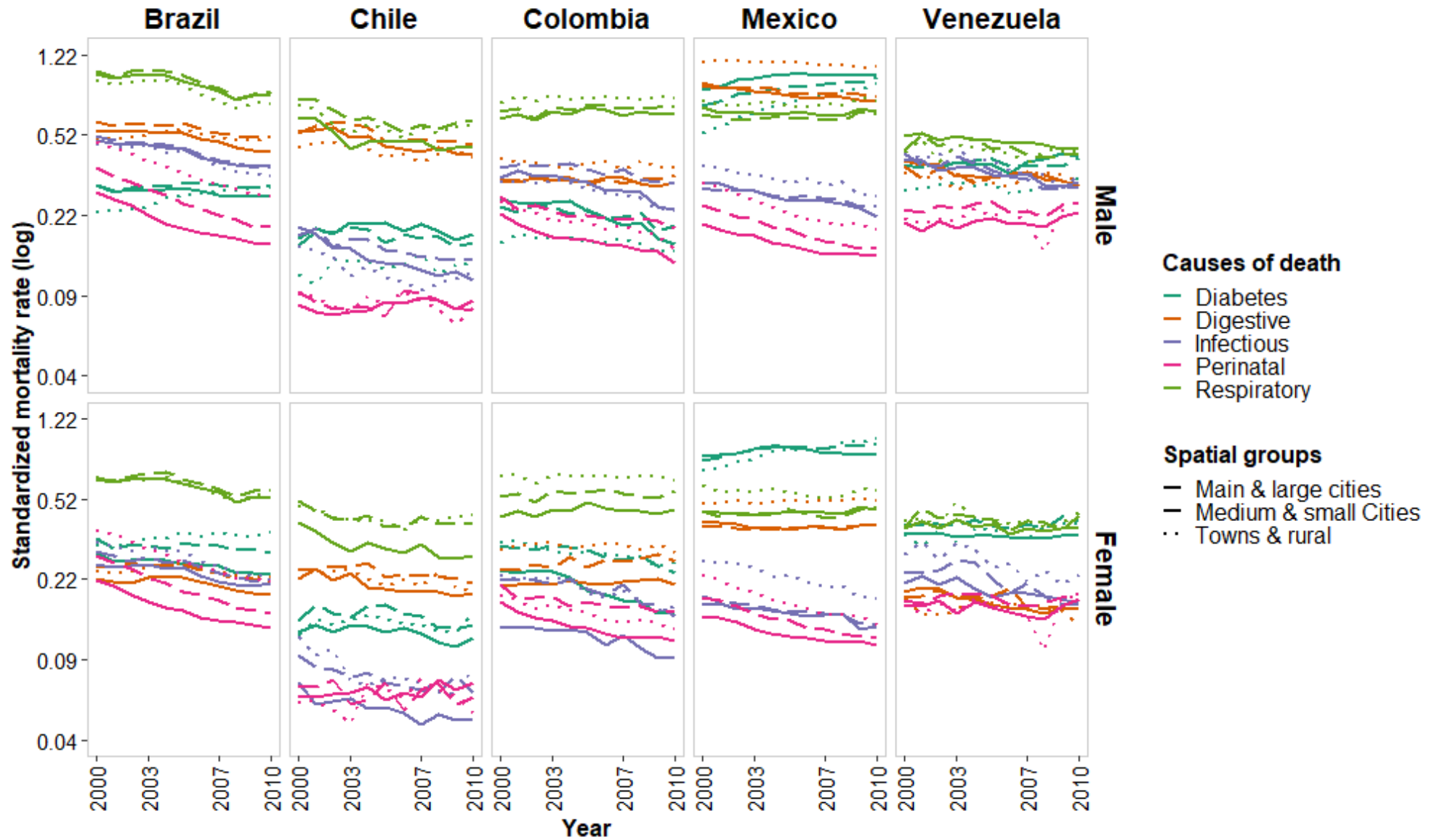


Annexes I: Causes of death analysis, Figure I.13B Contributions (in years) of other accidents to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).

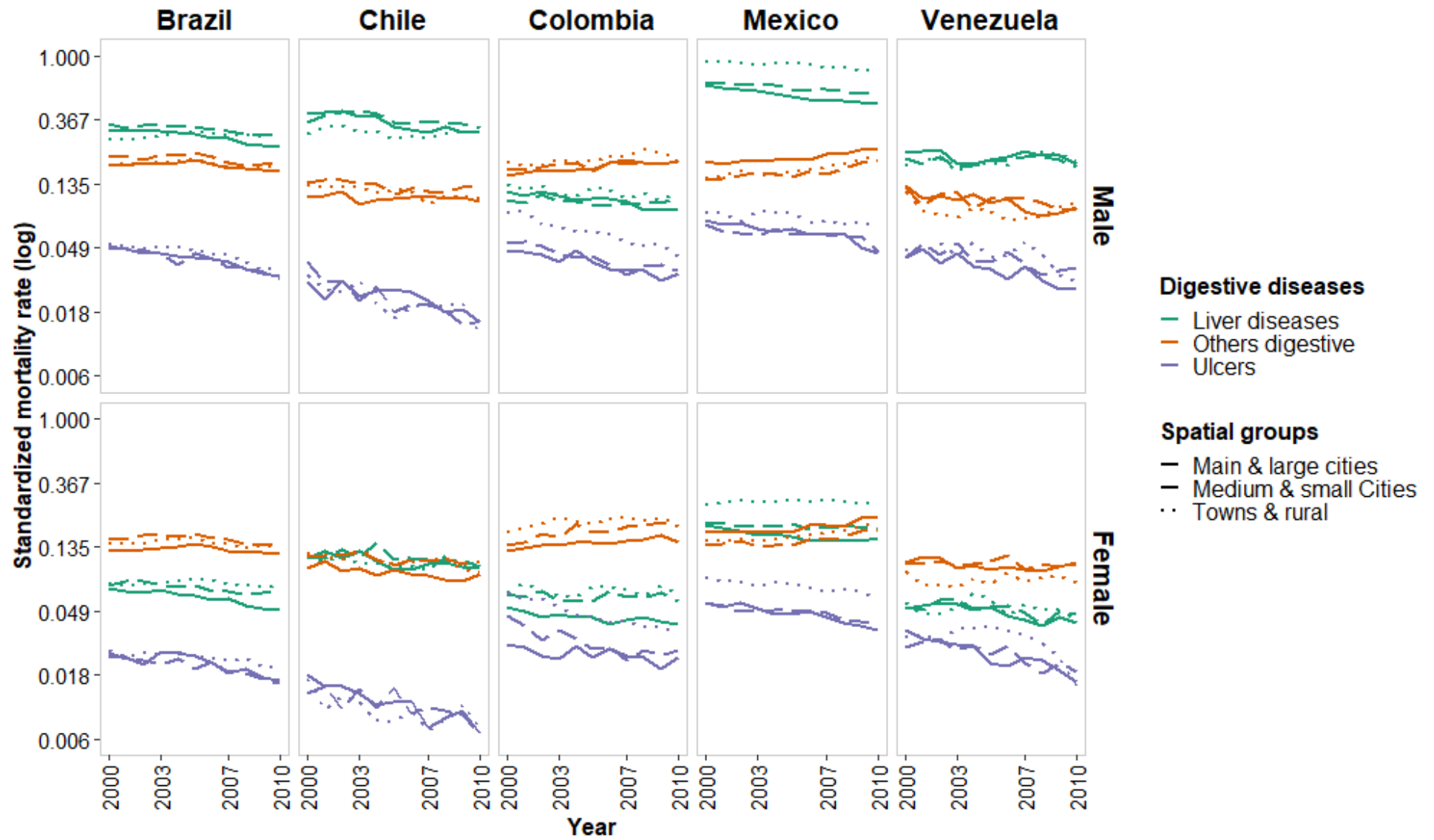




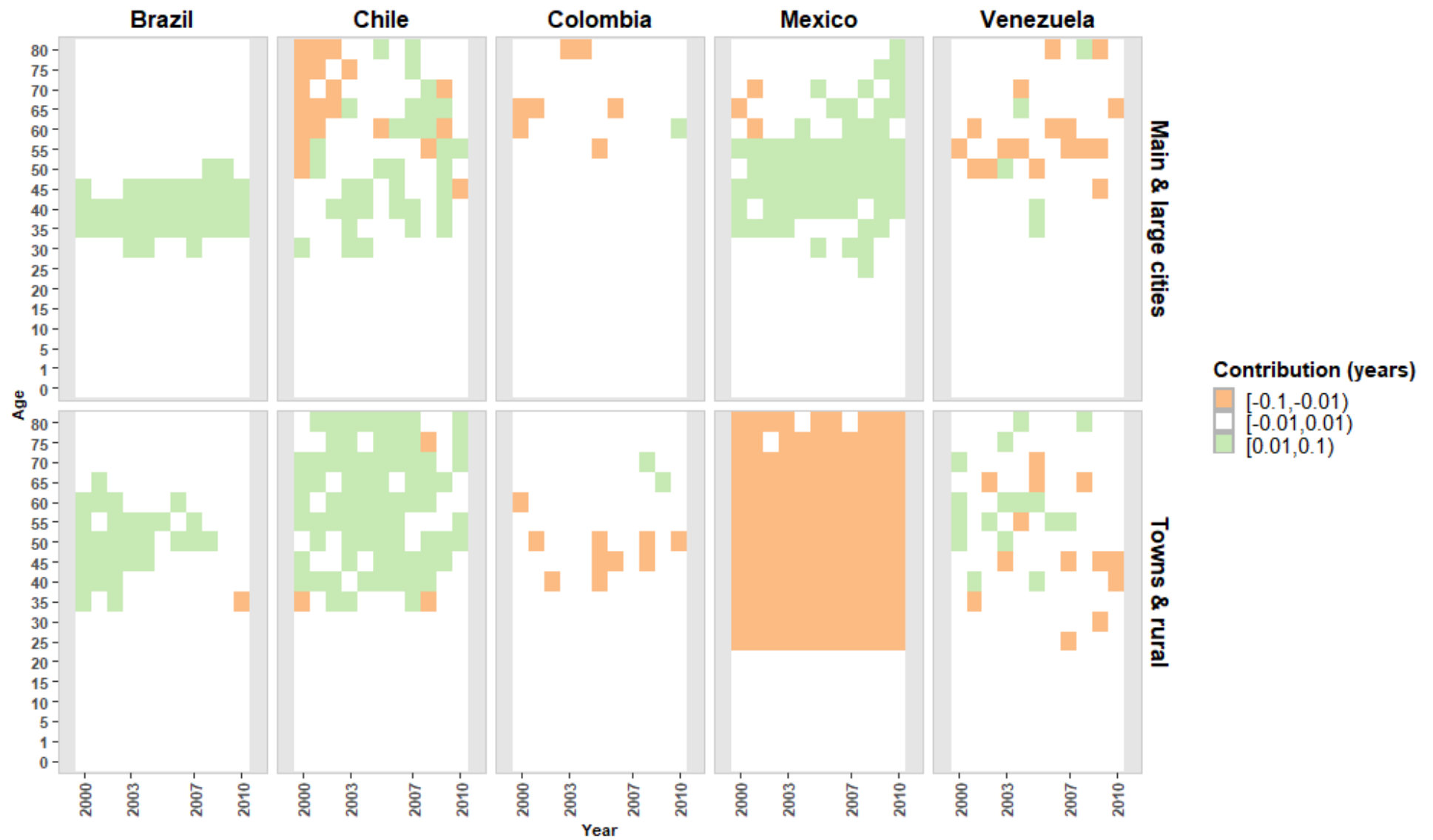
Annexes I: Causes of death analysis, Figure I.14 Others causes of death standardized rate by sex, spatial group and country.



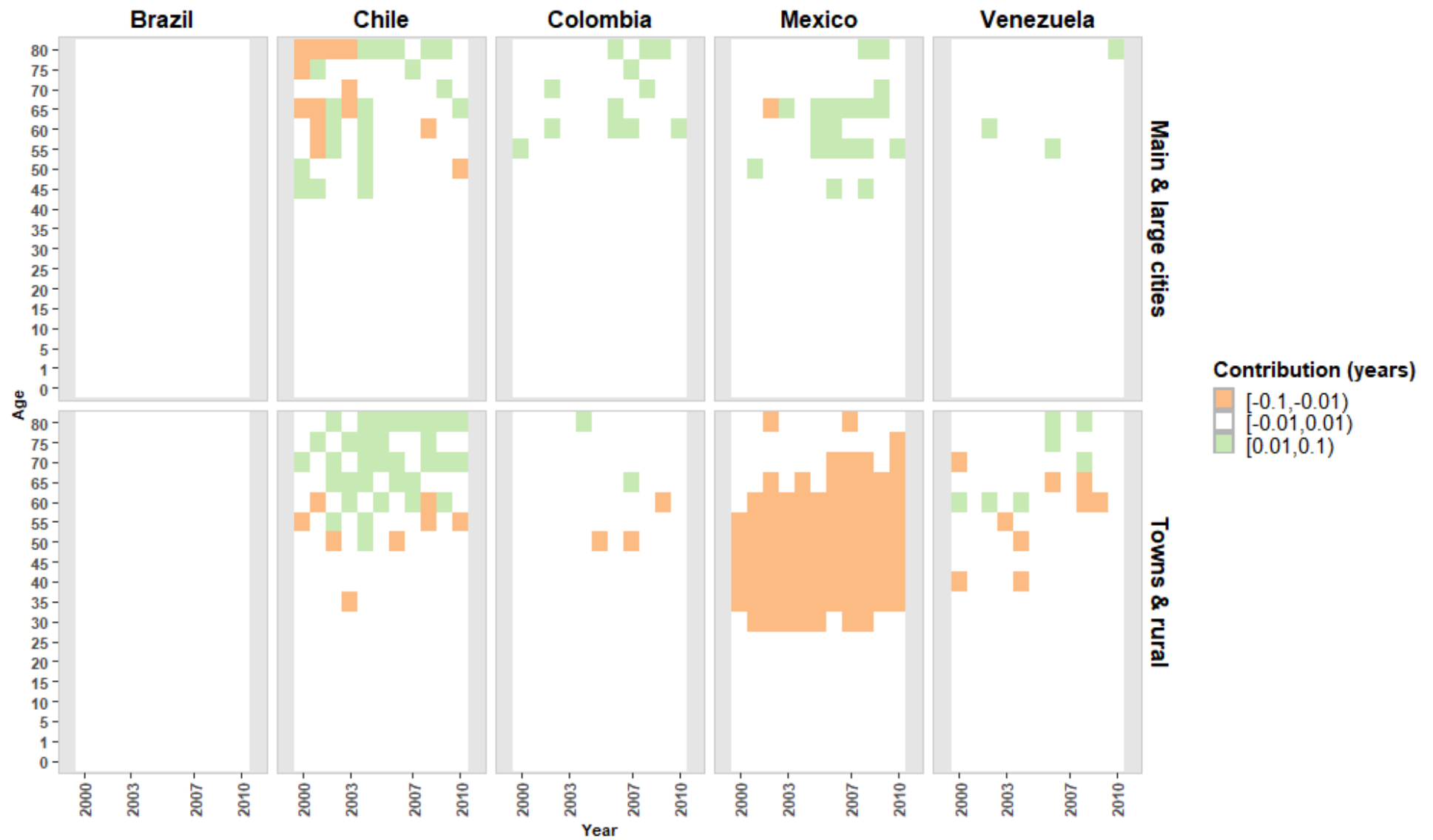
Annexes I: Causes of death analysis, Figure I.15 Digestive diseases standardized rate by sex, spatial group and country.



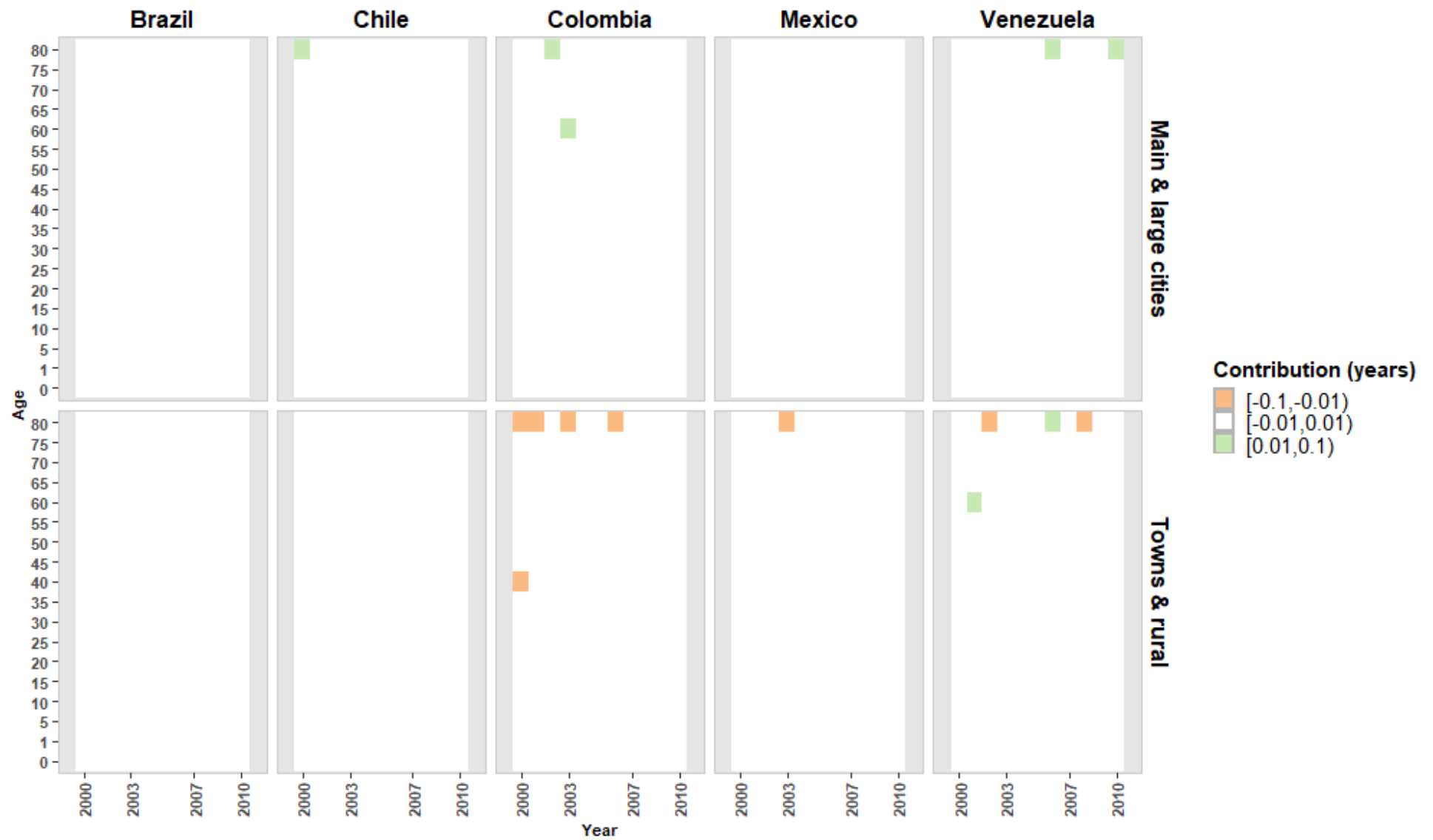
Annexes I: Causes of death analysis, Figure I.16A Contributions (in years) of liver diseases to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



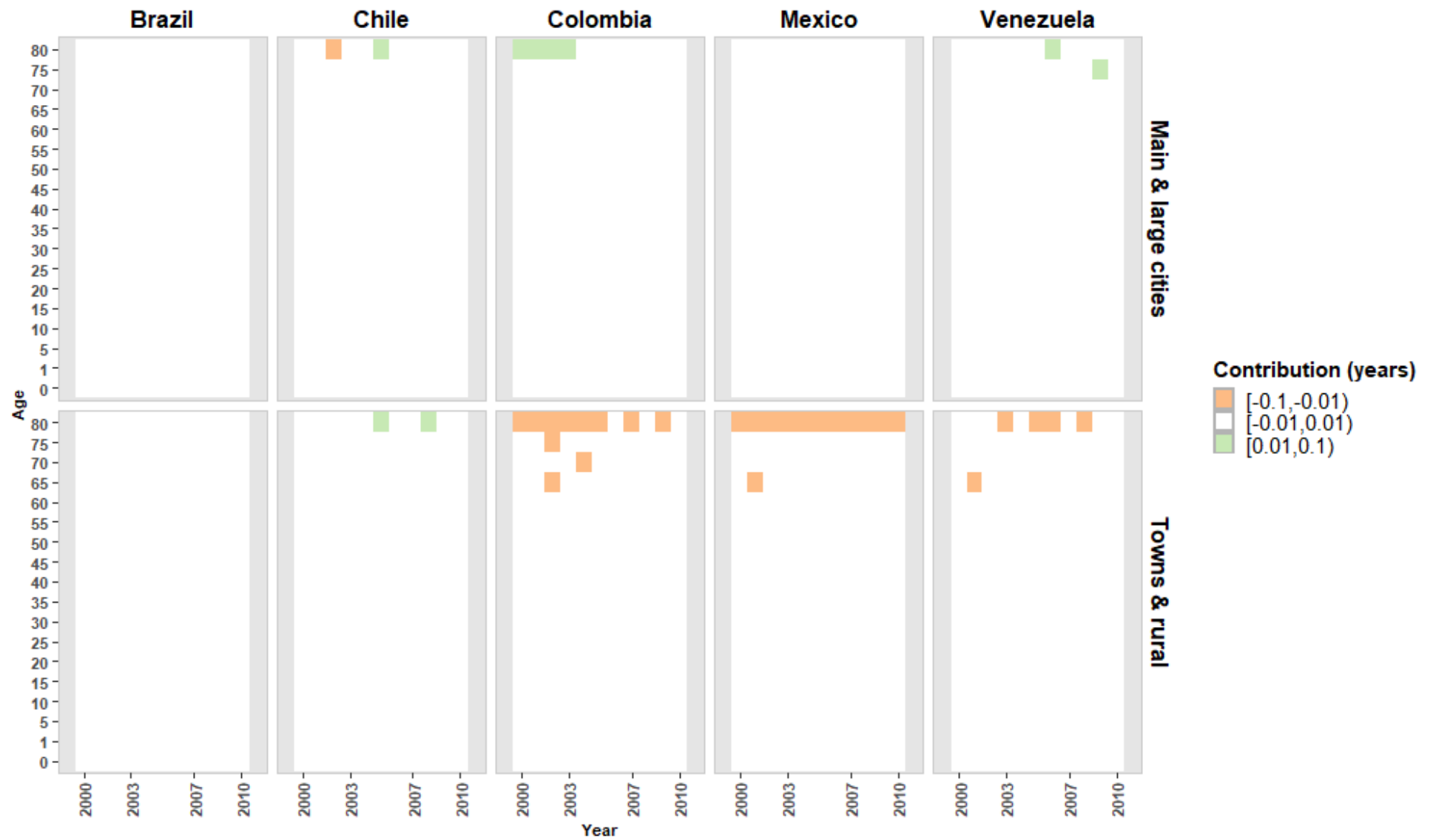
Annexes I: Causes of death analysis, Figure I.16A Contributions (in years) of liver diseases to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



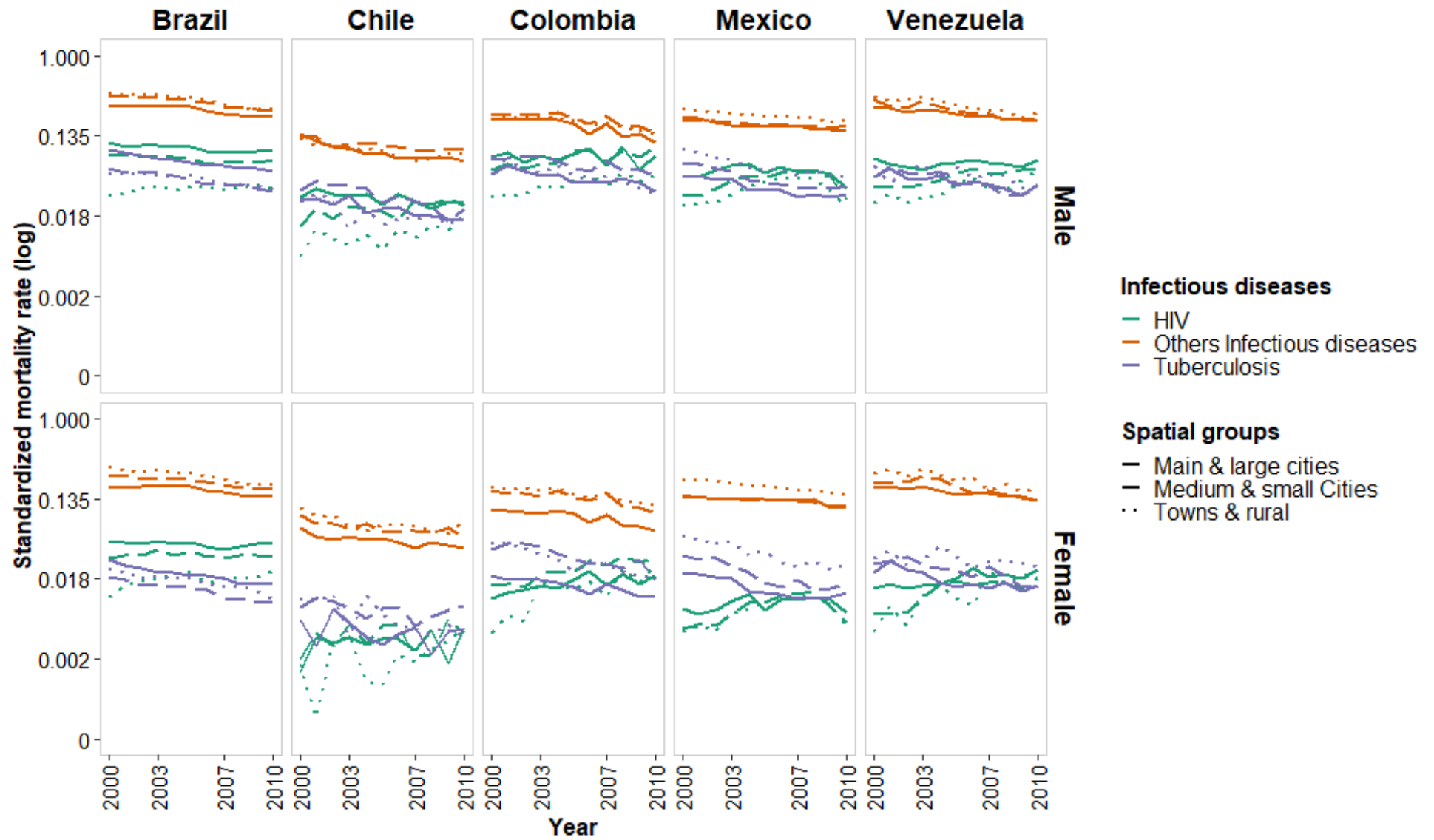
Annexes I: Causes of death analysis, Figure I.17A Contributions (in years) of ulcers to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



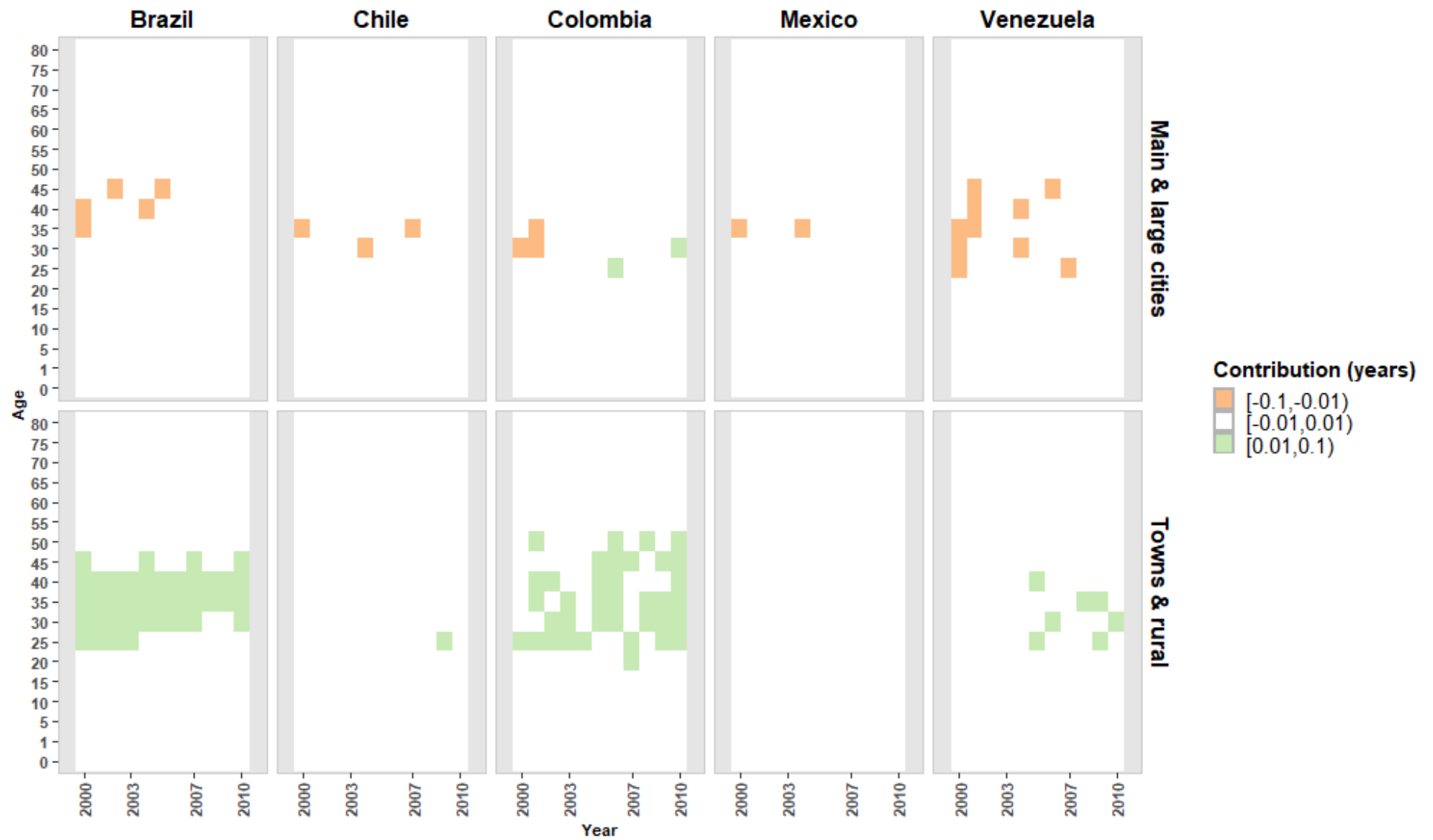
Annexes I: Causes of death analysis, Figure I.17B Contributions (in years) of ulcers to difference in female life expectancy at birth among spatial group (Medium-sized and small cities used as reference).



Annexes I: Causes of death analysis, Figure I.18 Infectious diseases standardized rate by sex, spatial group and country.



Annexes I: Causes of death analysis, Figure I.19 Contributions (in years) of HIV to difference in male life expectancy at birth among spatial group (Medium-sized and small cities used as reference).





Annexes I: Causes of death analysis, Figure I.20 Age contributions (in years) to changes in male life expectancy at birth by amenability, 2000 to 2010

