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Ivan Ledezma

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Université Paris I-Panthéon Sorbonne
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THESE

Pour obtenir le grade de
Docteur de l'Université Paris I-Panthéon Sorbonne
Discipline: Sciences Economiques

soutenue publiquement par

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le 30 juin 2008

**Market Structure and Productivity:
Theory and Evidence From Manufacturing**

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Juin 2008

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Résumé de la Thèse en Français

Structures de Marché et Productivité

Théorie et Analyse Empirique sur Données

Manufacturières

Résumé court. Dans cette thèse nous étudions le lien entre structure de marché et productivité. Une place particulière dans notre argumentation est réservée à certaines caractéristiques propres à l'industrie manufacturière: économies d'échelles, hétérogénéité des firmes et asymétries dans la connaissance technologique. Nous visons à comprendre comment les changements de la structure de marché, qu'ils soient orientés vers l'extérieur ou vers l'intérieur d'une économie, canalisent les incitations des firmes à obtenir des gains de productivité. La première partie de la thèse analyse l'effet de la politique commerciale sur la productivité des firmes. A l'aide d'un panel de firmes chiliennes (Chapitre 1) et d'un modèle théorique en économie ouverte (Chapitre 2), nous cherchons à expliquer les évolutions hétérogènes de la productivité des firmes. La seconde partie se focalise sur le lien entre structure de marché et innovation. A l'aide de données au niveau industriel pour un échantillon de pays de l'OCDE, nous testons l'effet de la concurrence et de la réglementation des marchés sur l'innovation, effet qui est mesuré conditionnellement à la proximité d'une industrie vis-à-vis de la frontière technologique (Chapitre 3). Finalement, nous proposons un modèle à échelles de qualité pour montrer comment la réglementation de marché peut canaliser la rivalité entre les concurrents d'une course aux brevets et influencer l'effort de R&D agrégé (Chapitre 4). Cet argument est testé au niveau industriel pour notre échantillon d'industries de l'OCDE.

Discipline: Sciences Economiques (05)

Mots-Clés: Commerce International, Innovation, Concurrence, Heterogeneité de Firmes.

1. Introduction

Les différents débats académiques portant sur l'obtention de gains de productivité à travers la modification de la structure de marché ont tendance à se concentrer sur les incitations des firmes à améliorer leur productivité plutôt que sur l'identification des déterminants de la productivité. Ainsi, si la plupart des économistes s'accordent sur l'importance de l'innovation en tant que déterminant du progrès technique, la question de savoir quelles sont les politiques qui encouragent les firmes à innover engendre plus de discussion. Cette focalisation sur les incitations provient du fait que, une fois que l'on abandonne les hypothèses théoriques de la concurrence parfaite, le comportement stratégique des firmes doit être pris en compte. Par conséquent, le résultat spécifique des politiques de réglementation de marché et d'ouverture commerciale n'est pas évident à anticiper et nécessite l'explicitation des caractéristiques particulières des technologies de production, des formes de consommation et du type de concurrence.

Cette thèse entre dans le détail de cette question et étudie le lien entre structure de marché et productivité en tenant compte de trois caractéristiques représentatives de l'industrie manufacturière qui ont la particularité de s'éloigner du cadre théorique de la concurrence parfaite : l'hétérogénéité des firmes, les économies d'échelle et les asymétries dans la connaissance technologique. En soulignant ces aspects, nous cherchons à comprendre par quels mécanismes la structure de marché, dans ses dimensions nationale et internationale, incite les firmes de façon différenciée à l'obtention des gains de productivité et quel type d'équilibre en découle. Nous étudions donc, explicitement, des questions théoriques et empiriques concernant le commerce international et la concurrence sur le marché de

produits. Des contributions récentes sur ces deux domaines de l'analyse économique fournissent de puissants outils pour comprendre comment les firmes améliorent leur productivité en réponse aux changements des politiques d'intégration commerciale et de concurrence et, plus important encore, quelles firmes sont en mesure de le faire.

La représentation de l'industrie manufacturière que nous adoptons dans ce travail a été mise en évidence par diverses contributions de la littérature. Tout d'abord, une vaste vague de travaux empiriques a montré l'existence d'une forte hétérogénéité des firmes au niveau intra-industriel et ceci même à des niveaux très désagrégés de classification industrielle. Ce fait stylisé concerne non seulement les pays en voie de développement (Aw, Chung et Roberts, 2000; Roberts et Tybout, 1997 ; Clerides, Lach et Tybout, 1998; Alvarez et Lopez, 2005) mais il est aussi valable pour des pays développés (Bernard et Wagner, 1997 ; Bernard et Jensen, 2001 ; Bernard, Jensen et Schott, 2003).

Ensuite, les économies d'échelle ont été souvent soulignées comme une caractéristique importante dans l'industrie manufacturière. C'est grâce à la prise en compte des économies d'échelle et de la concurrence imparfaite que la nouvelle théorie du commerce international (Krugman, 1980) permet d'expliquer pourquoi on constate des échanges au niveau intra-industriel entre pays similaires. A l'aide d'un échantillon de 27 industries manufacturières (et 7 non manufacturières) appartenant à 71 pays, Antweiller et Trefler (2002) montrent l'importance des économies d'échelle au moment d'expliquer la configuration des échanges internationaux. Dans leurs estimations, les auteurs trouvent qu'un tiers des industries de l'échantillon opère avec de rendements d'échelle croissants. L'une des conséquences importantes de ce constat est que la taille du marché détermine la structure

de coûts des firmes (Rodrik, 1992 ; Krugman, 1995). Puisque les possibilités des firmes d'élargir leur taille dépendent en grande mesure de leur accès aux marchés étrangers et à la concurrence internationale, les dimensions internationales de la structure de marché acquièrent une relevance particulière dans notre étude.

Enfin, un élément clé pour comprendre l'évolution de la productivité des firmes est la détention privée de connaissances technologiques de pointe et le comportement stratégique qui en découle. Dans la pratique, les firmes leaders utilisent un ensemble complexe de stratégies leur permettant de garder une position dominante. Cet ensemble va au-delà de la simple protection octroyée par les brevets et peut comprendre, entre autres, les secrets industriels, l'usage des avantages en termes d'apprentissage et de temps de développement ainsi que l'exploitation des complémentarités d'actifs (Cohen, Nelson et Walsh, 2000 ; Levin et al., 1987). Des firmes opérant sous différentes structures de marchés peuvent alors ne pas adopter les mêmes stratégies de recherche et développement (R&D). A l'aide de données provenant des enquêtes d'innovation, Cohen et al. (2002) montrent comment deux pays innovants, tels que les Etats Unis et le Japon, diffèrent dans les stratégies suivies au moment de s'approprier la valeur des innovations et même dans l'usage de ces stratégies.

La mise en lumière de ces caractéristiques de l'industrie manufacturière rend plus claire l'idée selon laquelle l'équilibre est déterminé non seulement par des fondamentaux économiques mais aussi par un ensemble d'institutions jouant le rôle de « règles du jeu » pour les agents économiques. Ces règles du jeu sont modifiées par les politiques économiques transformant la structure de marché et, par conséquent, elles canalisent les incitations des firmes à adopter des stratégies leur permettant d'augmenter leur productivité.

ité. Quelques exemples internationaux de réformes ont cherché à exploiter les propriétés de coordination du marché à travers l'élimination des barrières à l'entrepreneuriat et au libre flux de biens et facteurs. Le rôle important des politiques orientées vers le marché concurrentiel a été revendiqué dans la plupart des réformes structurelles en Amérique Latine durant les années quatre-vingt-dix. La déréglementation de marché et la libéralisation commerciale étaient au cœur des paquets de réformes cherchant à stimuler la croissance de la productivité. L'intensification attendue de la concurrence était vue comme un moyen de sélection des firmes les plus productives ainsi que d'incitation à réduire les inefficiences. Certains pays d'Asie de l'Est, par contre, se sont ouverts et intégrés commercialement tout en adoptant des politiques non-neutres cherchant à soutenir des secteurs stratégiques d'activité censés engendrer une forte croissance de long terme. Une vision dynamique de l'accumulation de connaissance était à la base des arguments favorables aux subsides temporaires et aux protections domestiques pour permettre aux firmes d'améliorer leurs coûts et d'acquérir une position compétitive au cours du temps. Plus récemment, la Commission Européenne, a mis au centre de la Stratégie de Lisbonne, ayant comme objectif la stimulation de l'innovation et de la productivité, l'engagement consistant à rendre l'environnement de réglementation plus « amical » aux affaires (European Commission, 2005). Cet engagement montre une tendance à octroyer à la déréglementation des marchés un rôle de moteur incitatif, tendance qui est déjà présent dès la moitié des années quatre-vingt-dix en Europe. En effet, les barrières au commerce international et à l'investissement étranger, la réglementation des services et des marchés de produits ainsi que la protection du travail

montrent dans l'OCDE, et notamment en Europe, pour la dernière décennie une claire tendance à la baisse (Conway, Janod and Nicoletti, 2005).

Malgré les différences de contexte et d'arguments, dans chacun de ces exemples les réformes ont cherché à transformer les dimensions nationales et internationales de la structure de marché. L'étude des conséquences que ces transformations peuvent avoir sur la productivité mérite donc la mobilisation des outils propres à l'étude du commerce international et de la concurrence imparfaite. Nous adoptons une telle approche et montrons, théoriquement et empiriquement, comment la prise en compte des caractéristiques représentatives de l'industrie manufacturière permet de comprendre l'hétérogénéité des gains de productivité ainsi que l'existence d'équilibres avec firmes durablement dominantes.

Ce message apparaît tout au long de la thèse. Dans la première partie nous étudions les effets de la politique commerciale sur la productivité. Nous montrons, en différenciant le type de politique (orientée à l'exportation ou à l'importation), que la libéralisation commerciale n'a pas les mêmes effets sur toutes les firmes et que la minorité qui exporte est celle qui reste sur le marché et *accumule* le plus de gains de productivité. Dans la seconde partie de la thèse, nous nous intéressons à la relation entre réglementation de marché et innovation. Nous montrons empiriquement que cette relation n'a pas systématiquement le signe négatif qui, de prime abord, lui est généralement attribué, notamment lorsque les firmes sont proches de la frontière technologique. Ces résultats peuvent être expliqués à partir de l'analyse des comportements stratégiques qui sont à l'origine de la présence de monopoles innovants de longue durée.

Dans les pages qui suivent, nous synthétisons brièvement comment la thèse s'inscrit dans la littérature (section 2). Nous présentons ensuite les principaux résultats de chaque chapitre (section 3) et les conclusions générales qui se dégagent de cette étude (section 4).

2. Insertion dans la littérature

Les arguments avancés dans la thèse prennent appui sur deux branches de la littérature économique: (i) les travaux étudiant le commerce international dans un cadre d'hétérogénéité des firmes et (ii) la littérature schumpetérienne traitant le lien entre concurrence et innovation. Nous consacrons une partie à chaque branche de la littérature. La première est orientée vers l'analyse des dimensions internationales de la structure de marché tandis que la seconde se focalise fondamentalement sur les dimensions nationales, en prenant comme objet d'analyse l'innovation, l'un des déterminants de la productivité les plus soulignés par la théorie économique de la croissance endogène.

Dans la « nouvelle nouvelle » théorie du commerce internationale

Le premier ensemble de travaux regroupe les articles constatant et permettant d'intégrer dans la théorie du commerce international la forte hétérogénéité de firmes au niveau intra-industriel et la caractérisation des exportateurs qui ressortent des travaux empiriques (cf. supra): ils sont, entre autres, peu nombreux, plus productifs et plus grands que les firmes qui vendent seulement sur le marché domestique. Hopenhayn (1992) introduit un modèle avec dynamique stochastique dans lequel l'entrée, la sortie et l'hétérogénéité des firmes sont susceptibles d'être étudiées à l'équilibre de long terme. Ce travail fondateur a permis de reproduire plusieurs faits stylisés concernant la survie des firmes, dont notamment la sélec-

tion des firmes les plus productives. Melitz (2003) fait une adaptation de ce modèle afin d'étudier l'équilibre en économie ouverte dans un cadre krugmanien de concurrence monopolistique et rendements croissants. La dynamique stochastique de la productivité des firmes est plus simple en comparaison à celle du modèle de Hopenhayn (1992). Les firmes ne connaissent leur niveau de productivité qu'après avoir payé un coût d'entrée et il reste le même pendant toute leur opération dans le marché. L'hypothèse de coûts fixes dans la production et dans l'exportation permet d'expliquer la sortie des firmes et l'auto sélection sur les marchés internationaux. Pour Melitz (2003), le commerce international implique aussi des coûts variables dont la réduction entraîne une hausse de la demande étrangère et, à l'équilibre, une hausse du salaire réel. Du fait de l'augmentation des coûts marginaux (le salaire), les firmes les moins productives sont forcées alors de quitter le marché, ce qui implique une augmentation de la productivité moyenne agrégée. Le modèle permet aussi de rendre compte des réallocations des parts de marché vers les firmes plus productives. Bernard et al. (2003) présentent la version ricardienne du commerce international avec hétérogénéité des firmes. Parmi les concurrents internationaux, une concurrence à la Bertrand détermine qui vend dans chaque marché. Cette configuration permet que la marge du monopole puisse varier parmi les firmes. De plus, la combinaison d'une concurrence à la Bertrand et de l'explication ricardienne des échanges aboutit à une sélection à l'exportation sans besoin de supposer la présence de coûts fixes à l'exportation, comme c'est le cas dans Melitz (2003). Par simulation, le modèle de Bernard et al. (2003) reproduit aussi les caractéristiques des exportateurs. Ce courant de la littérature a proliféré rapidement et grâce à la portée explicative de ses contributions on le désigne souvent comme la « nou-

velle nouvelle » théorie du commerce international. Une liste non-exhaustive d'extensions inclut l'étude des dynamiques de transition et de long terme (Ghironi et Melitz, 2005 ; Chaney, 2005), des fondements microéconomiques de la progression dans le temps de l'effet Balassa-Samuelson (Bergin, Glick et Taylor, 2006) ainsi que du choix entre exportation ou investissement direct étranger (Helpman, Melitz et Yeaple, 2004). Des contributions récentes se focalisent sur les effets de l'ouverture commerciale sur la croissance grâce à la prise en compte d'une innovation permettant d'élargir le nombre de variétés (Baldwin and Robert-Nicoud, 2006 ; Gustafsson and Segerstrom, 2007).

Les travaux appartenant à la « nouvelle nouvelle » théorie du commerce international se concentrent principalement sur les variations de productivité agrégée. Par contre, les déterminants de la productivité des firmes ont reçu une attention mineure. L'article de Yeaple (2005) est l'une des rares exceptions. Il explique, dans un modèle statique, l'hétérogénéité des firmes par l'allocation de travailleurs hétérogènes à des firmes homogènes qui doivent aussi faire leur choix d'adoption de technologie. Dans ce contexte, l'hétérogénéité des firmes est due à la rareté de travailleurs hautement qualifiés qui se complémentent avec les technologies les plus productives. Le résultat de Yeaple (2005) s'accorde aussi avec le constat selon lequel les exportateurs sont plus intensifs en main d'œuvre qualifiée et payent des salaires plus élevés. Une idée similaire peut être retrouvée dans Manasse et Turini (2001) pour qui la source d'hétérogénéité est la capacité managériale.

Si ces contributions fournissent des explications à l'hétérogénéité des firmes, les canaux d'amélioration de la productivité comme conséquence du commerce international

restent un terrain à explorer. On pourrait supposer, par exemple, une certaine hétérogénéité des productivités au moment où les firmes entrent sur le marché et étudier les conditions sous lesquelles cette productivité initiale est modifiée par les décisions des firmes en réponse aux changements dans la dimension internationale de la structure de marché.

La première partie de la thèse suit cette direction. Nous étudions l'impact de la politique commerciale sur la productivité des firmes. Nous analysons comment cette dernière évolue face à l'exposition à la concurrence internationale et grâce au meilleur accès aux marchés étrangers et aux nouvelles technologies internationales. Notre contribution à la « nouvelle nouvelle » théorie du commerce international réside dans le fait d'étudier de façon empirique et théorique des *évolutions* hétérogènes de la productivité des firmes face aux changements de la politique commerciale au cours du temps. Ces mécanismes intra-firme permettent en outre de compléter les explications existantes des changements de la productivité agrégée, lesquelles reposent principalement sur la mortalité des firmes et la réallocation des parts de marchés vers les plus productives. Empiriquement (Chapitre 1), nous montrons sur un panel de firmes manufacturières chiliennes (1979-1999) l'importance de différencier les effets des barrières à l'importation de ceux des barrières à l'exportation. Nos résultats soulignent l'importance des rendements d'échelle croissants comme un élément conditionnant les gains de productivité à obtenir à partir de l'ouverture au commerce international, notamment pour les firmes concurrençant les importations. Théoriquement (Chapitre 2), dans un cadre d'hétérogénéité de firmes, nous rendons l'évolution de la productivité endogène et montrons la possibilité d'effets de sélection suffisamment importants pour expliquer que la demande internationale augmente principalement la marge intensive

du commerce international. L'un des déterminants de ce résultat est le pouvoir de monopole local qui, en tant que capacité d'influencer la demande et d'intégrer les conséquences qui en découlent, joue un rôle important sur les incitations à investir pour améliorer la productivité. Les firmes ayant peu de possibilités de modifier leur productivité connaissent leur condition et anticipent une position désavantageuse dans la concurrence monopolistique. Ceci est à l'origine des externalités dans l'investissement et des effets de sélection.

Dans la littérature Schumpétérienne analysant concurrence et innovation

En analysant le lien entre structure de marché et productivité à travers l'innovation cette thèse prétend aussi contribuer à la littérature d'innovation schumpétérienne. Depuis Schumpeter (1934), le lien entre concurrence et innovation a été analysé selon l'idée que les incitations à l'innovation proviennent des profits qu'elle peut engendrer. C'est en effet un point central dans les travaux fondateurs essayant de formaliser la pensée schumpétérienne sur le processus de « destruction créatrice » (Segerstrom, Anant and Dinopoulos, 1990 ; Aghion et Howit, 1992). Selon cette tradition la concurrence a un effet négatif sur l'innovation puisque son intensification réduit les profits et donc dévalorise la récompense de l'innovateur. La littérature managériale, par contre, a souligné des effets positifs de la concurrence sur les incitations à innover. Selon cette optique, une concurrence accrue se traduit par une pression sur les firmes les contraignant à réduire leurs inefficiences et à résoudre leurs problèmes de gouvernance (Porter, 1990, Schmidt, 1997). Des effets positifs (Nickel, 1996) et négatifs (Crépon, Duguet et Kabla, 1995 ; Crépon Duguet et Mairesse, 1998) de la concurrence sur l'innovation sont mis en lumière par les études empiriques, ce

qui laisse la question ouverte. Selon l'indicateur utilisé, on peut même trouver au sein d'un même échantillon les deux résultats (Blundell, Griffith and van Reenen, 1999).

Aghion et al. (2005) font un effort théorique et empirique pour retrouver les effets positifs et négatifs de la concurrence sur l'innovation à l'intérieur du même cadre théorique. Leur logique consiste à analyser le choix des firmes qui opèrent dans le marché et à prendre en considération non pas la valeur post-innovation de la firme, mais la différence entre cette dernière et la valeur que la firme obtient sans faire de l'innovation. Dans cet argument, les effets pro-innovation de la concurrence apparaissent lorsque les firmes rivales opèrent avec un même niveau technologique de pointe. Dans ce cas, l'innovation est un moyen d'échapper à la concurrence et d'obtenir une position dominante. D'un autre côté, si la concurrence devient intense, les firmes en retard technologique ont peu d'incitations à innover pour rattraper le leader, puisque, du fait de la concurrence accrue, ils se retrouveront avec des profits réduits. Ces deux effets donnent à l'équilibre une relation entre concurrence et innovation représentée par une U-inversée. Cet argument est appliqué au débat actuel concernant les performances européennes et permet de soutenir les positions favorables à la concurrence et aux politiques de flexibilité (Aghion, 2006) : lorsqu'il s'agit de la concurrence à la frontière technologique, comme la concurrence entre l'Europe et les Etats Unis, son intensification serait favorable à l'innovation. Les preuves empiriques en faveur de ces arguments concernent fondamentalement le cas d'étude du Royaume-Uni au niveau des firmes. Par ailleurs, empiriquement, la relation en U-inversée entre concurrence et innovation peut concerner un groupe réduit de firmes (Askenazy, Cahn et Irac, 2007 en France) ou dépendre de l'indicateur utilisé (Tingvall and Poldahl, 2006 en Suède).

La prise en compte de données plus agrégées peut permettre de capturer des effets d'ordre macro et de faire une comparaison internationale entre des environnements concurrentiels différents. Moins abondants, les travaux provenant des comparaisons internationales au niveau industriel se focalisent sur le cadre de réglementation du marché et montrent des résultats intéressants : l'interaction entre réglementation de marché et proximité à la frontière technologique présente un effet positif sur la productivité (Nicoletti et Scarpetta, 2003 ; Conway et al. 2006). Bien que ce résultat soit interprété par les auteurs comme un effet négatif de la réglementation des marchés dans le processus de rattrapage, le signe semblerait contredire les prédictions d'Aghion et al. (2006).

Dans **la seconde partie** de la thèse, nous nous inscrivons dans cette ligne de comparaison internationales au niveau industriel et faisons la distinction entre la réglementation sous-jacente (de jure) et la concurrence observée (de facto). Nous étudions l'effet de la réglementation de marché sur l'évolution de l'intensité en innovation d'un échantillon d'industries de l'OCDE entre 1979 et 2003 (Chapitre 3). La configuration la plus robuste est celle d'un effet positif de la réglementation de marché sur l'innovation des industries à proximité de la frontière technologique. Nous suggérons une explication théorique de ces résultats en analysant la possibilité que l'innovation d'un leader rende plus difficile le rattrapage des firmes qui le suivent. Ceci peut aboutir à une relativisation de la relation en U-inversée et notamment à la possibilité d'une relation négative entre concurrence et innovation. Dans une formalisation plus détaillée (Chapitre 4), nous analysons l'effet des interactions stratégiques dans la course aux brevets dans le cadre d'un modèle à échelles de qualité. Nous faisons le lien théorique entre la présence de monopoles de longue

durée (Segerstrom, 2007; Barro et Sala-i-Martin, 2004, Etro 2008) et les comportements stratégiques visant à décourager les rivaux dans la course aux brevets (Dynopoulos et Syropoulos, 2007 ; Thoenig and Verdier, 2003). Dans ce contexte la réglementation de marché en contraignant les réactions défensives des firmes actives peut, sous certaines conditions, assurer plus de concurrence « de facto ». Nous montrons, empiriquement et théoriquement, que lorsque la taille de l'innovation est importante la réglementation de marché peut avoir un effet positif sur l'investissement en recherche et développement (R&D).

3. Résultats

Les principaux développements et résultats de la thèse sont présentés en quatre chapitres. La première partie, traitant des aspects internationaux de la structure de marché, est composée de deux chapitres l'un empirique et l'autre théorique sur l'effet de l'ouverture commerciale sur la productivité des firmes. La seconde partie est aussi composée de deux chapitres analysant théoriquement et empiriquement les effets de la concurrence et de la réglementation de marché sur l'innovation et la R&D. Nous synthétisons ici la portée de chacun de ces quatre chapitres.

Chapitre 1 : Commerce International, Concurrence aux Importations et Productivité des Firmes : l'Expérience Chilienne.

Le Chapitre 1 fournit une étude empirique de l'impact, au niveau des firmes, des barrières au commerce international sur la productivité. Nous revisitons le cas du Chili en tant qu'exemple international de libéralisation commerciale radicale. L'un des principaux apports à la littérature existante est la construction et l'utilisation de mesures détaillées

de l'intégration commerciale chilienne afin de différencier l'effet des politiques orientées à l'exportation de celui des politiques orientées à l'importation. Ceci est important car les coûts réels du commerce international ne sont pas nécessairement symétriques entre les partenaires et peuvent provenir de sources multiples (barrières directes et indirectes, infrastructure, institutions, etc.). Capturer ces coûts du commerce avec des mesures directes telles que les droits de douane peut donc conduire à négliger des aspects importants de l'intégration commerciale.

Pour faire face à ces difficultés l'étude est réalisée en combinant des estimations sur deux bases de données de nature différente: (i) un panel des établissements manufacturiers chiliens issu des recensements des établissements avec plus de 10 employés et (ii) des données sur les flux bilatéraux au niveau industriel (à trois digits de classification ISIC- rev2) entre le Chili et ses principaux partenaires commerciaux. Nous utilisons des informations pour la période allant de 1979 à 1999. Notre méthodologie est composée de trois étapes. Premièrement, sur le panel micro, nous estimons les fonctions de production pour chaque industrie chilienne afin de calculer postérieurement la productivité totale de facteurs (PTF) de chaque établissement comme le résidu de Solow. Etant donné que nous supposons une productivité hétérogène au niveau des établissements, qui varie au cours du temps et qui n'est pas observable directement, nous contrôlons par des éventuels biais de simultanéité dans la prise des décisions d'achat d'inputs (voir Olley et Pakes, 1996 ; Levhinson et Petrin, 2003). Diverses statistiques descriptives montrent que la productivité au niveau des firmes évolue au cours du temps et que ces évolutions intra-firme sont un objet important d'étude en ce qui elles participent à l'explication des évolutions agrégées.

Deuxièmement, à partir des données de flux de commerce bilatéral, nous estimons les barrières chiliennes à l'importation et à l'exportation à l'aide d'un modèle de gravité fondé théoriquement sur un modèle de commerce international avec concurrence monopolistique. Ici, nous appliquons la méthodologie d'« effet frontière » développée par Fontagné, Mayer et Zignago (2005). Dit de façon simple, ce type de méthodologie compare le commerce entre pays avec le commerce à l'intérieur des pays et capture comme « effet frontière » l'écart qui est dû au fait que les échanges ont lieu entre pays différents. Nous assimilons ces effets frontières aux barrières limitant le commerce international puisque par définition ils capturent toute difficulté à effectuer des échanges en dehors des frontières d'un pays. Par ailleurs, ces mesures permettent aussi de surmonter le problème du manque de variance transversal dans les droits douaniers chiliens, un problème récurrent auquel se sont heurtés les travaux précédents (Pavcnik, 2002 ; Bergoing, Hernando et Repetto, 2006).

Dans la troisième étape, nous utilisons les résultats obtenus dans les étapes précédentes. Nous estimons un modèle expliquant la productivité totale des facteurs au niveau d'établissement manufacturier à partir des variations des barrières au commerce. La stratégie d'identification permet de séparer l'effet des barrières à l'importation et à l'exportation selon l'orientation commerciale de l'industrie dans laquelle l'établissement opère. Selon la part des exportations et des importations, les industries sont définies à 3 digits classification (ISIC-rev2) comme étant orientées à l'exportation, en concurrence avec les importations ou abritées. Notre estimation identifie les évolutions de productivité par rapport à cette dernière catégorie. D'une part, les résultats suggèrent que la réduction des barrières à l'exportation a un impact positif dans les deux industries exposées au commerce (celles

orientées à l'exportation et celles en concurrence avec les importations). D'autre part, la réduction des barrières à l'importation peut avoir des conséquences négatives sur la productivité des firmes qui opèrent dans des industries concurrençant les importations. Dans des spécifications dynamiques, l'effet négatif des barrières à l'importation est aussi observé pour les exportateurs. Les estimations des fonctions de production révèlent qu'une bonne partie des industries et notamment celles qui sont en concurrence avec les importations présentent des rendements d'échelle croissants. Ceci serait une explication des effets négatifs de la réduction des barrières à l'exportation. Dans un pays où la taille de marché est limitée comme c'est le cas du Chili, la concurrence internationale sur le marché local peut réduire les possibilités d'exploiter des économies d'échelle (Rodrik, 1988). Finalement, nous montrons que la réduction de barrières à l'importation de biens de capital permet d'augmenter la productivité des firmes dans les deux secteurs exposés. La plupart de tests montrent aussi que ce canal d'amélioration de la productivité bénéficierait plus aux exportateurs.

Il est important de mentionner deux études sur le cas chilien. La première est celle de Pavcnik (2002) qui pour la période 1979-1986 trouve un effet positif de l'exposition à la concurrence internationale sur la productivité des firmes, notamment dans les secteurs concurrençant les importations. La différence avec nos résultats vient du fait que Pavcnik (2002) utilise une stratégie de différences en différences dans laquelle des indicateurs annuels servent à capturer l'effet de l'exposition au commerce. Or, du fait de la crise de la dette, le Chili applique durant la première moitié des années quatre-vingt des politiques protectionnistes. Les effets capturés par Pavcnik (2002) ne seraient alors pas associés à une

intensification de l'exposition au commerce international mais plutôt à une politique de protection. En utilisant nos données nous reproduisons les résultats de Pavcnik (2002) avec des indicateurs annuels et montrons comment cela change lorsqu'on utilise nos mesures d'intégration commerciale qui en outre font la distinction entre barrières à l'exportation et barrières à l'importation. La deuxième étude est celle de Bergoeing, Hernando et Repetto (2006), qui pour la période 1980-2000 capture l'ouverture au commerce avec des droits douaniers (effectifs) et trouve comme notre étude un effet négatif de la concurrence des importations sur la productivité des firmes. Chez les exportateurs par contre Bergoeing, Hernando et Repetto (2006) n'arrivent pas à montrer des effets significatifs. Sur ce dernier point ce chapitre contribue à la littérature en faisant ressortir des gains importants chez les exportateurs grâce à l'usage de mesures des barrières au commerce présentant plus de variabilité entre industries.

Chapitre 2 : Libéralisation Commerciale et Evolution de la Productivité des firmes.

Dans le Chapitre 2, nous développons un modèle de commerce international avec hétérogénéité des firmes dans le but d'analyser l'impact de la réduction des coûts du commerce sur la productivité des firmes. Le chapitre est motivé par deux constats importants. D'abord, malgré les différentes études qui montrent l'évolution de la productivité au niveau des firmes (dont le chapitre précédent), les modèles de la « nouvelle nouvelle » théorie du commerce international se focalisent sur les changements agrégés de productivité provenant des réallocations « entre firmes ». Les canaux d'évolution « intra firme », par contre, méritent une analyse plus attentive, d'autant plus que ceux-ci permettent aussi

d'expliquer quantitativement les évolutions agrégées. Ceci a été mis en évidence dans le Chapitre 1 pour la période allant de 1986 à 1999. Ensuite, tel que le suggèrent les résultats du Chapitre 1, la réduction de barrières à l'importation de biens de capital apparaît comme un canal important d'obtention de gains de productivité dans un pays en développement.

Nous proposons donc une extension du modèle de Melitz (2003) afin d'incorporer des améliorations de la productivité du travail à partir des décisions d'investissement en technologie incorporée dans des biens de capital. Comme dans Melitz (2003), les firmes ne connaissent leur niveau de productivité du travail qu'après leur entrée sur le marché. Le nouvel ingrédient est qu'elles ont la possibilité d'investir en capital importé pour obtenir une meilleure productivité du travail. Due à la substituabilité capital-travail, l'hétérogénéité initiale se traduit par un impact différencié du capital sur la productivité lequel est pris en compte dans les décisions des firmes.

A l'équilibre, plusieurs résultats sont à remarquer. La libéralisation commerciale réduit le coût du capital importé mais augmente aussi la demande étrangère. Ceci se traduit par une augmentation de la demande de facteurs et donc par une substitution capital-travail hétérogène. La concurrence monopolistique introduit un mécanisme multiplicateur qui rend plus important les effets de sélection à travers les différentes étapes de décision: les firmes choisissent non seulement un prix ajoutant un taux de marge au coût marginal, mais ce coût marginal lui-même. De plus, elles connaissent l'effet de ce dernier sur la demande et in fine sur leurs profits. Dans ce cadre de concurrence monopolistique, les décisions des firmes dépendent de l'impact de la nouvelle technologie sur le facteur travail mais relativement à celui de la moyenne de l'économie. A son tour, la productivité moyenne (productivité

ité agrégée) dépend de façon endogène de l'entrée, de la sortie et des réallocations et aussi des investissements individuels. Néanmoins, cet effet agrégé de l'investissement n'est pas intégré pas les firmes, car elles prennent les variables macro comme étant données. Une externalité de l'investissement apparaît ainsi et elle est à l'origine des effets de sélection. La conséquence est que la libéralisation commerciale est biaisée vers les firmes qui ex-ante obtiennent plus de gains de productivité à travers la substitution capital-travail. De même, la réduction des coûts du commerce a des effets principalement sur la marge intensive du commerce. Même parmi les exportateurs, un nombre réduit de firmes concentrera la plupart de l'augmentation de la demande due à l'ouverture commerciale.

Ces résultats s'accordent avec les changements de la distribution de la productivité des firmes au Chili. En effet, si l'on compare la distribution de la productivité du travail en 1987 à celle observée en 1995, c'est-à-dire après une période de forte évolution de productivité au niveau des firmes, on observe que les améliorations de productivité ont concerné seulement un ensemble très limité de firmes qui étaient initialement hautement productives. De plus, si l'on regarde la distribution du ratio de ventes d'exportations relatives aux ventes totales durant la décade des années quatre-vingt-dix, période d'intense agenda de promotion des exportations, l'aplatissement de la distribution est imperceptible et on observe plutôt une accentuation de la concentration des firmes avec faible proportion de ventes par exportation.

En rendant la productivité endogène, le modèle proposé dans ce chapitre peut proposer une explication à ces évolutions. Le modèle type de la « nouvelle nouvelle » théorie du commerce considère la productivité des firmes comme étant exogène et ne peut que

se focaliser sur les changements agrégés de productivité qui surviennent comme conséquence de l'entrée et de la sortie de firmes ainsi que de la réallocation des parts de marché. En relation au modèle de référence (Melitz, 2003) les effets de sélection sont renforcés puisque l'hétérogénéité initiale est considérée dans les décisions et les anticipations des agents dans un cadre de concurrence monopolistique permettant de reproduire des externalités de l'investissement. Il y a ainsi des mécanismes permettant de comprendre des changements de la distribution de productivités des firmes biaisés vers les firmes les plus productives.

Chapitre 3 : Concurrence sur le Marché de Produits et Innovation à la Frontière Technologique

Dans ce chapitre, nous testons les effets de la concurrence sur l'innovation sur un échantillon de 15 industries manufacturières appartenant à 17 pays de l'OCDE dont l'information est disponible pour la période allant de 1979 à 2003. L'un des éléments importants de ce chapitre est l'utilisation d'indicateurs capturant les aspects « de jure » et « de facto » de la concurrence. Dans le premier cas, nous utilisons divers indicateurs de réglementation du marché des produits fournis par l'OCDE et dans le second, le nombre relatif de firmes en tant que mesure observée de la concentration de marché. Nous nous intéressons à l'effet différencié de la concurrence lequel, d'après Aghion et al. (2005), dépendrait de la proximité des firmes vis-à-vis de la frontière technologique : la concurrence inciterait les firmes qui sont en concurrence à la frontière technologique à investir en innovation, tandis qu'elle découragerait les firmes plus retardées technologiquement. Nous avons ainsi collecté à partir de différentes sources (OCDE, EUROSTAT et Groningen and Growth Development

Centre) des données permettant de tester les performances internationales en innovation conditionnelles à la productivité des industries relativement à la frontière technologique.

Notre exercice contribue à la littérature existante sur trois plans. D'abord il propose une comparaison internationale au niveau industriel de l'activité innovatrice, capturée par une mesure de l'intensité des brevets déposés dans chaque industrie. Ensuite, comme mentionné précédemment, dans cette comparaison internationale nous prêtons une forte attention aux dimensions « de jure » de la concurrence (réglementation des marchés). Bien que la disponibilité de ce type d'indicateurs soit encore faible, ils présentent le double avantage d'être plus liés aux « inputs » de la concurrence, dont notamment la politique économique, et, de ce fait, d'être plus exogènes au processus économique (exception faite des fondements d'économie politique de l'émergence des réglementations de marché). Finalement, nous tenons compte d'une série d'aspects méthodologiques liés à ce type d'exercice, parmi lesquels on trouve notamment les potentiels biais dynamiques ainsi que l'obtention explicite d'une significativité conditionnelle (i.e. selon la proximité de la frontière technologique) de l'effet de la concurrence.

Une fois les aspects dynamiques contrôlés, à partir de nos diverses régressions et tests de robustesse, deux types de configurations émergent selon le type spécification : (i) la réglementation de marché apparaît exerçant un effet positif sur l'innovation, lequel diminue avec la distance à la frontière technologique, mais reste positif à la frontière elle-même ; (ii) la réglementation de marché apparaît exerçant un effet négatif sur l'innovation loin de la frontière technologique lequel disparaît ou devient positif proche de celle-ci. Ce qui est commun à ces deux configurations est que, proche de la frontière technologique,

on observe plutôt un effet positif de la réglementation sur l'innovation. Par ailleurs, notre indicateur de concurrence observée (le nombre relatif de firmes) ne montre pas un effet significatif proche de la frontière technologique.

Ces résultats, qui contredisent les effets pro-innovation de la concurrence, s'accordent avec certains travaux au niveau micro-économique (cf. *supra*). De plus, le signe de l'interaction entre réglementation de marché et proximité à la frontière (i.e. la pente de l'effet conditionnel de la réglementation) est conforme aux résultats obtenus par d'autres études qui utilisent des données interindustrielles mais en considérant la productivité en tant que mesure de performance (Nicoletti et Scarpeta, 2003; Conway et al. 2006). Afin d'expliquer ces résultats au sein du modèle de référence, nous faisons une extension d'Aghion et al. (2005) en permettant aux leaders d'innover. Ce scénario est souvent négligé du fait de l'hypothèse de symétrie des coûts d'innovation qui aboutit à l'effet de remplacement d'Arrow, selon lequel à l'équilibre les leaders n'innovent pas car ils ont moins d'incitations que les entrants potentiels. En effet, pour les leaders, l'innovation implique la destruction et le remplacement de la valeur de leur état technologique actuel. Dans notre adaptation, l'innovation des leaders rend plus difficile le processus de rattrapage expérimenté par les firmes qui les suivent. Cette modification induit une multiplicité d'équilibres dont la relation entre concurrence et innovation du type U-inversée n'est qu'un scénario très particulier. Il est possible d'obtenir notamment à l'équilibre une relation négative et monotone entre concurrence et innovation. Ce dernier équilibre est censé avoir lieu lorsque l'innovation des leaders a une forte incidence sur le processus de rattrapage.

Chapitre 4 : Réglementation de Marché et Stratégies Défensives dans la Course aux Brevets

Dans ce dernier chapitre, nous rentrons plus en détail sur les aspects interactifs suggérés théoriquement dans le chapitre précédent. Nous étudions ici les conséquences des stratégies défensives menées par les firmes actives afin d'éviter d'être dépassées par des concurrents potentiels. Nous développons un modèle d'innovation à échelles de qualité dans lequel les firmes qui ont réussi leur innovation utilisent leurs avantages d'apprentissage et de connaissance privé afin de maintenir dans le futur leur position dominante. La réglementation de marché, en ce qu'elle contraint et standardise le comportement des firmes, permet de gérer la rivalité des concurrents de la course aux brevets et de limiter les stratégies défensives, ce qui à l'équilibre peut augmenter les incitations à réaliser de la R&D. Nous testons cette prédiction avec l'échantillon international d'industries utilisé dans le chapitre précédent, mais cette fois-ci en analysant la R&D en tant que variable à expliquer.

Du point de vue théorique, la contribution du chapitre est de rendre endogène la possibilité d'avoir, à l'équilibre d'état stationnaire, des monopoles perpétuels qui innoveront et d'explicitier cette possibilité à partir du degré de réglementation. L'intuition est que la menace de « vol de rente » induit les firmes qui opèrent sur le marché à utiliser leurs connaissances privées pour biaiser le paradigme technologique. Ce faisant, elles rendent plus difficile le processus de R&D des entrants potentiels. Dans le modèle, les firmes actives peuvent exploiter les connaissances acquises durant le processus d'innovation qu'elles mêmes ont réussi et de choisir une composition qualitative du bien qui soit plus difficile à répliquer par leurs concurrents et donc plus difficile à améliorer.

La modélisation implique ainsi une extension du cadre conventionnel des modèles à échelles de qualité afin de concevoir la qualité comme étant composée de plusieurs dimensions substituables. Le choix de ces dernières permet de capturer le choix du biais à induire dans le paradigme technologique. Un deuxième élément important est la prise en compte d'un jeu stratégique à la Stackelberg où les firmes actives possèdent l'avantage d'être les premières à jouer et peuvent donner un signal d'engagement à réaliser une forte R&D future. Comme dans Barro et Sala-i-Martin (2004), la crédibilité de ce signal va dépendre des avantages technologiques relatifs des firmes actives. La nouveauté est que ces avantages ne sont pas exogènes mais proviennent du choix du biais du paradigme technologique, lui-même limité par la réglementation de marché. Ainsi, le degré de réglementation va déterminer qui participe activement en R&D à l'équilibre de long terme: le monopole en place (équilibre avec monopole innovant et permanent) ou les entrants potentiels qui menacent avec leur innovation (équilibre avec remplacement continu). Même dans ce dernier cas, le monopole en place, avec le biais technologique cherchera à prolonger sa durée.

Du fait d'une anticipation de la demande avec un pouvoir de monopole local, l'effet de la réglementation est conditionné par la taille de l'innovation, qui s'ajoute en tant qu'élément assurant le pouvoir de monopole. La prédiction est que l'effet positif de la réglementation de marché sur l'innovation devrait être plus facilement observé lorsque la taille de l'innovation est importante. De cette façon, en soulignant un rôle actif de la réglementation de marché (par opposition à un coût d'entrée sans contrepartie), une dissociation entre les aspects « de jure » et « de facto » de la concurrence est mise en évidence.

Pour tester cet argument nous considérons l'intensité en R&D, variable prédite par notre modèle théorique, et capturons la présence d'innovations importantes si les industries sont de haut niveau technologique. Dans cette catégorie nous distinguons les industries qui produisent des technologies de l'information et de la communication (TIC) ainsi que celles qui les utilisent fortement. Les résultats sont consistants avec les prédictions du modèle : l'effet positif des réglementations de marché sur l'intensité en R&D dans les industries de haut niveau technologique est significativement plus important que dans le reste des industries. Plusieurs contrôles et tests de robustesse confirment ce résultat. Cette exercice empirique s'accorde ainsi aux résultats du chapitre précédent et invite à réfléchir à la façon dont on conçoit les effets de la réglementation de marché.

On constate ainsi une richesse explicative dans la littérature théorique étudiant la présence des leaders innovants. Quelques contributions comme par exemple Segerstrom (2007) se focalisent sur des équilibres stratégiques simultanés du type Nash-Cournot avec des asymétries technologiques. Le contexte d'un jeu séquentiel du type Stackelberg (Barro et Sala-i-Martin, 2004 ; Etro, 2007) est intéressant du fait qu'il exploite les avantages des leaders à travers leur influence sur les anticipations de leurs concurrents, ce qui, comme nous avons essayé de le montrer dans ce chapitre, donne un cadre plus riche et subtile pour comprendre le lien entre réglementation et concurrence effectivement observée.

4. Conclusion

A travers divers outils théoriques et empiriques, cette thèse souligne le rôle de la structure de marché sur les incitations des firmes à améliorer leur productivité. L'enjeu était de mon-

trer comment la présence de rendements d'échelle croissants, de firmes hétérogènes et de connaissances technologiques asymétriques peut aboutir à des mécanismes non triviaux par lesquels des structures de marché particulières engendrent des évolutions asymétriques de la productivité auto renforcées à l'équilibre. Ces caractéristiques de l'industrie manufacturière s'avèrent alors importantes pour comprendre les effets de la politique commerciale et de la politique de concurrence.

Les résultats obtenus dans ce travail peuvent être résumés en deux apports majeurs. Premièrement, la thèse souligne et étudie des gains de productivité hétérogènes en économie ouverte. Dans ce sens, elle contribue à la « nouvelle nouvelle » théorie du commerce international en analysant l'évolution de la productivité des firmes et en explicitant des canaux *intra*-firme par lesquels l'intégration commerciale affecte la productivité. Ces mécanismes *intra*-firme, dans lesquels les rendements d'échelle croissant et la concurrence imparfaite jouent un rôle central, viennent compléter les mécanismes qui soulignent la réallocation des parts de marché *entre* firmes ainsi que l'entrée et la mortalité des firmes au moment d'expliquer les évolutions agrégées.

Deuxièmement, en mettant en avant le comportement stratégique des firmes, la thèse fournit des éléments empiriques et théoriques permettant de revisiter plus attentivement le lien entre la réglementation de marché et les incitations des firmes à innover. Sur ce plan, elle contribue à la littérature d'innovation schumpéterienne en soulignant que si les stratégies à disposition des firmes vont au delà de la seule innovation et peuvent notamment inclure des réactions défensives, alors les effets de rivalité induits par la concurrence potentielle pourraient, paradoxalement, aboutir à la présence des monopoles permanents qui

participent activement à la R&D. Empiriquement, après avoir testé divers indicateurs et spécifications, la seconde partie de la thèse montre que les politiques de déréglementation ne sauraient être l'élément clé à partir duquel une économie de l'innovation peut se fonder.

Les apports de la thèse suggèrent des pistes concrètes de recherche encore peu explorées. L'une des extensions naturelles de ce travail est sans doute l'étude de l'intersection des dimensions internationale et intra nationale de la structure de marché. Plus précisément, cette extension consisterait à enrichir le cadre micro-économique des modèles en économie ouverte avec des outils avancés d'organisation industrielle et à étudier l'effet des asymétries des environnements concurrentiels nationaux sur les échanges internationaux et sur la productivité.

Abstract

This thesis studies the link between market structure and productivity. The core of the analysis takes into account relevant features of manufacturing such as economies of scales, firm heterogeneity and asymmetric knowledge. We investigate how the change in both inward and outward aspects of market structure shapes firms incentives to obtain productivity gains. The first part of the thesis analyses the effect of trade policy on firm productivity. We use firm-level data of Chilean plants (Chapter 1) and propose a theoretical model of international trade (Chapter 2) to explain heterogeneous within-firm productivity evolutions. The second part addresses the link between market structure and innovation. Using industry-level data for a sample of OECD countries we test the effect of competition and regulation on innovation, conditional to proximity to the technological frontier (Chapter 3). Finally, we provide a quality-ladders model to show how regulation can handle the rivalry among R&D competitors and play a central role boosting R&D intensity (Chapter 4). This argument is also tested at the industry level in our OECD sample.

Keywords: International Trade, Competition, Productivity, Innovation, Firm heterogeneity.

General Introduction

Productivity enhancement is one of the most claimed targets of policy packages that seek to modify market structure. Lively academic and political debates are devoted to this issue. They not only question the nature of the actions to carry out in order to improve productivity, but more especially discuss the incentives to undertake these actions. For instance, while most economists would agree about the key role of innovation on productivity gains, the question concerning which policies induce firms to innovate would generate more discussion. The focus on incentives mainly stems from the fact that, once the theoretical assumptions ensuring perfect competition no longer hold true, strategic behaviour needs to be taken into account. As a consequence, the expected outcome of market regulation and trade policies is not obvious and depends on the specific features of production, consumption and the form of competition. Indeed, the inclusion in trade theory of ingredients such as imperfect competition, increasing returns and firm heterogeneity significantly contributes to our understanding of international trade patterns. Similarly, the possibilities of private knowledge appropriation introduce asymmetric advantages which are crucial for growth theory to endogenously explain technical progress. Recent contributions in these fields provide useful tools to understand how firms, and which ones, make productivity improvements in response to changes in market structure.

This thesis aims at studying the link between market structure and productivity by taking into account three relevant features of manufacturing, namely: firm heterogeneity, the possibilities of economies of scale and asymmetric knowledge. In fact, these ele-

ments, along with market structures departing from perfect competition and free trade, can be found in plausible representation of manufacturing. A large body of empirical work has facilitated the task of convincing of the extent of within-industry heterogeneity among firms, even at a very disaggregated level. This stylised fact concerns not only developing countries (Aw, Chung and Roberts, 2000; Roberts and Tybout, 1997; Clerides, Lach and Tybout, 1998; Alvarez and Lopez, 2005) but also developed ones (Bernard and Wagner, 1997; Bernard and Jensen, 2001; Bernard, Jensen and Schott, 2003). Furthermore, manufactured goods are usually seen as enjoying some degree of differentiation allowing to influence demands. In line with firm-level national evidence, Scarpetta et al. (2002), using international data of firm demography, show that larger firms tend to remain in the market, which is a usual outcome of asymmetric monopolistic competition.

Thanks to the incorporation of increasing returns, trade theory became able to explain trade patterns within similar industries (Krugman, 1980). One of the consequences of this argument is that market size shapes cost structures (Rodrik, 1992; Krugman, 1995). While, to some extent, firms can influence their size and exploit scale economies, their possibilities depend on the access to larger markets and on the fierceness of foreign competition. This is an important reason why outward-oriented market structure matters. One can observe that trade between different countries is costly and relies on different policies. Trade frictions are important, even for neighbouring countries highly integrated such as the US and Canada. Accordingly to the lowest estimation, which carefully controls for geographical and economic factors, trade between Canadian provinces turns out to be 11 times higher than trade between American states and Canadian provinces (Anderson and van Wincoop,

2003). Underlying this finding is the fact that, besides local tastes, institutions related to insurance, informational networks or enforcement laws and property rights may indirectly act as trade barriers.

Finally, a key element to understand productivity evolution relates to knowledge diffusion. Firms use a set of strategies to protect innovation rewards that goes beyond mere patent protection (Cohen, Nelson and Walsh, 2000; Levin et al. 1987). This set concerns secrecy, first mover advantages and even manufacturing strategies such as complexification or multiple composite manufacturing. Actually, firms operating under different market structure might decide to adopt different R&D strategies. Cohen et al. (2002) show how innovative countries like the US and Japan differ in the manner in which firms appropriate the value of their innovations and in the use of protecting strategies.

These findings make clearer the idea that what we call market builds on a structure determined by economic fundamentals along with a set of institutions acting as the "rules of the game" for economic agents. Basically, market policies modify these "rules of the game" and, as a consequence, they shape firm's incentives to adopt strategies improving productivity. Some examples of policy-making seek to exploit the properties of market coordination by removing barriers to entrepreneurship and to the free flow of goods and factors. For instance, a key role of free market policies was claimed in most structural reforms in Latin American during the 1980s. Market deregulation and trade liberalisation were at the core of reform packages aiming at stimulating productivity growth. The expected increase in competition was seen as a "slack-reducing device" in their business process. Conversely, East Asian countries followed international integration by adopting

non-neutral policies aiming at boosting some key sectors expected to yield higher long term economic growth. A dynamic view of knowledge accumulation was the rationale to argue that some temporal subsidy or domestic protection may lead firms to move down their cost curve and to acquire a more competitive position. More recently, the European Commission, in its "integrated guidelines", has put at the centre of the Lisbon Strategy, seeking to foster innovation and productivity, a commitment for a regulatory environment "more business-friendly" (European Commission, 2005). According to OECD policy indicators, barriers to trade and foreign investment, regulation in services as well as regulation in labour and domestic markets depict a clear downward trend for the last decade (Conway, Janod and Nicoletti, 2005).

In spite of the differences in context and arguments, in all these examples economic policies targeted both inward and outward dimensions of market structure. Thus, a suitable approach to study the link between market structure and productivity is to deal with trade and competition. In this thesis, we adopt such an approach and devote particular attention to two brands of the literature: the works on trade theory analysing firm heterogeneity and the Schumpeterian growth literature linking competition and innovation. We intend to contribute to both.

The first body of theoretical literature encompasses the empirical findings regarding within-industry heterogeneity (see *supra*) and the characteristics of exporters highlighted on those empirical studies: they are few, larger and more productive. Hopenhayn (1992) introduces a dynamic stochastic model allowing for a long run equilibrium in which entry, exit, and firm heterogeneity are possible. This pioneer model matched several findings of

survival analysis, including the selection of most productive firms and the age of cohorts. In this line, Melitz (2003) extends the model to consider an open economy with monopolistic competition and increasing returns, as in Krugman's (1980) setup. The stochastic dynamics of firm productivity is reduced in comparison to Hopenhayn (1992). Firms draw their productivity after entering the market and remain with this level until they go out. The presence of fixed costs in both production and exporting activities explains firm's exit and self-selection to the export market. Trade involves also variable costs. Their reduction implies higher foreign demands and an higher real wages in general equilibrium. This leads to the exit of less productive firms and, as a consequence, to an increase in average productivity. The model also features market share re-allocations, which are in line with observed size advantages of most productive firms and exporters. Bernard et al. (2003) develop a Ricardian version of trade with heterogeneous firms. Among international competitors, Bertrand competition determines who sells to each market. Thanks to productivity heterogeneity, mark-ups vary among firms. This combination of Bertrand competition and Ricardian explanation of trade does not need fixed costs to explain endogenous export status. At the same time, by simulating, the model is able to reproduce the above-mentioned exporter characterisation. This literature has rapidly proliferated. A non-exhaustive list includes the study of transitional and long run dynamics (Ghironi and Melitz, 2005; Chaney, 2005), dynamic foundations of the Balassa-Samuelson effect (Bergin, Glick and Taylor, 2006), the choice related to exports and FDI (Helpman, Melitz and Yeaple, 2004). Recent contributions have discussed growth and anti-growth effects of trade by introducing

a theoretical block of innovation that accounts for the increase in the number of varieties (Baldwin and Robert-Nicoud, 2006; Gustafsson and Segerstrom, 2007).

These models addressing firm heterogeneity and trade, usually called "new new" trade theory, focus on variations of aggregate productivity. By contrast, the determinants of firm productivity have received less attention. One exception is Yeaple (2005), in which heterogeneous workers are allocated to homogeneous firms within a static model. In his setup, firms have also to choose between low and high productivity technologies. Their heterogeneity arises from the availability of skilled workers who are complements with the advanced technology. Similar ideas can be found in Manasse and Turini (2001) for whom the source of heterogeneity is entrepreneurship. While these explanations address the heterogeneity among firms, within-firm productivity improvements remain a field to be explored. For instance, one may assume some exogenous heterogeneity in productivity levels when firms enter the market, but allow for further modifications as consequences of firm's decisions responding to changes in market structure.

The **first part** of the thesis follows this direction. We study the impact of trade policy on productivity. We analyse how firm productivity evolves as a consequence of the exposition to foreign competition, the access to larger markets and to new technologies. Our contribution to the "new new" trade theory is to address empirically (Chapter 1) and theoretically (Chapter 2) the reaction of firm productivity to changes in trade policy over the time. With respect to changes in aggregate industrial productivity, most of works focus on market share re-allocation *between* firms. We put forward a complementary explanation: heterogeneous *within*-firm productivity improvements. Our results highlight the impor-

tance of increasing returns in determining the possibilities of productivity gains stemming from a reduction of trade protection. Monopolistic power, allowing firms to anticipate and influence their demands, also plays a key role in shaping firm's investment decisions that modify their initial level of productivity. Firms having fewer possibilities to increase their productivity are aware of their condition and of their disadvantages relative to the whole economy. This leads to selection mechanisms significant enough to explain that foreign demand mainly increases the intensive margin of trade.

The second brand of the literature linking market structure and productivity brings us into Schumpeterian innovation. Since Schumpeter (1934), the link between competition and innovation has been analysed under the idea that the incentives to innovate are the expected profits stemming from innovation. This is a central point in seminal works formalising Schumpeterian thought on creative destruction (Aghion and Howitt, 1992; Segerstrom, Anant and Dinopoulos, 1990). Following this tradition, higher competition reduces innovators rewards and, consequently, innovation. On the contrary, managerial literature has stressed pro-innovation incentives generated by competition. Indeed, a fierce competition might be a pressure to reduce inefficiencies or to solve agency problems (Porter, 1990; Schmidt, 1997). Empirical works, testing performances at the firm level, provide support for both Schumpeterian (Crépon, Duguet and Kabla, 1995; Crépon, Duguet and Mairesse, 1998) and "trimming fats" mechanisms (Nickell, 1996). One can even find both results in the same work depending on the indicator (Blundell, Griffith and vanReenen, 1999).

Aghion et al. (2005) make a theoretical and empirical attempt to capture both effects within the same framework. The rationale is to consider, under a Schumpeterian setup, not

merely the discounted post-innovation profits, but the difference between post-innovation and pre-innovation values. In this argument, pro-innovation effects of competition arise when firms compete at the same technological level. Innovation allows them to escape from competition. On the other hand, if competition becomes intense, laggards have fewer incentives to catch-up the leader position. Both effect leads to an inverted U-shape relationship between competition and innovation. This argument is extended to the current debate about Europe's performances and gives support to pro-competition and flexibility policies (Aghion, 2006): at the leading edge, competition should foster innovation. This conclusion is directly tested in Aghion et al. (2006) using firm entry. While this evidence remains at the firm level and mainly for the UK, more aggregate samples allow for an international comparison among different regulatory environments. Though less abundant, results stemming from industry-level data reveal interesting findings: a positive sign of the interaction between regulation and the proximity to the leading edge in productivity regressions (Nicoletti and Scarpetta, 2003; Conway, Nicoletti and Steiner, 2006). While this result is interpreted as a negative effect of product market regulation in the catch-up process, the sign contradicts the results of Aghion et al. (2006).

In the **second part** of the thesis we follow these empirical literature at the industry level (Chapter 3) and suggest an explanation for the contrasted results concerning regulation (Chapter 4). As industrial organisation contributions have emphasised, competition is an outcome that, in the presence of market imperfections, is not immediately ensured under *laissez-faire* (Shaked and Sutton, 1983). Therefore, we directly address market regulation policies. In this part of the thesis, we focus on innovation, a key engine of technical

progress. More precisely, we study how the regulatory environment shapes firm's incentives to innovate. The way through which regulation canalises the strategic behaviour of competitors is at the core of our developments. Differently from most Schumpeterian literature we consider innovative leaders (Segerstrom, 2007; Barro and Sala-i-Martin, 2004) and take strategic behaviour in R&D races into account (Dinopoulos and Syropoulos, 2007; Thoenig and Verdier, 2003). We show, empirically and theoretically, how fierce competition may trigger defensive strategies that reduce knowledge diffusion and innovation incentives. This argument is in line with previous evidence indicating negative within-industry R&D externalities (Crépon and Duguet, 1997). In the usual framework leaders do not innovate. This refers to the so-called Arrow replacement effect by which incumbents have less incentives to innovate than outsiders, because they replace their own business. In contrast our contribution is to study strategies by which leaders may endogenously have technological advantages that can account for long life monopolists. Regulation in this context can canalise the effects of rivalry among competitors.

Overall, inward and outward aspects of market structure define an environment that influences firm's decisions to undertake investments to improve their productivity. The presence of heterogeneity, economies of scale and asymmetries of knowledge need to be considered to understand why, in some cases, the outcome of trade and market competition policies may beneficiate a reduced number of producers and yields to externalities that explain self-selection in both production and innovative activities.

Thesis Preview

The main results of the thesis are presented in four chapters. The first part, which studies within-firm productivity evolution and trade policy, is composed of two chapters. **Chapter 1** provides an empirical study of the impact of trade barriers on plant productivity. We use two data sets: (a) a panel of Chilean manufacturing plants and (b) bilateral trade flows between Chile and its main trading partners at the industry level, both for the period 1979-1999. One of the chapter's contributions is the construction of detailed measures of trade liberalisation disentangling the impact of export and import oriented policies. This distinction is important since trade costs are not necessarily symmetric nor exclusively related to tariffs. For instance, average nominal tariffs look quite flat during nineties, the decade in which Chile started signing several trade agreements seeking to boost exports.

The estimation proceeds in three stages. First, using the plant-level data, we estimate industrial production functions to measure the contributions of factors to plant's output. We then compute total factor productivity of plants as the Solow-residual. Since we suppose a heterogeneous time-varying unobservable firm productivity, we control for endogeneity concerns leading to different bias in factor's elasticities (see Olley and Pakes, 1996; Levinson and Petrin, 2003). Second, using the bilateral trade flows data, we estimate a theoretically grounded gravity model and obtain a measure of export and import barriers. In this stage, we apply the border effect methodology of Fontagné, Mayer and Zignago (2005). Basically, this methodology compares trade between countries with trade inside countries and capture as "border effect" the part of missing trade explained by the fact that trade takes place between two *different* countries. We assimilate these border effects to trade barriers

since by definition they capture trade frictions related to deviations from an intuitive empirical ideal type of free trade: the one taking place inside borders. These measures also enable to avoid the lack of variance in nominal tariffs among Chilean industries, which is a recurrent problem in previous works (Pavcnik, 2002; Bergoeing, Hernando and Repetto, 2006). In the final stage, we estimate the impact of the Chilean trade reform on plant's productivity using the border effects estimated in the previous step. We identify within-firm productivity improvements by comparing the reaction of productivity to trade policy for plants belonging to traded sectors (export-oriented and import-competing) relative to those belonging to non-traded sectors.

Results depend on the orientation of trade policy. First, the evidence suggests that policies reducing export barriers have a positive impact on productivity for firms belonging to both traded sectors. Second, the reduction of import barriers has a positive impact on productivity in export-oriented sectors, but it hurts local firms in import-competing ones. Interestingly, production function estimates reveal the existence of increasing returns precisely for the latter. Finally, the reduction of import barriers for capital equipment explains productivity differences between exporter and non-exporters.

In **Chapter 2** we develop a model of trade with heterogeneous firms in order to analyse the impact of a reduction of trade barriers on firm productivity. The chapter is motivated by some of the results of Chapter 1. Namely, exporters obtain productivity advantages after a reduction of import barriers on goods related to machinery industry. Moreover, heterogeneous within-firm productivity improvements do explain the average evolution. We extend the work of Melitz (2003) by incorporating endogenous labour pro-

ductivity gains determined by an initial investment in technology embodied in imported capital goods. Firms enter the market and draw an initial level of productivity. They can then invest in imported capital to modify their labour productivity. Because of substitutability, the initial heterogeneity translates into a differentiated impact of technology on labour efficiency.

Trade liberalisation reduces the price of imported capital equipment and increases factor demands. Monopolistic competition introduces a multiplier that emphasises self selection. This is because firms not only choose the well known mark-up over marginal costs, but also marginal costs themselves. In this Dixit-Stiglitz framework, firm's investment decisions will depend on the reaction of their labour productivity to the new technology, relative to that of the average economy. The average productivity changes endogenously as a consequence of entry, exit and reallocation, but also thanks to investment. Since firms compete with the whole economy, but do not take into account the fact that their investment affects the average productivity, the model highlights an externality of investment. This introduces a strong self selection process that in turn induces two results. First, trade liberalisation is biased towards firms in which capital labour substitution allows higher productivity gains. Second, the reduction of trade costs principally concerns the intensive margin of trade. Even among exporters, a reduced number of firms will concentrate most of gains from trade.

These predictions are in line with the changes in Chilean plants' productivity distribution. If we compare the changes in the observed distribution of labour productivity, we observe that productivity improvements concern a few number of firms: initially-high

productive plants. Moreover, the distribution of exports over total sales shows that during the 1990s no significant changes are observed. If anything, one observes an increase in the skewness of the distribution.

The second part, which deals with market structure and innovation, is also composed of two chapters. **Chapter 3** tests the effect of competition and regulation on innovative activity measured by patenting. We use a variety of indicators: the relative number of firms in an industry and various proxies of product market regulation provided by the OECD. We collect a time-series cross-section data of 15 industries for 17 OECD countries over the period 1979-2003. We are interested in the differentiated effect of competition, which, following Aghion et al. (2005), depends on the proximity to the technological frontier. Under the authors' predictions, competition discourages laggards to innovate but for firms competing at the leading edge it should boost innovation.

Our results can be summarised as follows. Depending on specifications, regulation appears (i) as a positive engine of innovation, which diminishes with the productivity gap but remains positive at the leading edge, or (ii) as having a negative impact on innovation far from the frontier, which vanishes or becomes positive when the technological gap is reduced. On the other hand, the relative number of firms also fails to yield a positive and significant effect close to the technological frontier. While contradicting the belief of a boosting-innovation effect of competition, these results are in line with some previous microeconomic studies (see *supra*). Further, the sign of the effect of the interaction between regulation and technology gap is consistent with previous industry-level evidence using productivity as performance. In order to explain these results, in a simple model of

Schumpeterian innovation à la Aghion et al. (2005) we allow for innovative leaders: by innovating leaders can reduce the catching-up process. This modification induces multiple equilibriums accounting not only for the inverted U-shape relationship, but also for the possibility of a monotonic negative effect of competition on innovation. The latter equilibrium is likely to occur when the incidence of the leader on the follower's R&D process is high.

In **Chapter 4** we provide deeper insights into the interactive features of the innovative process. We focus on the consequences of defensive strategies of incumbents in R&D races. Using a quality ladder model, we endogenously explain incumbents' R&D advantages due to strategies that allow to limit knowledge diffusion. Namely, the threat of the Schumpeterian rent-stealing effect pushes incumbents to adopt technological paradigms that render more costly the next R&D race. After innovating and before production, incumbents choose the visible characteristics of the good to be manufactured. They can exploit their private knowledge about the new discovery and complexify the manufactured version. At each discovery, innovators add further changes in the qualitative composition of the good in order to induce a bias in the diffusion of the state-of-the-art knowledge. This introduces the possibility of endogenous technological advantages in R&D races for incumbents.

We model strategic behaviour in R&D as in a Stackelberg game. Incumbents have a first mover advantage of high R&D commitment. The endogenous technological advantages can be high enough to overwhelm the Arrow-replacement effect and to explain innovative leaders. Thus, market institutions may limit the extent to which incumbents can

introduce a bias in knowledge diffusion and become credible in their R&D commitment. Regulatory provisions reducing the set of possibilities of complexification in manufacturing can have a positive impact on R&D incentives and appear to be crucial in determining who innovates. They can explain endogenously two long run equilibrium: (a) permanent innovative monopolist and (b) continuous Schumpeterian replacement. Because of monopolistic behaviour, at equilibrium, the effect of market institutions is modulated by the size of innovation. Their positive effect on R&D effort should be namely observed when the size of innovation is high.

We test these predictions using the time-series cross-section sample of the previous Chapter. This time we focus on R&D intensity (R&D expenditure over value added) rather than patenting. To test our argument, we assume that high-technological industries make bigger steps of technological upgrade than the rest of industries. These industries are defined as those producing and using information and communication technologies (ICT). Results are consistent with the model's predictions: the effect of regulation on R&D intensity has an additional positive impact in these industries relative to the rest.

I.- WITHIN-FIRM PRODUCTIVITY EVOLUTION AND TRADE POLICY

The way in which a country protects its market from foreign competition and integrates international markets determines what we call the outward dimension of market structure. This part of the thesis focuses on this dimension. We explicitly address the effect of trade policy on the evolution of firm productivity. Our work is mainly motivated by the case of a developing economy. During the 1970s and mostly during the 1980s, an important process of structural reforms took place in many developing countries. The link between the reduction of trade barriers and productivity gains is a key topic in the ex-post study of these important reform packages.

In Chapter 1 we analyse the Chilean experience. We exploit a plant-level panel data and bilateral flows data to show that the reaction of firm productivity is not homogenous across firms and that the orientation of trade policy (import or export) matters. In Chapter 2, the empirical results of heterogenous firm productivity improvements are theoretically analysed. This part of the thesis emphasises mechanisms linking trade policy and productivity improvements at the firm level. Firm heterogeneity, monopolistic competition and increasing returns are key elements to explain the evidence.

Chapter 1

Trade, Foreign Competition and Within-Plant Productivity: The Chilean Experience¹

1.1 Introduction

Trade liberalisation was at the core of reform packages implemented in many developing economies during the 1980s. In this Chapter we revisit the case of Chile, one of the earliest and most radical examples of trade liberalisation in developing countries. We aim at testing the link between trade policy and productivity in Chilean manufacturing plants. While several empirical works have found evidence of a positive correlation between the reduction of trade costs and productivity (Pavcnik, 2002; Bernard and Jensen, 2001; Clerides, Lach and Tybout, 1998; Bernard, Jensen and Schott, 2003), the arguments do not always go in the same direction. We propose to fill this gap by disentangling the consequences of export and import barriers.

On the import side, foreign competition is often viewed as a positive engine of productivity (Pavcnik, 2002). It pushes less productive firms to exit the market and surviving ones to correct their inefficiencies. However, the presence of increasing returns to scale and imperfect competition may introduce new ingredients (Devarajan and Rodrik, 1989;

¹ This Chapter is based on Bas and Ledezma (2007). "Market Access and the Evolution of Within Plant Productivity in Chile". CESifo Working Paper Series No. 2077; and on Bas and Ledezma (2008). "The Evolution of Trade Integration in Chilean Manufacturing". In "Trade Integration and Economic Development: The EU and Latin America". G. Tondl (eds.) ECSA-Austria, Springer. Wien, 2008. *Forthcoming*

Rodrik, 1992; Krugman, 1980). Indeed, one of the most important consequences of the economies of scale is precisely the fact that average cost falls as output increases. In that sense, the size of local market plays an important role in mapping cost structures. In a country like Chile, with a current population of 16 million (11 million in the 1982 census), the opportunities for scale economies in import-competing sectors are likely to be limited after a radical reduction of import barriers. Using a wide sample of 27 manufacturing industries (and 7 non-manufacturing) for 71 countries, Antweiler and Trefler (2002) show that scale economies do matter to explain trade patterns. The authors find strong evidence of increasing returns for one third of industries.

On the export side, the literature suggests learning-by-exporting as a plausible mechanism to explain the effects of trade liberalisation on plant's productivity. Empirical works highlight ex-post productivity gains arising after selling in foreign markets: Aw, Chung and Roberts (2000) on Korea; Kraay (2002) on Chinese firms, and Alvarez and Lopez (2005) on Chile. Theoretically, explanations focus on productivity improvements resulting from knowledge and expertise gained in the export process. Exporters can learn from their international partners and from the state-of-the-art in the foreign market. As a consequence, they adopt better production methods and achieve higher productivity. Clerides, Lach and Tybout (1998) construct a dynamic model based on Baldwin (1989), Dixit (1989) and Krugman (1989). In their model, firm productivity depends on prior export experience. Learning-by-exporting then widens the productivity gap between firms that enter the export market and those that sell only to the domestic market. More generally, the tradition of models of trade and innovation inspired by Grossman and Helpman (1991) puts forward

the role of international spillovers in the growth process. In this case, these spillovers may also benefit to firms competing with foreign producers.

These channels call for further analysis on each side of trade policy. Our contribution to previous works is to differentiate between the implication of export- and import-oriented policies. To test the impact of trade policy on productivity, we obtain estimates of plant's total factor productivity (TFP) and also estimates of trade barriers. To do so, we use (a) the annual industry survey ENIA of Chilean manufacturing plants provided by the INE (*Instituto Nacional de Estadísticas*) and (b) the Trade and Production database of bilateral flows provided by CEPII (*Centre d'Etudes Prospectives et d'Information Internationales*) for each estimation, respectively. Our estimation of plant's TFP follows the Levinsohn and Petrin (2003)'s methodology (LP), which in turn extends the Olley and Pakes (1996)' strategy (OP) to consistently estimate production functions in the presence of unobserved time-varying firm heterogeneity. To estimate trade barriers, we construct an indirect measure of trade policy that takes into account the evolution of market access between Chile and its main trading at the industry level. We rely on the "border effects" methodology of Fontagné, Mayer and Zignago (2005), which essentially captures trade difficulties related to the fact of crossing national borders. Considering direct measures of trade policy such as tariffs indicators neglects two important features of trade. First, import tariff reduction may not be symmetric among trade partners. Second, several indirect factors, acting as important barriers to trade, may be omitted (Anderson and van Wincoop, 2004). Among them one finds not only non-tariffs barriers and fixed export costs, but also bilateral agreements, institutional arrangement, infrastructure and even political integration.

Since the strategy of Chilean governments was to set a combination of trade policies, we should be able to capture the effect of the full set of barriers faced by Chilean exporters to access foreign markets, as well as the effect of barriers faced by Chilean partners to reach the domestic market. This also means the identification of potential asymmetries in policy protection and their evolution. The methodology stemming from the empirical literature of border effects meets these requirements, since it captures all missing trade due to the fact of crossing the border.

The Chilean dictatorship, in office from 1973 to 1990, implemented a deep package of market-oriented reforms concerning every economic field. Among them, trade liberalisation took place in the second half of the 1970s. Since the beginning of the period, all trade barriers and restrictions to trade were removed. Average nominal tariff rates decreased gradually from 98% in 1973 to 10% in 1979 (Figure 1.1). While the evolution of tariffs remains flat during the nineties, in that period, Chile started signing several trade agreements with different countries and regions, avoiding being tied to one single regional customs union. Since then, Chile has pursued trade agreements not only with almost all Latin American countries, but also with the United States, the European Union and, in recent years, with Asia.

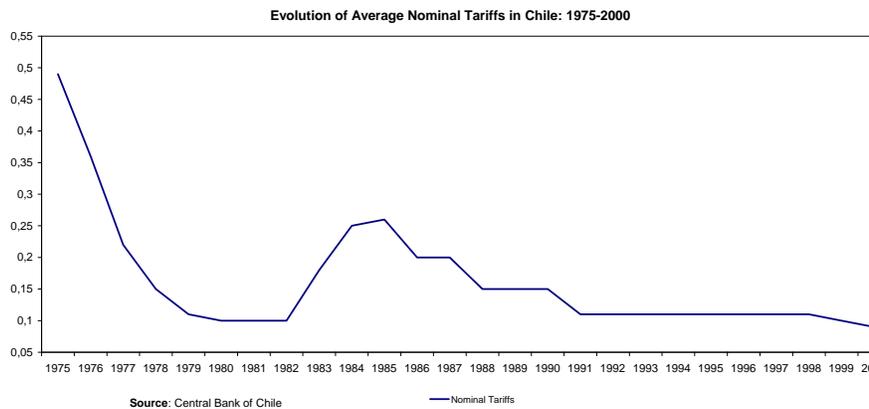


Figure 1.1. Nominal tariffs in Chile

Theoretical models of trade with firm heterogeneity predict aggregate productivity improvements coming from the reallocation of market shares towards most productive firms (Melitz, 2003; Bernard et al., 2003). In this Chapter, we are more particularly interested in productivity improvements at the firm level. Figure 1.2 presents the evolution of the ratio of the weighted (by market share) to the simple unweighted average labour productivity between 1979 and 2000. While the unweighted average can be related to within-plant productivity improvements, the weighted measure takes into account the gains due to the reallocation between firms. The graph shows that after 1987 the ratio measuring the gap between both averages decreases gradually. Thus, within-plant productivity gains become a key factor to explain aggregate levels. Consequently, the data suggest the relevance of mechanisms that modify firm productivity after a change in the exposure to trade. These mechanisms complete explanations highlighting the exit of less productive firms and the reallocation of market shares².

² We theoretically address this finding in Chapter 2.

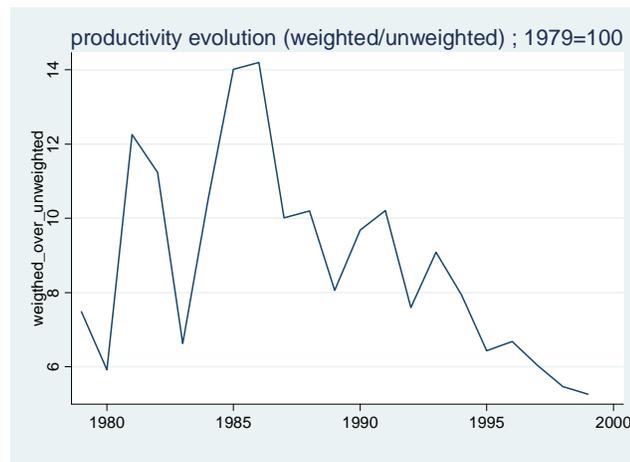


Figure 1.2. Weighted versus unweighted labour productivity evolution

We are particularly interested in two works dealing with the Chilean experience. Based on the ENIA Survey, Pavcnik (2002) makes an estimation of the impact of trade on plants' productivity in Chile during the period 1979-1986. She applies OP strategy and controls explicitly for simultaneity and selection issues. Using a difference-in-difference framework and average productivity decompositions, the conclusion of Pavcnik (2002) is that aggregate productivity improvements are explained by two factors induced by trade liberalisation: (a) the growth of within-plant productivity in importing-competing industries and (b) the exit of less productive firms and the corresponding reallocation of market share towards most productive ones. However tariffs rose between 1983 and 1985 (see Figure 1.1). Due to the debt and recession crisis in 1982, the government increased tariffs and nominal averages to 26% between 1983 and 1985. Thus, the exposure to trade does not increase regularly during the Pavcnik's sample period. Furthermore, using year indicators in interaction with an indicator of trade orientation (by industry) implies the implicit as-

sumption that the rest of macroeconomic shocks, captured by these year dummies, affect all sectors in a uniform way.

Chilean market reforms were recently revisited by Bergoeing, Hernando and Repetto (2006). They study the impact of trade and financial liberalisation on productivity gains in Chile in a longer period of time (1980-2001). Their TFP measure follows the LP strategy. Their results show that aggregate productivity gains come from within-plant improvements over time in traded industries relative to non-traded ones (during the nineties) and from the net-entry of more productive firms. That is to say, firms that enter the market are more productive than those that exit the market. They also find that the process of resource reallocation among incumbents play a minor role in enhancing aggregate productivity. In regressions using effective tariffs, productivity advantages of traded industries are not significant and import-competing industries get (significantly) productivity gains from protection.

Unfortunately for identification, the drop of Chilean tariffs was quite radical but homogeneous across industries. This is probably the reason why Pavcnik (2002) is compelled to use year dummies indicators and the reason why Bergoeing, Hernando and Repetto (2006) can not get enough variance for their estimates. Estimating the evolution of market access (border effects) between Chile and its trading partners enables us to identify heterogeneity in both industry and time dimensions. In that sense, this Chapter yields new findings of trade policy implications. In order to facilitate the comparison of the results with previous works we also distinguish between export-oriented, import-competing and non-traded industries. We start by reproducing Pavcnik's (2002) results for our full sample

period. Then we extend her work by introducing specific indicators of exported and imported barriers. In this case, we run regressions that explain productivity by the measures of trade barriers. The latter are put in interaction with the trade orientation of the industry in which the firm operates. Our identification follows the difference-in-difference-like specification of Pavcnik (2002) and Bergoening, Hernando and Repetto (2006). Results are then relative to non-traded industries. First, we find a positive significant effect of a reduction of export barriers on productivity in both export-oriented and import-competing industries. Second, we also find evidence of a positive impact of the reduction of import difficulties on productivity in export-oriented industries. Finally, regressions show that a decrease in import barriers might have a negative impact on productivity in import-competing industries. This result implies that industries in import-competing industries may actually suffer from foreign competition. Production function estimates suggest that this result is probably due to increasing returns.

The rest of the Chapter is organised as follows. Section 1.2 presents the estimation strategy in three steps. Section 1.3 discusses the main estimation results. Section 1.4 concludes.

1.2 Estimation strategy

The estimation strategy consists of three steps. In the first one, we estimate the production function using OLS, fixed effects (Within-group) and the LP methodology. The aim is to obtain the elasticity of each factor in order to calculate the total factor productivity (TFP) of plants as a residual. In the second step, we construct the measure of trade liberalisation by

estimating the border effects from a gravity model based on Fontagné, Mayer and Zignago (2006). Finally, in the third step, we estimate the impact of trade barriers by regressing productivity on border effects estimates. In this stage we identify productivity gains by trade orientation (exporters, import-competing and non-traded industries).

1.2.1 Step 1: Production function

We estimate the following specification of a Cobb- Douglas production function at two digit industry level:

$$y_{it} = \beta_0 + \beta_x x_{it} + \beta_k k_{it} + \varepsilon_{it} \quad (1.1)$$

Where all variables are expressed in natural logs, y_{it} is the value added of plant i at time t , the vector x includes variable inputs (skilled and unskilled labour) and k the stock of capital. The error term can be decomposed into an intrinsical "transmitted" component ω_{it} (productivity shock) and an i.i.d. component η_{it} . Consequently, Plant's TFP a_{it} is calculated as the residual given by the difference between the observed output and the predicted factor contribution:

$$\hat{a}_{it} = y_{it} - \hat{\beta}_x x_{it} - \hat{\beta}_k k_{it} \quad (1.2)$$

When estimating production functions using firm panel data, eventual problems concerning simultaneity and selection should be considered. Simultaneity arises because inputs demands and unobserved productivity are positively correlated. Firm specific productivity is known by the firm but not by the econometrician. On the other hand, in panel data productivity measures are usually heterogeneous among firms and evolve over the time. If a firm expects a high productivity shock it will anticipate an increase in demands and conse-

quently it will purchase more inputs. OLS will tend to provide upwardly biased estimates of labour coefficients. Actually, OLS elasticities can be stated as:

$$\hat{\beta}_x = \beta_x + \frac{\hat{\sigma}_{kk}\hat{\sigma}_{x\varepsilon} - \hat{\sigma}_{xk}\hat{\sigma}_{k\varepsilon}}{\hat{\sigma}_{xx}\hat{\sigma}_{kk} - \hat{\sigma}_{xk}^2} \quad (1.3)$$

$$\hat{\beta}_k = \beta_k + \frac{\hat{\sigma}_{xx}\hat{\sigma}_{k\varepsilon} - \hat{\sigma}_{xk}\hat{\sigma}_{x\varepsilon}}{\hat{\sigma}_{xx}\hat{\sigma}_{kk} - \hat{\sigma}_{xk}^2}$$

Where $\hat{\sigma}_{rs}$ is the covariance between variables r and s in the sample. If capital is positively correlated with labour and labour's correlation with the productivity shock is higher than capital one (which is the realistic case) then the coefficient of capital $\hat{\beta}_k$ could be underestimated and the one of labour $\hat{\beta}_x$ upward-biased.

Selection problems are likely to be present because unobserved productivity influences the exit decision of the firm and we can only observe those firms that remain in the market. On the other hand, if capital is positively correlated with profits, firms with larger capital stock will decide to stay in the market even for low realisations of productivity shocks. This implies a potential source of negative correlation in the sample between productivity shocks and capital stock, which translates into a downward bias in capital elasticity estimates.

Olley and Pakes (1996) (OP) propose a methodology of three stages to control for unobserved productivity, by dealing explicitly with exit and investment behaviour. In the first stage, they address simultaneity by using an investment rule derived from a theoretical optimal behaviour. This rule express investment i_{it} as a function of capital stock and unobserved productivity, say $i(\omega_{it}, k_{it})$. OP invert this investment rule to express unobserved productivity as a function of investment and capital $\omega_{it}(i_{it}, k_{it})$. This allows to write (1.1)

as:

$$y_{it} = \beta_x x_{it} + \phi_t(i_{it}, k_{it}) + \eta_{it} \quad (1.4)$$

Where $\phi_t(i_{it}, k_{it}) = \beta_0 + \omega_{it}(i_{it}, k_{it}) + \beta_k k_{it}$. Thus, after using a polynomial expansion $\phi_t(i_{it}, k_{it})$ of i_{it} and k_{it} , no-intercept OLS can be applied to obtain a consistent estimate of labour elasticity β_x . In the second stage, they estimate the probability of survival conditional on available information to the firm. They derive a theoretical exit rule stating that firms decide to exit the market if the realisation of productivity shocks are lower than a specific productivity cutoff, which in turn is given by capital stock and productivity. The estimates of this survival probability are used to control for selection bias. To obtain the capital coefficient, one substitute the estimates of labour coefficient (first stage), the productivity function (inverted investment decision) and the survival probability (second stage) into the production function equation. Assume ω_{it} to follow a first-order Markov process and that capital does not react immediately to innovations in productivity over the last expectation $\xi_{it} = \omega_{it} - E[\omega_{it} | \omega_{it-1}, \chi_t = 1]$. Where $\chi_t = 1$ reflects the decision of the firm to stay in the market. $E[\omega_{it} | \omega_{it-1}, \chi_t = 1]$ can be estimated using available information for the firm. For simplicity call this approximation as $g(\phi_{t-1} - \beta_k k_{it-1}, \hat{P})$, where \hat{P} is the fitted probability of survival conditional on i_{it} and k_{it} . Thus, one may use an expansion on i_{it} and k_{it} to approximate g . This leads to:

$$y_{it} - \beta_x x_{it} = \beta_0 + \beta_k k_{it} + \hat{g}(\cdot) + \xi_{it} + \eta_{it} \quad (1.5)$$

Since k_{it} and ξ_{it} are uncorrected, this regression leads to unbiased estimates of β_k . Levinsohn and Petrin (2003) (LP) extend the OP idea, by noting that some inputs, such as electricity or materials, can be better proxies to control for unobserved productivity when

one deals with simultaneity. Inputs adjust in a more flexible way, so they are more responsive to productivity shocks. Although LP basically follow the OP methodology some adaptations need to be mentioned. First, regressions are run using alternative non-parametric estimators based on conditional moments. Let be e_{it} electricity. Taking the expectation of (1.4) conditional on e_{it}, k_{it} and subtracting the result from (1.4) gives:

$$y_{it} - E[y_{it}|e_{it}, k_{it}] = \beta_x [x_{it} - E[x_{it}|e_{it}, k_{it}]] + \eta_{it} \quad (1.6)$$

One notes that η_{it} is independent of x_{it} . Thus after estimating $E[x_{it}|e_{it}, k_{it}]$ no-intercept OLS can get the first stage parameters³. Second, the methodology does not take into account directly selection. To estimate $E[\omega_{it}|\omega_{it-1}]$, LP use ϕ_t and the first stage candidates of elasticities. They choose the final estimates of elasticities by a routine that seeks to minimise a GMM criterion function. Finally, in order to take into account the variance of intermediate estimates, LP use bootstrapping for inference.

Inputs usually have more non-zero observations than investment, a property that has consequences on estimation efficiency. In the case of the ENIA this property is important. As LP show the risk of selection biases are significantly reduced by considering a non balanced panel. In order to maximise sample size with a reduced risk of selection we keep the LP strategy and use electricity as a proxy for unobserved productivity.

There are some advantages of OP-LP strategy over alternative methods. Firstly, it performs better than fixed effects because it does not assume that the unobserved individual effect (productivity) is constant over time when controlling for simultaneity. Secondly,

³ $E[x_{it}|e_{it}, k_{it}]$ is estimated by regressing x_{it} on e_{it} and k_{it} with locally weighted quadratic least square approximation.

approaches based on instrumental variables can be limited by the instruments availability. Finally, it does not assume restrictions on the parameters. For instance, an alternative approach is the one developed by Katayama, Lu and Tybout (2005). They show how misleading can be the use of sale revenues to measure output in productivity accounting. Factor prices and mark-ups can produce important distortions if they are not homogeneous. However, the methodology proposed in their paper assumes constant returns to scale and neglect entry-exit process to facilitate likelihood estimates. Again both assumptions are not neutral in the case of the ENIA.

1.2.2 Step 2: Border effects

It is well known that the reduction of tariffs in Chile was homogeneous across industries. As a consequence, we do not have variance in tariffs measures among industries. Even their rise in early 1980s, during the deep debt crisis, was homogeneous. On the other hand, tariffs are not the only measure that matters to measure trade costs. One should also consider bilateral agreements, asymmetries between export and import costs and indirect difficulties to trade. Theoretically, these indirect difficulties include a large list of country specificities, which relates not only to insurance, infrastructure and institutional issues but also but also to tastes, bias of consumption towards home goods and the like. As long as the latter can be interpreted, at least in part, as the outcome of history and political efforts, we consider them as a part of the measure of trade integration. Actually, by considering all these elements, we do obtain heterogeneity in both industrial and time dimensions.

Previous studies concerning Chilean integration have mainly focused on macro-economic and welfare effects of trade agreements using general equilibrium models (Harrison, Rutherford and Tarr, 2003; Chumacero, Fuentes and Schmidt-Hebbel, 2004; Cabezas, 2003). Among the exceptions using a gravity approach, Nowak-Lehman, Herzer and Vollmer (2007) analyse the impact of trade agreements between Chile and the EU on the structure of exports and predict important export expansion on foods industries (mainly fish, fruits and beverages). Our contribution to this literature consists of providing an assessment of the evolution of trade integration at the industry level by capturing *all* barriers to trade.

To do so we apply a border effect methodology. This type of methodology makes use of gravity equations and provides a measure of international trade integration by considering, as a very intuitive benchmark, the market access of domestic producers reaching domestic (intra-border) destinations. Consider for instance two countries. If, after crossing the national border, producers face no additional barriers to trade than those already present in the national market, both countries will be considered as completely integrated. The pioneer work of McCallum (1995) uses this idea along with detailed intra-national trade data to study the market access between Canada and the US. Despite of their high expected trade integration, trade between US and Canada is found to be around 22 times more difficult than Canadian intra-national trade.

In Step 2, we follow the identification strategy of Fontagné, Mayer and Zignago (2005) based on Head and Mayer (2001) gravity model derivation. This strategy seems suitable to measure Chilean trade integration as it corrects for the lack of theoretical foun-

dations of earlier works, keeping the intuitive strategy of using intra-national trade as a benchmark of trade integration. Let us consider a CES utility function in which the representative consumer of country i has specific preferences for each variety h depending on the country of origin j (the exporter).

$$U_i = \left[\sum_{j=1}^N \sum_{h=1}^{M_j} (a_{ij} c_{ijh})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where $\sigma > 1$ is the constant elasticity of substitution among domestic and foreign differentiated varieties. For symmetric varieties, this weighted CES formulation implies the following expenditure m_{ij} in imports from country j :

$$m_{ij} = c_{ij} p_{ij} = \left(\frac{p_{ij}}{a_{ij} P_i} \right)^{1-\sigma} M_j Y_i \quad (1.7)$$

Since varieties belonging to the same country share the same weight in the utility function, we just drop the h subscript. Imports are valued at the point of consumption (c.i.f) $p_{ij} = p_j \tau_{ij}$ and include the producer price (f.o.b.) p_j augmented of all transaction costs related to trade, modeled as iceberg costs τ_{ij} . Total expenditure of country i and considers all imports $Y_i = \sum_{j'=1}^N m_{ij'}$, including intra-national ones. This gravity-like equation

in (1.7) summarises in $P_i = \left[\sum_{j'=1}^N \left(\frac{p_{ij'}}{a_{ij'}} \right)^{1-\sigma} M_{j'} \right]^{\frac{1}{1-\sigma}}$ consumer price of all varieties.

This index helps to introduce the Anderson and van Wincoop (2003)'s critics concerning the absence of theoretical foundations and, namely, the implicit assumption of identical prices across countries. P_i is a multilateral variable that takes into account differences in price setting across countries. If omitted, not only a multilateral control is missing but also a bias is induced between the error term and the border effect dummies. Anderson and van Wincoop (2003) argue that the omission of multilateral price effects (what

they call "multilateral resistances") explains the upward bias in border effects of Canada vis-à-vis the US estimated by McCallum (1995).

One might mention four possible strategies to consistently estimate an equation of the type of (1.7), which includes price effects in a theoretical index. The first strategy is to use price index data. Bergstrand (1989) and Baier and Bergstrand (2001) follow this strategy measuring prices with GDP deflators. However, as highlighted by Anderson and van Wincoop (2004), empirical counterparts of P_i such as CPIs measures neglect changes in the true set of varieties and do not accurately reflect non tariff barriers and indirect trade policies.

The second strategy is the one followed by Anderson and van Wincoop (2003). They develop a method using estimated border effects to measure multilateral price effects. This estimation strategy is based on two steps. The first one consists in the estimation of the gravity equation using a non-linear least squares estimator to obtain the parameters. In the second step, they remove border barriers and calculate the change in bilateral trade flows to determine the impact of national borders on trade flows. Besides practical difficulties of implementation⁴, one crucial limitation for our purposes, as we previously explained, is the assumption of symmetry in bilateral trade costs.

The third approach uses fixed effects specification to measure unobservable prices. Price indexes are considered as unobservable variables and they are measured as the coefficients of individual fixed effects related to source and destination (Harrigan, 1996; Redding

⁴ One should implement a routine in which at each iteration the sum of square residuals of the gravity equation are minimized, solving simultaneously the estimation of trade cost at each stage and computing the multilateral prices index

and Venables, 2004). Feenstra (2003) shows that the coefficients of fixed effects estimation are consistent and present values very similar to the non-linear least squares estimation.

An additional strategy is to eliminate the price index in equation (1.7) by expressing inter-national imports m_{ij} , relative to intra-national ones m_{ii} . This is what Head and Mayer (2001) do. Under symmetric monopolistic competition quantities are symmetric at the equilibrium. The number of firms of each country is obtained by simply dividing output value v_j by firm output value: $M_j = \frac{v_j}{qp_j}$. Considering $p_{ij} = p_j \tau_{ij}$, equation (1.7) can be written as:

$$\frac{m_{ij}}{m_{ii}} = \left(\frac{a_{ij}}{a_{ii}} \right)^{\sigma-1} \left(\frac{p_j}{p_i} \right)^{-\sigma} \left(\frac{\tau_{ij}}{\tau_{ii}} \right)^{1-\sigma} \left(\frac{v_j}{v_i} \right) \quad (1.8)$$

To obtain an empirical counterpart of this gravity equation, Fontagné, Mayer and Zignago (2005) state that trade costs τ_{ij} are composed by distance d_{ij} (related to transport costs), ad-valorem tariffs t_{ij} and "tariff equivalent" of non tariff barriers NTB_{ij} . Applying this to p_{ij} gives:

$$\tau_{ij} p_j \equiv d_{ij}^{\delta} (1 + t_{ij}) (1 + NTB_{ij}) p_j$$

The structure of protection varies across all partner pairs and depends on the direction of the flow for a given pair. To capture this protection framework, taking the example of the US as trade partner, the following dummy structure is defined:

$$(1 + t_{ij}) (1 + NTB_{ij}) \equiv \exp [\eta US_CHL_{ij} + \gamma CHL_US_{ij}]$$

Where US_CHL_{ij} is a dummy variable set equal to 1 when j is Chile and i is the US (related to imports of the US from Chile). Similarly, CHL_US_{ij} is a dummy variable set equal to 1 when j is the US and i is Chile (imports of Chile from the US).

Preferences a_{ij} are composed by a random component e_{ij} and a coefficient β_i , representing a systematic preference for goods produced in the home country. This "home market bias" β_i is reduced by λ when the countries share the same language ($L_{ij} = 1$). This defines a_{ij} as:

$$a_{ij} \equiv \exp [e_{ij} - (\beta_i - \lambda L_{ij}) (US_CHL_{ij} + CHL_US_{ij})]$$

Combining the previous equations and adding the subscript s for variables that will be used at the industry level, the following estimable equation is obtained:

$$\begin{aligned} \ln \left(\frac{m_{ijs}}{m_{iis}} \right) &= \ln \left(\frac{v_{js}}{v_{is}} \right) - (\sigma - 1) \delta \ln \left(\frac{d_{ij}}{d_{ii}} \right) + (\sigma - 1) \lambda L_{ij} - \sigma \ln \left(\frac{p_j}{p_i} \right) \quad (1.9) \\ &\quad - (\sigma - 1) [\beta_i + \eta] US_CHL_{ijs} - (\sigma - 1) [\beta_i + \gamma] CHL_US_{ijs} \\ &\quad + \epsilon_{ij} \end{aligned}$$

Where $\epsilon_{ij} = (\sigma - 1) (e_{ij} - e_{ii})$. The ratio of bilateral trade flows over intra-national trade flows at the industry level $\frac{m_{ijs}}{m_{iis}}$ is explained by a list of observable variables: the relative value added of partners in the industry $\frac{v_{js}}{v_{is}}$, their relative distance $\frac{d_{ij}}{d_{ii}}$, the relative prices at national level $\frac{p_j}{p_i}$ and a dummy to indicate if the pair (i, j) share the same language L_{ij} . The part of missing trade not explained by these determinants is attributed to the fact that the exchanges take place between two particular and different nations. In that sense,

the border effects coefficients reveal all market access difficulties for each specific trade flow.

In the regressions, we drop the constant and incorporate both dummy variables, each for one direction of trade flows. Thus, their coefficients can be directly interpreted as the border effect of each combination. For example, the exponential of the coefficient of US_CHL_{ij} multiplied by -1 , $\exp((\sigma - 1) [\beta_i + \eta])$ indicates the difficulty for Chilean exporters in accessing US markets. All regressions are run using OLS and Hubert and White standard errors to control for the correlation in the error term in (1.9). We estimate equation (1.9) for each industry at the two digit level. From these estimations, we obtain the global trade barrier measure for each industry as the weighted average of border effect estimates across all partners. In order to take into account the evolution over the full time period, we run the regressions using a rolling window of four years. For instance, border effects of the year 1982 consider the estimates of the regression between 1979 and 1982. This also allow to consider a lag on the effect of trade policy.

We consider a representative set of countries trading with Chile. Looking at the aggregated trade flow data of the Economic Commission for Latin America and the Caribbean (ECLAC) between 1990 and 1999, the main destination of Chilean manufacturing exports are Latin America (AL), the United States (USA) and the European Union (UE) (Figure 1.10 in appendix). The graph also shows that, during the same period, most manufacturing imports of Chile came from these countries.

Fontagné, Mayer and Zignago (2005) use aggregate prices to address the possible endogeneity problem that might arise in the estimation of equation (1.9). This potential

endogeneity is associated to the simultaneity in the determination of prices and output in a monopolistic competition framework. Prices at national level are less likely to be correlated with profit maximisation at the firm level. On the other hand, there is another potential source of endogeneity since, in Step 3, we use the estimates of border effect to test the impact of trade liberalisation on plant's TFP in different industries. Most productive industries or those producing high quality goods will tend to increase their trade flows and to have a smaller border effect. To address this issue we use relative wages at the industry level instead of aggregate prices in the estimation of border effects. This alternative measure of relative prices are used to control for potential asymmetries in technology since more productive industries are expected to have lower border effects. In that sense the residual measure of missing trade that is captured by the border effect will be free of productivity concerns.

1.2.3 Step 3: The impact of trade policy on plant's TFP

In this final step, we use the weighted average of border effects of each industry. We measure the impact of trade liberalisation on productivity across export and import-competing industries relative to non-traded industries. We estimate the following reduced equation, similar to the difference-in-difference framework implemented by Pavcnik (2002):

$$\widehat{a}_{it} = \alpha_0 + \beta B_{it} + \gamma T_i + \delta B_{it} \cdot T_i + \lambda Z_{it} + \epsilon_{it} \quad (1.10)$$

Where \widehat{a}_{it} is the log of plant's TFP estimated by the LP strategy or by the Within-group estimator. B_{it} is a vector of trade barriers: import border effects (BE_M) and export

border effect (BE_X) estimates at the two digit industry level. T_i is a vector of trade orientation dummies: export-oriented (Export) and import-competing (Import) industries. We classify industries by trade orientation at the 3-digit industry level. Plants are classified as export-oriented if they belong to a 3-digit industry which has more than 15% of exports over total production. Plants classified as import-competing if they belong to a 3-digit industry which have more than 15% of import penetration. The rest are considered as non-traded. This classification is based on Pavcnik (2002) and concerns the initial period of 1980-1986. By using this typology, we can get results that are comparable with previous works. The initial sample classification also helps to avoid the endogeneity problems of the classification. As Pavcnik (2002) notes, classification at 3- or 4-digit does not change significantly. Neither does it when considering pre-sample period.

Z_{it} : vector of plant characteristics: industry affiliation at 2-digit ⁵, the Herfindahl index of competition (ind_comp), indicators of entry and exit (Entry_ind; Exit_ind) and plant characteristics that might change over time: imported inputs and credit constraint indicators. We also introduce year indicators to control for macroeconomic shocks. The excluded categories are non-traded industries, the year 1982 and the industry 38.

We are mainly interested in the estimates of the vector coefficient δ . A negative and significant coefficient means that a reduction of trade barriers has a positive effect on productivity in traded industries (export-oriented and import-competing) relative to non-traded ones. This strategy of identification enables us to measure separately the effect of

⁵ We introduce industry indicators in order to control for specific characteristics of industries. In order to avoid possible colinearity issues, following Pavcnik (2002), the industry affiliation dummies are defined at the 2 digit industry level, while trade orientation dummies are defined at the 3 digit industry level

import and export barriers, depending on trade orientation. The vector coefficient γ informs about the relative productivity advantage of traded industries in Chilean manufacture.

Finally, we consider a dynamic specification of equation (1.10) in which plant's productivity depends on its past values. This implies the following auto-regressive multivariate model:

$$\widehat{a}_{it} = \alpha_0 + \alpha_1 \widehat{a}_{it-1} + \beta B_{it} + \gamma T_i + \delta B_{it} \cdot T_i + \lambda Z_{it} + \epsilon_{it} \quad (1.11)$$

If we believe that the error term contains a specific time-invariant unobserved heterogeneity ($\epsilon_{it} = \eta_i + \mu_{it}$), the lagged value of TFP, a_{it-1} , is then endogenous to the error term (as it also contains η_i). Econometric literature provides well known strategies for this dynamic concerns. These strategies exploit moment conditions of exogeneity of the lags of the endogenous dependent variable (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). Here we use the GMM estimator of Arellano and Bond (1991), slightly modified to consider a special case of orthogonal transformation instead of differences when trying to eliminate η_i . This transformation subtracts the average of future values instead of past values. It is the recommended solution to maximise sample size when the sample contains gaps (Rodman, 2006).

1.2.4 Data

In the first step, we use plant level data from the ENIA survey, which is provided by the Chilean institute of statistics INE (*Instituto Nacional de Estadísticas*). This survey is a manufacturing census of Chilean plants with more than 10 employees. Our data covers the

period 1979-2000 and contains information of added value, materials, labour, investment and exports (only available from 1990). The ENIA survey has been used in previous studies such as Pavcnik (2002), Liu and Tybout (1996), Levinsohn and Petrin (2003) and Bergoeing, Hernando and Repetto (2006) for different sample periods. We used different specific deflators at the 3-digit ISIC Rev-2 and year base 1992 for added value, exports, materials and investment. For the latter, specific deflator are also considered for infrastructure, vehicles and machinery. Capital series were constructed using the methodology of Bergoeing, Hernando and Repetto (2006). Table 1.7 (appendix) shows a description of the variables and Table 1.8 (appendix) reports general descriptive statistics of the sample.

In the second step we use data from the "Trade and Production Database" constructed by CEPII. The main source is the Trade and Production Database constructed by Nicita and Olarreaga (2001) at the World Bank. Since this database presents many missing values for production variables in recent years, the CEPII (*centre d'études prospectives et d'information internationales*) has extended this database using production variables of UNIDO and OECD-STAN (for OECD members). CEPII has also completed trade data with the international trade database BACI of CEPII. The final data set cover the period 1976-1999 for 67 developing and developed countries. It provides information on value added, export and import trade flows, origin and destination countries, wages and labour at the 3-digit industry level (ISIC Rev-2). Price indexes stem from Penn World Table as price level of GDP expressed relative to United States.

Detailed intra-national trade flows for our sample of countries are not available. Following Wei (1996), intra-national trade is computed as output minus exports. This requires

an appropriate measure of internal distance that should take into account economic activity to weight internal regions. For distance variables, contiguity and common language, we also used the CEPII database of internal and external distances. The CEPII uses specific city-level data in order to compute a matrix of distance including the geographic population density for each country. Similarly, distance between two countries are measured based on bilateral distance between cities weighted by the share of the city in the overall country's population.

At the end, bilateral trade data is available for nine members of the European Union throughout the whole period 1979-1999 (Germany, France, Great Britain, Italy, Belgium, Luxembourg, Ireland, Netherlands and Denmark) and for six Latin American partners (Bolivia, Argentina, Brazil, Mexico, Uruguay and Venezuela).

1.3 Results

1.3.1 Results step 1: TFP estimates

In this step we estimate the Cobb Douglas production function in equation (1.1) at 2-digit industry level by the means of OLS, Fixed Effects (Within group) and LP estimators. Table 1.1 shows the results. As expected, LP estimates of unskilled labour elasticities are generally the lowest and those of capital elasticities the highest, meaning that the bias induced by the higher responsiveness of the labour input respect to capital is addressed. Considering LP estimates, in five industries (Food (31); wood (33); non-metallic minerals (36); basic metals (37) and other industries (39)) we can not reject at 5% the null hypothesis of

constant returns to scale in the Wald test. Excepting industry 39, these are mainly exporters (Figures 1.8 and 1.9 in Appendix). On the other hand, for the Wald test, industries presenting increasing returns are mainly importers. For these industries the size of the market may affect their productivity.

	Factors	Estimates of Production Function					
		OLS	S.E.	Fixed Effects	S.E.	L.P.	S.E.
Food and Beverage	U	0.815	0.010	0.627	0.012	0.570	0.024
	S	0.359	0.009	0.159	0.008	0.212	0.015
	K	0.250	0.005	0.083	0.007	0.208	0.046
obs: 18559							
Textil	U	0.833	0.011	0.777	0.014	0.710	0.024
	S	0.202	0.010	0.165	0.009	0.174	0.018
	K	0.206	0.005	0.102	0.008	0.249	0.034
obs: 11063							
Wood	U	0.865	0.017	0.849	0.021	0.681	0.034
	S	0.208	0.015	0.095	0.014	0.131	0.021
	K	0.209	0.009	0.104	0.013	0.275	0.040
obs: 5711							
Paper	U	0.763	0.018	0.539	0.024	0.692	0.044
	S	0.252	0.014	0.175	0.015	0.207	0.025
	K	0.229	0.010	0.182	0.014	0.299	0.055
obs: 3175							
Chemicals	U	0.604	0.016	0.639	0.017	0.528	0.045
	S	0.337	0.015	0.168	0.013	0.266	0.028
	K	0.294	0.008	0.149	0.011	0.354	0.057
	N						
obs: 6588							
Non metallic products	U	0.780	0.028	0.797	0.031	0.577	0.074
	S	0.241	0.026	0.130	0.025	0.103	0.049
	K	0.244	0.013	0.136	0.018	0.281	0.074
obs: 2153							
Basic Metals	U	0.280	0.070	0.346	0.061	0.217	0.104
	S	0.485	0.063	0.161	0.045	0.263	0.094
	K	0.412	0.042	0.059	0.049	0.290	0.189
obs: 640							
Machinery	U	0.897	0.012	0.766	0.015	0.767	0.033
	S	0.242	0.011	0.204	0.011	0.178	0.022
	K	0.164	0.006	0.111	0.010	0.236	0.058
obs: 8524							
Other	U	0.880	0.054	0.669	0.063	0.671	0.114
	S	0.214	0.042	0.214	0.046	0.160	0.081
	K	0.093	0.022	0.180	0.032	0.277	0.082
obs: 647							

Note: U: unskilled labor, S: skilled labor and K: Capital

Table 1.1

After estimating production function elasticities, we calculate TFP as a residual. Figure 1.3 presents the average evolution of different measures of plant's productivity: fixed effects (tfp_fe), LP (tfp_lp), OLS (tfp_ols) and labour productivity (lnproductivity).



Figure 1.3. Average productivity evolution for different measures

As a first robustness check of our productivity measures, the graph shows that labour productivity and all TFP measures depicts similar evolutions. Although the elasticities estimated by fixed effects and by LP show some differences, the TFP path illustrated by both measures is very similar. Even if fixed effects may overestimate capital elasticity and underestimate labour one, after computing all factors contribution, the evolution of the residual is not drastically affected.

Figure 1.4 shows the evolution of TFP (LP estimates) by trade orientation. Plants in export-oriented industries are in average more productive than those in import-competing industries. Productivity in non-traded plants slows down during the 1980s and it recovers during the 1990s, but it is always behind the TFP of traded industries.

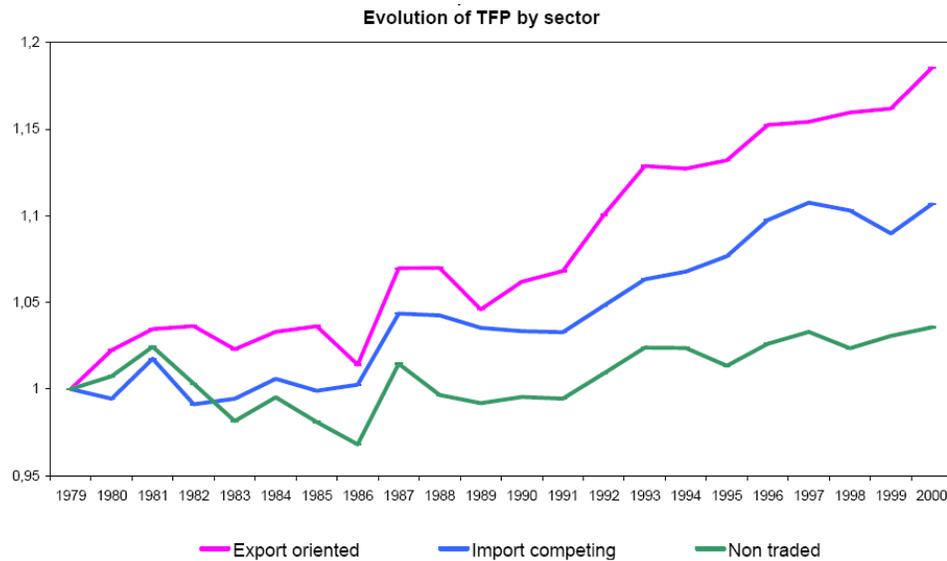


Figure 1.4. TFP evolution by trade orientation

1.3.2 Results step 2: Border effects estimates

In the second step we construct our measure of market access by estimating equation (1.9) at 2-digit industry level to capture the heterogeneity of the degree of trade integration across industries. Figure 1.5 plots the estimates of our rolling window of four year. All of coefficients are significant, at least at 5%. The dashed line depicts import border effects and the solid one those corresponding to exports. The figure summarise the weighted average of export border effects and import border effects across partners. Weights are based on their export or imports share over total export or imports of Chile, respectively.

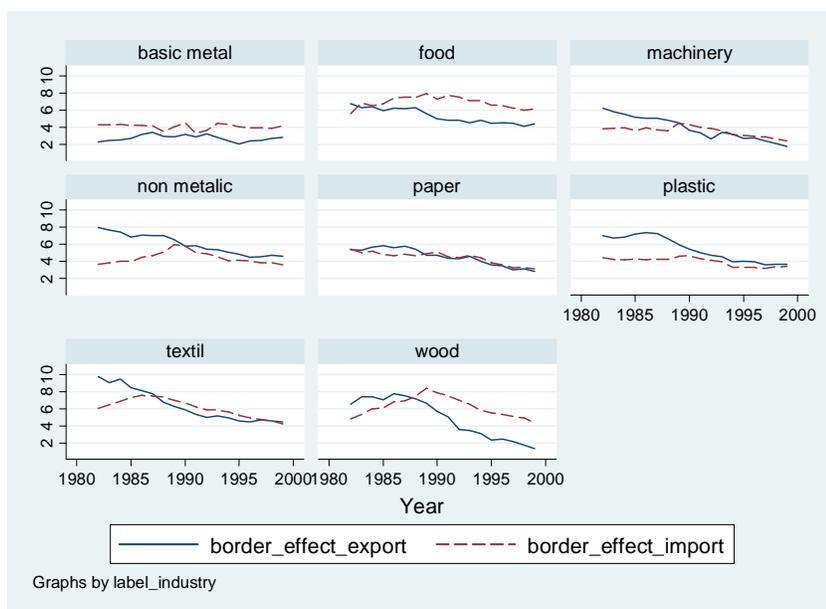


Figure 1.5. Trade barriers measures

Difficulties of Chilean exporters accessing foreign markets were relatively constant at the beginning of eighties. Reflecting the beginning of the active trade agreements agenda and political integration, most of industries switch to a downward trend at the end of eighties. This becomes specially pronounced during nineties. This is namely the case of wood, textile, plastic and machinery. Two important exporting industries, basic metals and food, experiment an evolution of export border effects almost flat. The former, however, is the most traditional exporting industry and trade barriers are already low at the beginning of the period. On the other hand, the rather flat evolution of export barriers on foods might namely reflect quality controls imposed by EU and the US. Home biases are also likely to be present with this type of industry. Once again one observes the extent to which direct measures of trade such as tariffs do not reflect the whole picture of trade policies : export

difficulties have considerably diminished in all industries during the 1990s, even if tariffs were already low.

Figure 1.5 also shows the evolution of the weighted measure of industry-level barriers faced by UE, LA and USA to access Chilean markets: the import border effects (dashed line). In many industries, market access difficulties increased during the first half of the 1980s (food, textile, wood, non metallic goods and machinery). This seems very consistent with the rise in import tariffs during this period and other discretionary measures to control the current account deficit during the crises. As we consider a moving average this tendency is observed even in late eighties, reflecting a lagged effect of protection.

During the 1990s, import border effects have been reduced in almost all industries except in basic metals. Tariffs attain a very low level at the beginning of 1990s (11%). This is also the decade in which the new strategy of trade integration based on several bilateral and multilateral trade agreements begins. The reduction and convergence of import border effects observed for some industries (machinery, non metallic products, plastic and textiles) seems also consistent with the Chilean agenda of trade integration. In appendix we present additional results concerning Chilean trade integration at the national level. One note that asymmetries in trade costs are an important issue.

1.3.3 Results step 3: The impact of trade policy on plant's TFP

The final step consists in identifying the influence of specific trade reforms on the evolution of plant's productivity. Equation (1.10) disentangles the variation in productivity due to changes in trade policy depending on trade orientation. We are interested in the coefficient

vector δ , concerning the interactions between the indicator of trade orientation and our measure of trade barriers (border effects). The coefficients of these interactions capture the effect of trade policy on plants belonging to traded industries relative to those belonging to non-traded industries.

Reproducing Pavcnik's (2002) results

In order to provide a baseline estimation, we start reproducing Pavcnik's (2002) regressions for our full sample period. Thus, we consider fixed effects regressions and use year indicators as a measure of trade liberalisation. We obtain similar results to Pavcnik (2002). Once controlling for exit and plant's specific characteristics, trade liberalisation (if captured by year dummies) has a positive impact on productivity in traded industries (export-oriented and import-competing) relative to non-traded ones. These estimates are illustrated in Figure 1.6 (export-oriented industries) and Figure 1.7 (import-competing industries). Interestingly, for Pavcnik (2002), productivity gains in export-oriented industries are less observable. This is because her regressions consider the period 1980-1986. The trend seems to change in the full sample period after 1990. The opposite is true for import-competing industries.

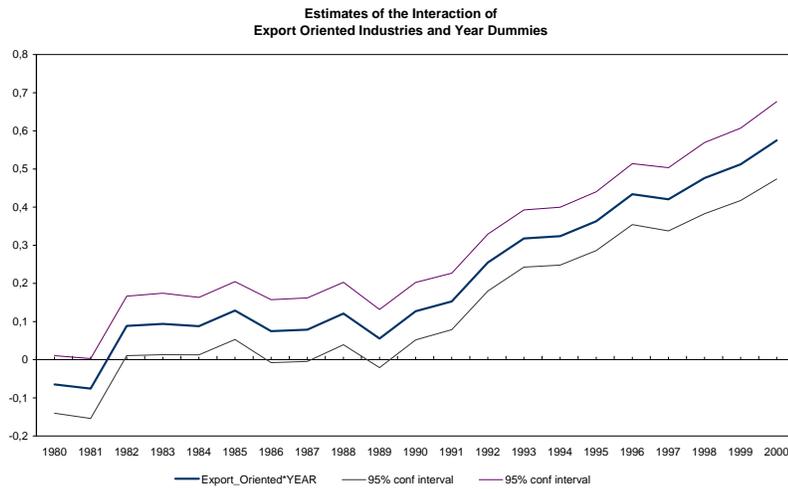


Figure 1.6. Reproduction of Pavcnik’s (2002) results (a)

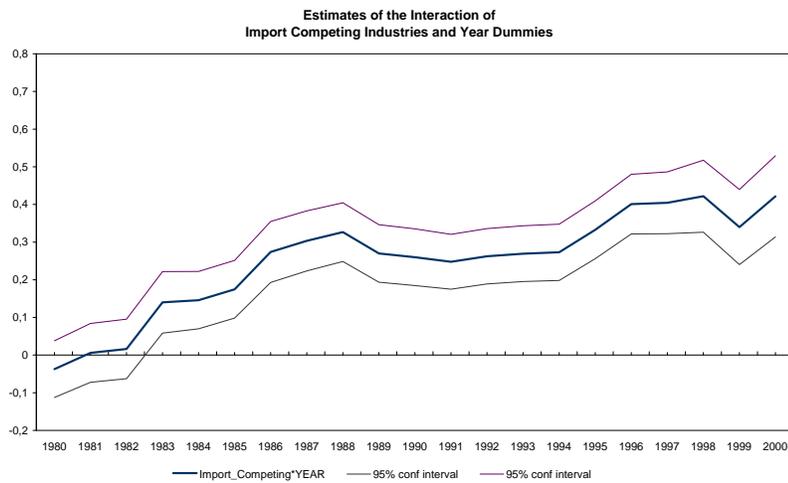


Figure 1.7. Reproduction of Pavcnik’s (2002) results (b)

Disentangling the effect of export and import barriers

Now we use the moving average of weighted border effects estimated in step 2 for each industry. As we previously mentioned, this measure captures not only the current but also the "lagged" effect of trade integration on plant’s TFP. This also implies the loss the three first available years (1979, 1980 and 1981): the border effect of the year 1982 is an

average of border effects from 1979 to 1982. On the other hand, this lagged composition of trade barriers measures in addition to the control of technical differences in the second step, reduces considerably the risk of endogeneity. In the next Section we instrument border effect within the framework of GMM.

The impact of trade barriers on productivity (TFP_FE)					
	(1)	(2)	(3)	(4)	(5)
Export	0.522*** (0.074)	0.519*** (0.074)	0.494*** (0.075)	0.500*** (0.075)	0.495*** (0.075)
Import	0.223*** (0.062)	0.231*** (0.062)	0.249*** (0.062)	0.245*** (0.062)	0.249*** (0.062)
Export*BE_X	-0.017** (0.007)	-0.017*** (0.007)	-0.016** (0.007)	-0.018*** (0.007)	-0.019*** (0.007)
Import*BE_X	-0.060*** (0.007)	-0.060*** (0.007)	-0.059*** (0.007)	-0.059*** (0.006)	-0.058*** (0.006)
Export*BE_M	-0.092*** (0.011)	-0.090*** (0.011)	-0.089*** (0.011)	-0.088*** (0.011)	-0.088*** (0.011)
Import*BE_M	0.051*** (0.012)	0.050*** (0.012)	0.050*** (0.012)	0.051*** (0.012)	0.051*** (0.012)
BE_X	0.092*** (0.007)	0.091*** (0.007)	0.090*** (0.007)	0.091*** (0.007)	0.091*** (0.007)
BE_M	0.064*** (0.010)	0.064*** (0.010)	0.062*** (0.010)	0.060*** (0.010)	0.061*** (0.010)
Exit_ind		-0.148*** (0.013)	-0.148*** (0.013)	-0.146*** (0.013)	-0.145*** (0.013)
Entry_ind		-0.066*** (0.015)	-0.066*** (0.015)	-0.067*** (0.015)	-0.066*** (0.015)
ind_comp			-0.306*** (0.098)	-0.306*** (0.098)	-0.306*** (0.098)
Imported Inputs				0.064*** (0.010)	0.063*** (0.010)
credit					0.032*** (0.009)
constant	6.690*** (0.106)	6.686*** (0.106)	6.692*** (0.106)	6.666*** (0.105)	6.653*** (0.105)
ISIC 2 Ind	YES	YES	YES	YES	YES
YEAR Ind	YES	YES	YES	YES	YES
PLANT Ind	YES	YES	YES	YES	YES
Obs	46894	46894	46894	46894	46894
R-Sq.	0.180	0.190	0.190	0.206	0.214

Note: Huber White Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.2.

We check robustness of our results using as dependent variable the TFP measured by fixed effects (TFP_FE, Table 1.2) and the one measured by LP (TFP_LP, Table 1.3)

estimations. Once we use year and industry indicators to control for industry specific effects and macro economic shocks, the coefficients of the rest of variables only capture the effects of within industry productivity variation. We consider fixed effects in all regressions and use Huber-White corrected standard errors.

In the first column of each table we start with the basic regression. Then we control for exit, entry indicators, domestic competition, imported inputs and credit constraint indicators. Given our framework we interpret the coefficients of interactions relative to non-traded industries, the omitted category. Results in both tables are quite similar. Let us focus on interactions. Export border effect interacted with both export-oriented (Export*BE_X) and import-competing (Import*BE_X) dummies presents a negative and significant coefficient. Thus, contrary to Bergoeing, Hernando and Repetto (2006) our estimates suggest a positive and significant impact of a reduction of export barriers on plant's productivity. This is true for both export-oriented and import-competing industries. What we observe may be related to learning-by-exporting and knowledge spillovers coming from international markets (Aw, Chung, Roberts, 1999).

Regarding the crossed relationship (Import*BE_X), the positive effect of the reduction of export barriers on plants belonging to import-competing industries can be driven by exporters inside these industries. It is well documented in firm heterogeneity literature that even in narrow defined industries exporters and importers compete with some degree of differentiation. The reduction of export costs will allow new firms to export. Bergoeing, Micco and Repetto (2005) show that, in Chile, many plants started exporting during the nineties in those industries having a small aggregate export share.

The impact of trade barriers on productivity (TFP_LP)					
	(1)	(2)	(3)	(4)	(5)
Export	0.636*** (0.078)	0.633*** (0.078)	0.616*** (0.079)	0.620*** (0.079)	0.617*** (0.079)
Import	0.283*** (0.065)	0.291*** (0.065)	0.304*** (0.065)	0.301*** (0.065)	0.304*** (0.065)
Export*BE_X	-0.023*** (0.007)	-0.023*** (0.007)	-0.023*** (0.007)	-0.024*** (0.007)	-0.024*** (0.007)
Import*BE_X	-0.063*** (0.007)	-0.062*** (0.007)	-0.062*** (0.007)	-0.062*** (0.007)	-0.062*** (0.007)
Export*BE_M	-0.103*** (0.011)	-0.101*** (0.011)	-0.100*** (0.011)	-0.100*** (0.011)	-0.099*** (0.011)
Import*BE_M	0.040*** (0.012)	0.038*** (0.012)	0.039*** (0.012)	0.040*** (0.012)	0.039*** (0.012)
BE_X	0.095*** (0.007)	0.095*** (0.007)	0.094*** (0.007)	0.095*** (0.007)	0.095*** (0.007)
BE_M	0.083*** (0.011)	0.083*** (0.011)	0.081*** (0.011)	0.079*** (0.011)	0.080*** (0.011)
Exit_ind		-0.139*** (0.013)	-0.138*** (0.013)	-0.137*** (0.013)	-0.136*** (0.013)
Entry_ind		-0.063*** (0.016)	-0.063*** (0.016)	-0.063*** (0.016)	-0.062*** (0.016)
ind_comp			-0.218** (0.101)	-0.217** (0.101)	-0.218** (0.101)
Imported Inputs				0.051*** (0.010)	0.050*** (0.010)
credit					0.025*** (0.009)
constant	5.284*** (0.107)	5.280*** (0.107)	5.284*** (0.107)	5.263*** (0.107)	5.253*** (0.107)
ISIC 2 Ind	YES	YES	YES	YES	YES
YEAR Ind	YES	YES	YES	YES	YES
PLANT Ind	YES	YES	YES	YES	YES
Obs	46894	46894	46894	46894	46894
R-Sq.	0.220	0.229	0.229	0.238	0.241

Note: Huber White Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.3.

Concerning the impact of import barriers, results depend on trade orientation. We find evidence of a negative effect of a reduction of import barriers on productivity of plants belonging to import-competing industries (Import*BE_M). Therefore, contrary to Pavcnik's (2002) results, increasing foreign competition will dampen the productivity of plants in these industries. We observed in the estimates of production functions that import-competing industries present in general increasing returns to scale. Foreign competition re-

duces the market shares of domestic firms shrinking the opportunities to exploit economies of scale. This possibly explanation has also been noted by Bergoeing, Hernando and Repetto (2006) for different production function estimates and data transformation.

On the other hand, the reduction of import barriers has a positive impact on productivity in export-oriented industries (Export*BE_M). Exporting firms also sell in the domestic market. Hence, these firms might have adopted "imitation" strategies to face foreign competition. On the other hand, exporters do have access to larger markets. If one may infer a positive and a negative effect of foreign competition, for plants belonging to import-competing industries, the effect of the reduction of market size is negative enough to counteract an eventual positive outcome of the reduction of import barriers.

In these static regressions we control for unobserved plant's characteristics not only by using fixed effects in all regressions, but also by introducing variables concerning specific plant's characteristics that might change over time (the use of imported inputs and the access to credit). Moreover, we also introduce an indicator of domestic competition using a Herfindahl index of market concentration at 3-digit industry level to control for the increase in domestic competition. The above results (interaction terms) remain qualitatively unchanged under these controls: entry and exit (column (1)), domestic competition (column (3)), imported inputs indicator (column (4)) and a financial constraint indicator (column (5)).

As expected, the exit indicator has a negative coefficient meaning that exiting firms are less productive than those that decide to stay in the market. Exiting plants are on average 15% less productive than surviving plants. The coefficient of the entry indicator is also

negative indicating that new firms are roughly 7% less productive than incumbents. Thus, a firm that enter the market is in average less productive than incumbents but more productive than those firms that exit the market. Since average productivity increases with constant firm renewal, firms do improve their productivity after entering the market. The coefficient of domestic competition is negative, though less significant, implying that a reduction of market concentration will enhance productivity. The introduction of the Herfindhal index at the 3-digit industry level helps to controls for changes in mark-ups inside the 2-digit industry.

The last column introduces a financial indicator. Following Bergoening, Hernando and Repetto (2006), we identify plants that may face liquidity constraints using as proxy plant-level information on loan tax payment. In Chile, all financial credits are subject to this tax. "Credit" is a dummy variable equals to one if the plant reports having paid this tax in a given year. This indicates that it has not been subject to financial constraints. Although the coefficient is small, it has a positive sign.⁶

Finally, note that the coefficients of both border effects (without interaction) are positive and significant, meaning that the reduction of trade barriers in both sides may have negative effects on productivity in non-traded industries (put zeros in import-competing and export-oriented dummies). This may be explained by general equilibrium effects that should be studied in more detail ⁷.

⁶ It can be an identification problem in some cases. For example, some firms can receive only a partial funding and still remain credit constrained. Other firms might not pay the tax in one particular year, not because they are credit constrained, but because they are already financed

⁷ One possible mechanism is the increase in the cost of the (mobile) labour factor as a consequence of the increase in foreign demand. This may induce substitution in consumption towards foreign exporters. The size of local firms will be reduced, which harms the exploitation of economies of scale.

The better access to inputs and technology

In a developing country like Chile, improvements in plant's productivity, after trade liberalisation, might also be related to the better access to new technologies embodied in high-quality imported inputs and capital equipment. Actually these mechanisms are present in our data. Firstly, in the previous regressions, in column (4) we introduce imported inputs. This is a dummy variable equals to one if the plant reports having used foreign inputs in a year. The coefficient of this variable is small but positive and highly significant (7%) indicating that firms producing with foreign inputs have a higher TFP than those that only use domestic inputs.

	Import barriers on imported machinery and productivity (TFP_LP)				
	(1)	(2)	(3)	(4)	(5)
Export	0.950*** (0.075)	0.950*** (0.075)	0.929*** (0.075)	0.928*** (0.075)	0.925*** (0.075)
Import	0.482*** (0.069)	0.491*** (0.069)	0.504*** (0.069)	0.502*** (0.069)	0.505*** (0.069)
Export*BE_Machinery	-0.264*** (0.013)	-0.263*** (0.013)	-0.259*** (0.013)	-0.259*** (0.013)	-0.259*** (0.013)
Import*BE_Machinery	-0.105*** (0.014)	-0.107*** (0.014)	-0.105*** (0.014)	-0.104*** (0.014)	-0.104*** (0.014)
BE_Machinery	-0.001 (0.013)	-0.023* (0.013)	-0.027** (0.013)	-0.027** (0.013)	-0.027** (0.013)
Exit_ind		-0.141*** (0.013)	-0.140*** (0.013)	-0.139*** (0.013)	-0.138*** (0.013)
Entry_ind		-0.059*** (0.016)	-0.059*** (0.016)	-0.060*** (0.016)	-0.059*** (0.016)
ind_comp			-0.250** (0.100)	-0.251** (0.100)	-0.252** (0.100)
Imported inputs				0.051*** (0.010)	0.050*** (0.010)
credit					0.024*** (0.009)
constant	6.345*** (0.108)	6.447*** (0.108)	6.456*** (0.108)	6.432*** (0.108)	6.425*** (0.108)
ISIC 2 Ind	YES	YES	YES	YES	YES
YEAR Ind	YES	YES	YES	YES	YES
PLANT Ind	YES	YES	YES	YES	YES
Obs	46894	46894	46894	46894	46894
R-Sq.	0.241	0.253	0.256	0.261	0.263

Note: Huber White Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.4.

Secondly, instead of using the import border effect at the 2-digit industry level for each industry, we only use this measure for machinery (BE_Machinery). Therefore, the interaction of this specific import border effect with the trade orientation dummy captures the impact of import barriers on capital equipment goods. Table 1.4 presents the results of these estimations. Relative to non-traded industries, all firms belonging to traded industries enhance their productivity after a reduction of import barriers on machinery. However, productivity gains are significantly higher in export-oriented industries (Export*BE_Machinery) than in import-competing ones (Import*BE_Machinery).

To sum up, we find robust evidence that traded industries increase their productivity, relative to non-traded industries, as a consequence of export-oriented policies⁸. In the case of import oriented policies, the effects depend on trade orientation. While export-oriented industries improve their productivity, domestic plants competing with imported goods may suffer from the increase in foreign competition. Finally exporters have significantly improve their productivity thanks to the reduction of import barriers on technology embodied in capital goods.

Dynamic specification

In this Section we use a specification in which current values of productivity are explained by past ones (equation (1.11)). Table 1.5 presents the results. We include OLS and Within-group estimators. Though biased, these estimators help to identify an interval

⁸ In a working paper version of this chapter as an additional check we run quantile regressions (Koenker and Hallock, 2001). The idea is to estimate models for conditional quantile functions, that is, quantiles of the conditional distribution of TFP expressed as functions of the observed covariates. This allows asking whether the conditional fit of the mean is also representative for the median or other conditional quantiles. Under this specification the results remains unchanged.

in which a consistent estimation of the autoregressive coefficient α_1 should lie (Bond, 2002; Benavente et al., 2005). By neglecting η_i , the source of correlation between a_{it-1} and ϵ_{it} , OLS is expected to be upward biased. On the other hand, when the Within-group estimator subtracts the mean to eliminate η_i it introduces a downward bias. However as shown by Benavente et al. (2005) simulations, the Within-group estimator bias tends to be smaller for long sample periods. The main purpose of GMM strategies is to face the problem in the context of big "N" and small "T". What does exactly mean small "T"? this is difficult to state. One might notice that our sample period is around four times bigger than the seminal empirical works using GMM, however the number of observations per-group can be in practice small because of plant-exit or gaps. These caveats should be kept in mind when analysing the results.

The first three columns the Table 1.5 (OLS_1, FE_1 and GMM_1) report regressions for the TFP estimated by the LP methodology (tfp_lp) using OLS, Within-group and GMM, respectively. The following columns (OLS_2, FE_2 and GMM_2) show similar regressions, but this time for the TFP estimated by Within-group (tfp_fe) in the second step. As expected, the coefficient of the auto-regressive term, tfp_lp(t-1) and tfp_fe(t-1), are bigger in OLS (column OLS_1 and OLS_2) than in Within-group (column FE_1 and FE_2) regressions. The GMM estimates (column GMM_1 and GMM_2) are between both. This is a signal of a consistent dynamic specification, meaning a correct number of lags of TFP in the right-hand-side.

The impact of trade barriers on productivity: dynamic model						
	OLS_1	FE_1	GMM_1	OLS_2	FE_2	GMM_2
tfp_lp(t-1)	0.861*** (0.004)	0.480*** (0.008)	0.792*** (0.087)			
tfp_fe(t-1)				0.884*** (0.004)	0.460*** (0.009)	0.778*** (0.091)
Export	0.167*** (0.042)	0.351 (0.545)	-0.708** (0.315)	0.165*** (0.042)	-0.246 (0.458)	-0.623** (0.290)
Import	0.170*** (0.027)	-0.668 (0.547)	-0.792** (0.393)	-0.001 (0.027)	-1.315*** (0.464)	-1.027** (0.415)
Export*BE_X	-0.010* (0.006)	-0.019*** (0.007)	-0.241** (0.098)	-0.008 (0.006)	-0.016** (0.007)	-0.223** (0.096)
Import*BE_X	-0.010* (0.005)	-0.032*** (0.007)	-0.338** (0.140)	0.000 (0.005)	-0.034*** (0.007)	-0.313** (0.138)
Export*BE_M	-0.010 (0.007)	-0.056*** (0.012)	0.308*** (0.114)	-0.011 (0.007)	-0.049*** (0.011)	0.285** (0.111)
Import*BE_M	-0.020*** (0.007)	0.014 (0.012)	0.343** (0.170)	-0.004 (0.007)	0.026** (0.012)	0.319* (0.166)
BE_X	0.002 (0.004)	0.065*** (0.007)	0.275*** (0.094)	-0.001 (0.004)	0.065*** (0.007)	0.254*** (0.093)
BE_M	0.032*** (0.005)	0.032*** (0.011)	-0.322*** (0.115)	0.002 (0.004)	0.022** (0.011)	-0.300*** (0.112)
Exit_ind	-0.147*** (0.012)	-0.115*** (0.013)	-0.240*** (0.037)	-0.145*** (0.012)	-0.120*** (0.013)	-0.246*** (0.037)
ind_comp	0.112** (0.044)	0.114 (0.103)	0.037 (0.819)	0.121*** (0.043)	0.021 (0.101)	0.010 (0.805)
credit	0.022*** (0.006)	0.013 (0.009)	0.355 (0.224)	0.040*** (0.006)	0.018** (0.009)	0.341 (0.220)
Imported Inputs	0.067*** (0.006)	0.034*** (0.010)	0.090 (0.127)	0.094*** (0.007)	0.043*** (0.010)	0.100 (0.123)
constant	0.689*** (0.035)	3.134*** (0.469)		0.863*** (0.040)	4.502*** (0.380)	
Number of Obs	35117	35117	33808	35117	35117	33808
Sargan-Hansen p			0.207			0.291
AR(2)p			0.000			0.001
AR(3)p			0.460			0.450
instruments			104			104
individuals		5392	5072		5392	5072
R-Sq.	0.752	0.653		0.790	0.687	

Note: Huber White Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.5.

The set of instruments is composed of deep lags of border effect measures and TFP, which are treated as endogenous variables⁹. Although we have already addressed the po-

⁹ Since the Arellano-Bond test of autocorrelation reveals that the disturbance might be in its self autocor-

tential endogeneity between border effects and productivity in step 2, we provide additional robustness by including nominal tariffs as an exogenous instrument. The Hansen-Sargan Test validates our instrument choice. The number of individuals relative to the number of instruments is by far very reassuring concerning eventual bias in the test when instruments are many (Windmeijer, 2005).

Hereafter we will focus on GMM and Within-group results since OLS estimates are less pertinent for our dynamic structure. All dynamic regressions confirm the positive response of plant's productivity after a reduction of export barriers in both traded industries. Moreover, the previous static results remain unchanged in a dynamic regression using a Within-group estimator and considering the measure of TFP using fixed effects in Step 2 (column FE_2). In this case, the reduction of import barriers still presents a negative and significant impact on import-competing industries and a positive effect on export-oriented (always relatively to non-traded industries). The former result, the positive sign in the interaction between import barriers and the import-competing dummy (Import*BE_M), also resists the dynamic control in both GMM regressions (columns GMM_1 and GMM_2). Only in the case of a Within group estimation, using the TFP provided by the LP strategy (column FE_1), this effect fails to be significant.

On the contrary, more contrasted results appear in the case of the productivity advantage of export-oriented industries after a reduction of import barriers, one of the conclusion of the static specification. While Within-group regressions confirm this finding (columns FE_1 and FE_2), in GMM ones (columns GMM_1 and GMM_2) the sign changes. In

related of order-1, we take a deepness of lags between $t - 4$ and $t - 6$ to ensure valid instruments. As usually, we use as exogenous instruments the industry affiliation and years

the latter, the coefficient of the interaction between import barriers and the export-oriented identification becomes positive and significant (Export*BE_M): a reduction of import barriers would also harm firms in export-oriented industries. If GMM regressions address the dynamic panel bias as it is expected to do, this result means that, after a plausible control of the persistence of plant productivity series, in export-oriented industries, firms also suffer from foreign competition. Their domestic sales are reduced after a reduction of trade barriers. Their high productivity trend overwhelms this effect in a static specification or in the case of remaining panel data bias in the Within-group estimation.

Note also that the positive effect of imported inputs disappears in these dynamic regressions. In order to test the robustness of the static result concerning productivity gains arising from the reduction of import barriers on machinery, we also test the corresponding autoregressive model (Table 1.6). All regressions confirm the positive and significant effect of this channel. Moreover, while Within-group regressions (column FE_1 and FE_2) also confirm the advantage of exporters, in GMM ones (column GMM_1 and GMM_2) we can not conclude a significant advantage. Again, it is difficult to state if this difference is a consequence of weak instruments, a recurrent issue in GMM, or a consequence of the expected downward bias of Within-group regressions. However, in any case, the reduction of import barriers on capital goods does has a positive impact on the evolution of plant productivity.

Dynamic version of the impact of imported capital equipment barriers on productivity

	OLS_1	FE_1	GMM_1	OLS_2	FE_2	GMM_2
tfp_lp(t-1)	0.812*** (0.005)	0.482*** (0.008)	0.745*** (0.084)			
tfp_fe(t-1)				0.840*** (0.004)	0.462*** (0.009)	0.753*** (0.094)
Export		0.489 (0.555)	-0.766 (4.144)		-0.130 (0.463)	-0.120 (4.017)
Import	-0.232 .	-0.543 (0.559)	2.931 (5.547)	-0.267 .	-1.188** (0.471)	3.045 (5.692)
Export*B_Machinery	-0.073*** (0.012)	-0.148*** (0.013)	-0.086*** (0.032)	-0.060*** (0.012)	-0.134*** (0.013)	-0.073** (0.031)
Import*B_Machinery	-0.036*** (0.012)	-0.066*** (0.013)	-0.084*** (0.032)	-0.027** (0.012)	-0.055*** (0.013)	-0.070** (0.031)
BE_M	0.019* (0.011)	0.015 (0.012)	0.232** (0.103)	0.014 (0.011)	-0.020* (0.012)	0.227** (0.044)
Exit_ind	-0.150*** (0.012)	-0.115*** (0.013)	-0.259*** (0.048)	-0.149*** (0.012)	-0.121*** (0.013)	-0.265*** (0.048)
ind_comp	0.057 (0.099)	0.094 (0.102)	1.374 (1.372)	0.046 (0.095)	0.007 (0.101)	1.363 (1.335)
Imported Inputs	0.082*** (0.007)	0.032*** (0.010)	-0.011 (0.096)	0.112*** (0.007)	0.042*** (0.010)	-0.004 (0.095)
credit	0.038*** (0.006)	0.012 (0.009)	0.159 (0.183)	0.055*** (0.006)	0.018** (0.009)	0.189 (0.184)
constant	1.331	3.795*** (0.481)		1.309 .	5.234*** (0.389)	
Number of Obs	35117	35117	31853	35117	35117	31853
Sargan-Hansen p			0.177			0.381
AR(2)p			0.000			0.000
AR(3)p			0.282			0.289
instruments			139			139
individuals		5392	4911		5392	4911

Note: Huber White Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.6.

1.4 Conclusion

We have studied the effect of import and export-oriented policies on the evolution of plant's productivity using Chilean data of manufacturing plants. To measure plant's TFP we estimated the production function of each 2-digit industry using a methodology that takes into account the time-varying heterogeneity of firms' productivity. The main contribution

of the Chapter is to construct a measure of trade costs at the industry-level. This measure is obtained by identifying the part of missing trade related to policy factors. As a consequence we are able to disentangle between the impact of the reduction of export and import barriers on plant productivity.

The incorporation of a more detailed measure of trade liberalisation introduces new results. First, the reduction of export barriers improves productivity of plants belonging to both export-oriented and import-competing industries, relative to non-traded industries. As the export costs fall, more firms are able to export increasing their size and probably benefiting from knowledge spillovers stemming from international markets.

Second, the reduction of import barriers shows a positive impact on the evolution of plant's productivity of export-oriented industries relative to non-traded. However, this is not the case for plants competing with foreign exporters. The reduction of import barriers may prevent firms to exploit economies of scale since they must share the local market with foreign competitors. This has consequences on policy implications.

Third, the reduction of import barriers on capital goods induces productivity gains. We have also provided some evidence that productivity improvements stemming from this channel can be higher for firms belonging to export-oriented industries.

Overall, all these results point out that firm productivity changes over the time as a consequence of trade policy and that this evolution is not homogeneous across firms. In the next Chapter we develop a model of international trade with heterogeneous firms that can improve their productivity thanks to technology embodied in imported capital goods. Market structure under the form of monopolistic competition will play a key role.

1.A Appendix to Chapter 1

1.A.1 Descriptive Statistics

	Variables description	
	[Variable]	[Data]
Skilled labor	S	Non production workers
Unskilled labor	U	Production workers
Skill intensity	S/L	Non production workers over total labour
Value Added	VA	Sales minus variable inputs deflated by sectoral level deflators (Isic-3dig Rev 2 1992)
Capital Stock	K	Capital stock over calculated following Bergoeing, Hernando and Repetto (2006)
Capital intensity	K/L	Capital stock over total workers
Labor productivity	VA/L	Value Added over total labor
Total factor productivity OLS	TFP_ols	Total factor productivity estimated using OLS estimator
Total factor productivity FE	TFP_fe	Total factor productivity estimated using Within Group estimator
Total factor productivity LP	TFP_lp	Total factor productivity estimated using Levinsohn and Petrin methodology
Domestic competition	Ind_comp	Herfindahl index of market concentration at 3 digit industry level
Imported Inputs	Imported_Ind	Dummy variable equal to one if the plant reports having used imported inputs
Credit Indicator	Credit	Dummy variable equals to one if the plant reports having paid a loan tax in year "t"
Border Effect Exporter	BX	Export barriers at 2 digit industry level estimated by a gravity model in step 2.
Border Effect Importer	BM	Import barriers at 2 digit industry level estimated by a gravity model in step 2.
Export oriented sector	Export	Dummy variable equal to one if the firm belongs to a 3 digit industry with more than 15% of exports over sales
Import competing sector	Import	Dummy variable equal to one if the firm belongs to a 3 digit industry with more than 15% of import penetration

Table 1.7.

Summary Statistics by Industry (ISIC 2 digits)					
	VA_L	VA_L Growth	S_L	K_L	Exports share
Food (31)	5108 (10204)	0.10 (0.66)	0.13 (0.11)	3420 (10709)	0.09 (0.2)
Textile (32)	3828 (3770)	0.07 (0.5)	0.13 (0.10)	2198 (8676)	0.02 (0.09)
Wood (33)	4099 (6428)	0.11 (0.93)	0.11 (0.10)	2192 (4143)	0.07 (0.18)
Paper (34)	7119 (9492)	0.02 (0.42)	0.17 (0.15)	4775 (14877)	0.03 (0.12)
Chemicals (35)	10832 (23366)	0.07 (0.57)	0.16 (0.11)	4793 (10573)	0.04 (0.13)
Non Metallic (36)	8130 (14480)	0.09 (0.59)	0.13 (0.10)	5356 (16133)	0.01 (0.06)
Basic Metals (37)	34409 (93787)	0.13 (0.71)	0.19 (0.14)	7826 (12033)	0.18 (0.31)
Machinery (38)	5375 (5987)	0.10 (0.68)	0.16 (0.13)	3122 (6519)	0.02 (0.07)

Note: Mean of variables reported and s.d. in parentheses
Table 1.8.

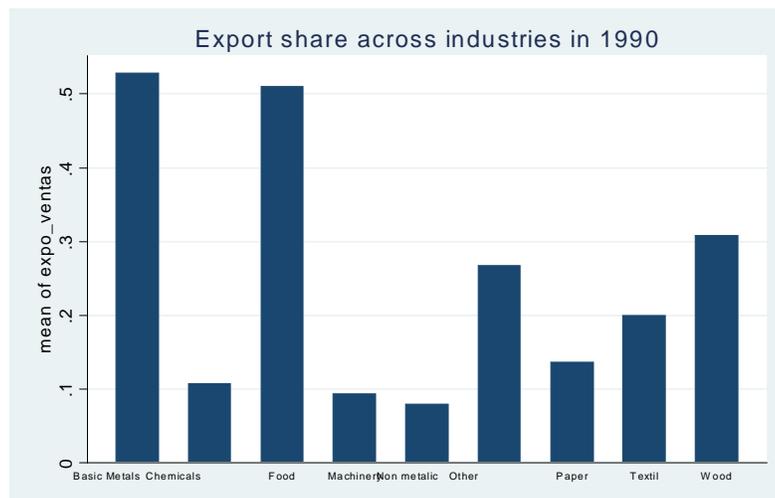


Figure 1.8. Export shares (1990)

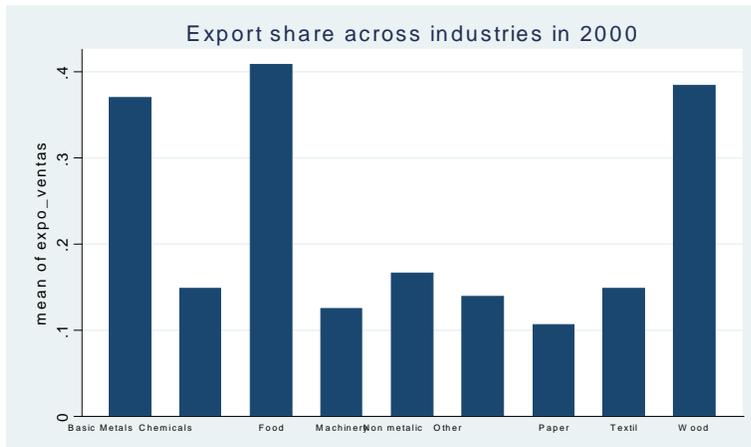


Figure 1.9. Export shares (2000)

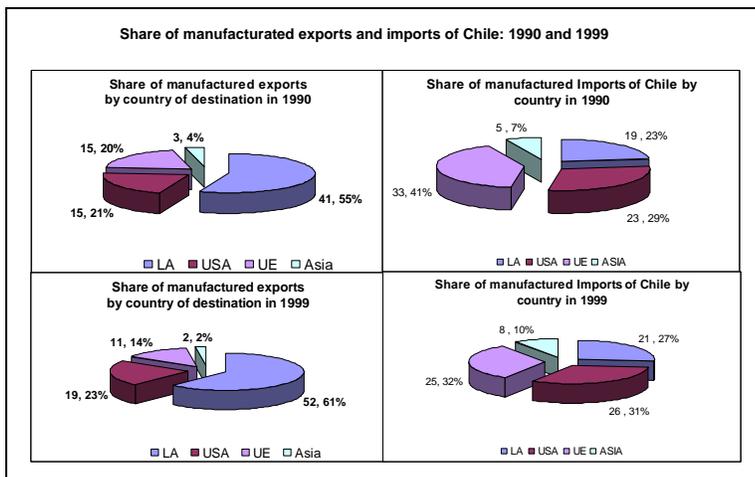


Figure 1.10. Import and export Chilean partners

1.A.2 Border effects at the national level

Table 1.9 presents the results of border effect estimation at the national level (across all industries and years). Column [1] reports regressions using contemporaneous values of aggregated prices. As predicted by the theory, the coefficient on relative value added is significant, positive and relatively closed to one. The coefficient on relative prices is significant and negative. However as usually in this kind of exercise, its value is smaller than the expected elasticity of substitution. The effect of contiguity is also significant and positive indicating that having a common border facilitates trade. Surprisingly and contrary to regressions performed at the industry level, the coefficient of the dummy variable indicating whether the partners share a common language is negative. This can be explained by the countries present in the sample. Relative to Latin American countries, those sharing the Spanish language, the EU and the US represent important international flows that might offset the effect of language.

In column [2], we use relative wages at the industry level instead of relative price at national level. In the monopolistic competition framework relative prices equals relative wages. More importantly wages take into account labour productivity differentials among partners. Their effect turns out to be similar to relative prices but with a lower coefficient that might reflect labour market asymmetries. Column [3] in Table 1.9 introduces the lag of relative value added and relative prices to address potential correlation between both sides of the equation stemming from the valuation of nominal trade flows and output. Results remain almost unchanged. A Similar conclusion can be obtained from column [4], which considers lagged relative wages.

	[1]	[2]	[3]	[4]
Rel. VA	0.822*** (0.007)	0.829*** (0.007)		
Rel Price	-1.012*** (0.066)			
Rel Wage		-0.742*** (0.013)		
Rel.VA (t-1)			0.815*** (0.008)	0.819*** (0.007)
Rel Price (t-1)			-1.122*** (0.068)	
Rel Wage (t-1)				-0.743*** (0.012)
Rel Distance	-0.827*** (0.025)	-0.776*** (0.025)	-0.819*** (0.026)	-0.754*** (0.026)
contiguity	0.876*** (0.035)	0.990*** (0.036)	0.890*** (0.037)	1.035*** (0.038)
Language	-0.350*** (0.033)	-0.360*** (0.029)	-0.355*** (0.035)	-0.355*** (0.030)
UE_CHL	-5.386*** (0.138)	-5.783*** (0.131)	-5.190*** (0.146)	-5.582*** (0.138)
CHL_UE	-4.239*** (0.124)	-4.269*** (0.112)	-4.079*** (0.128)	-4.224*** (0.115)
USA_CHL	-4.061*** (0.114)	-4.399*** (0.105)	-4.071*** (0.116)	-4.381*** (0.106)
CHL_USA	-3.897*** (0.113)	-3.822*** (0.105)	-3.828*** (0.118)	-3.860*** (0.110)
UE_UE	-2.723*** (0.054)	-2.836*** (0.054)	-2.744*** (0.057)	-2.893*** (0.057)
AL_CHL	-5.120*** (0.092)	-4.946*** (0.093)	-4.944*** (0.096)	-4.828*** (0.097)
CHL_AL	-4.765*** (0.103)	-5.200*** (0.099)	-4.622*** (0.107)	-5.099*** (0.102)
AL_AL	-5.347*** (0.079)	-5.663*** (0.077)	-5.276*** (0.083)	-5.674*** (0.081)
UE_AL	-5.020*** (0.120)	-5.609*** (0.110)	-5.141*** (0.126)	-5.726*** (0.115)
AL_UE	-4.774*** (0.098)	-4.913*** (0.088)	-4.679*** (0.103)	-4.945*** (0.092)
AL_USA	-4.508*** (0.091)	-4.403*** (0.081)	-4.359*** (0.095)	-4.406*** (0.084)
USA_AL	-3.752*** (0.095)	-4.738*** (0.085)	-3.856*** (0.099)	-4.811*** (0.087)
UE_USA	-2.878*** (0.092)	-2.744*** (0.093)	-2.873*** (0.096)	-2.775*** (0.097)
USA_UE	-2.685*** (0.070)	-2.883*** (0.068)	-2.703*** (0.072)	-2.938*** (0.071)
Number of Obs	53278	63073	47843	57861
Adjusted R-Sq.	0.912	0.911	0.912	0.911

Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01

Table 1.9.

The coefficients of border effects estimates indicate that, on average, during the period 1979-1999 Chilean exporters faced higher barriers to enter the European Union than the barriers faced by European's exporters to sell in Chilean markets (5.386 versus 4.30). A similar asymmetry is founded in flows regarding the US (4.061 against 3.897). These first results indicate that, on average, Chilean exporters experienced more difficulties to ac-

cess foreign markets in the period than their partners. The larger border effect found in the case of Latin American countries illustrate that distance, language and contiguity are not the only source of barriers. Although higher, these estimates are in line with those found by Fontagné, Mayer and Zignago (2005) for the US and the EU. Inside the EU trade is reduced by a factor of 14.87 ($\exp(2.73)$, column [1]) when crossing the border of European nations.

One possible explanation of these high average estimates relates with the high protection of Chilean economy in early '70. To analyse this, Table 1.10 splits the sample in five periods. This time, regressions consider wage differentials, the specification in column [2] of Table 1.9. Clearly, trade integration in recent years is higher than their initial level and the average of the period. On the other hand, our initial results are confirmed: even though trade has become easier over time, Chile appears as more open to imports from Europe (CHL_UE) than Europe to Chilean exporters (UE_CHL).

	[79-82]	[83-86]	[87-90]	[91-94]	[95-99]
Rel. VA	0.793*** (0.018)	0.835*** (0.016)	0.822*** (0.015)	0.834*** (0.017)	0.832*** (0.015)
Rel Wage	-0.905*** (0.073)	-0.855*** (0.017)	-0.471*** (0.071)	-0.435*** (0.059)	-0.301*** (0.044)
Rel. Distance	-0.651*** (0.070)	-0.691*** (0.054)	-0.701*** (0.050)	-0.868*** (0.052)	-0.921*** (0.048)
Contiguity	1.014*** (0.084)	0.995*** (0.081)	1.068*** (0.078)	0.983*** (0.074)	0.779*** (0.070)
Language	0.028 (0.064)	-0.061 (0.066)	-0.144** (0.065)	-0.234*** (0.067)	-0.315*** (0.051)
UE_CHL	-6.617*** (0.366)	-6.663*** (0.297)	-5.871*** (0.281)	-4.497*** (0.280)	-4.507*** (0.264)
CHL_UE	-4.844*** (0.323)	-5.021*** (0.246)	-5.048*** (0.254)	-4.113*** (0.251)	-3.754*** (0.208)
USA_CHL	-6.491*** (0.379)	-5.604*** (0.237)	-4.009*** (0.203)	-3.248*** (0.209)	-2.787*** (0.180)
CHL_USA	-4.185*** (0.296)	-4.433*** (0.220)	-4.815*** (0.259)	-3.627*** (0.233)	-3.372*** (0.187)
UE_UE	-3.273*** (0.140)	-3.057*** (0.116)	-2.996*** (0.111)	-2.483*** (0.117)	-2.378*** (0.114)
AL_CHL	-6.096*** (0.359)	-6.599*** (0.239)	-6.141*** (0.192)	-4.583*** (0.176)	-3.879*** (0.152)
CHL_AL	-6.391*** (0.278)	-6.517*** (0.214)	-5.904*** (0.204)	-4.913*** (0.210)	-3.862*** (0.172)
AL_AL	-7.035*** (0.280)	-6.813*** (0.169)	-6.338*** (0.159)	-5.486*** (0.158)	-4.876*** (0.139)
UE_AL	-6.561*** (0.310)	-6.515*** (0.242)	-5.569*** (0.241)	-4.637*** (0.242)	-3.982*** (0.229)
AL_UE	-5.529*** (0.279)	-5.649*** (0.189)	-5.800*** (0.213)	-4.764*** (0.194)	-4.545*** (0.169)
AL_USA	-4.635*** (0.250)	-5.212*** (0.177)	-5.441*** (0.202)	-4.120*** (0.178)	-4.115*** (0.158)
USA_AL	-6.292*** (0.218)	-5.440*** (0.182)	-4.354*** (0.195)	-3.827*** (0.185)	-3.076*** (0.184)
UE_USA	-3.207*** (0.260)	-3.175*** (0.201)	-3.189*** (0.188)	-2.339*** (0.201)	-2.253*** (0.186)
USA_UE	-3.886*** (0.170)	-3.307*** (0.147)	-3.002*** (0.140)	-2.550*** (0.145)	-2.123*** (0.136)
Number of Obs	9110	12769	13950	11642	15602
Adjusted R-Sq.	0.915	0.915	0.916	0.915	0.912

Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01

Table 1.10

A similar asymmetry is found in trade flows with the US until the first half of '80. However, in the last two periods (1987-1999) the US has become more open to Chile than Chile vis-a-vis the US. Regarding Latin American countries, trade barriers have evolved almost symmetrically, though the border effects still remain important. In the last period, trade between Chile and a Latin American country of the sample was reduced in average by a factor of 49% ($=\exp(3.9)$) in comparison with intra-national trade. Figure 1.11 summarises the reduction of border effect during time by comparing the last period to the

first one. The most important change in trade integration is found in the US market access for Chilean exporters (USA←-CHL). Trade barriers faced by Chilean producers when reaching American markets have been reduced by around 57%. In addition, considering differences instead of levels highlights asymmetries: Chilean border effects vis-à-vis the US (CHL←-USA) have been reduced only by 19%.

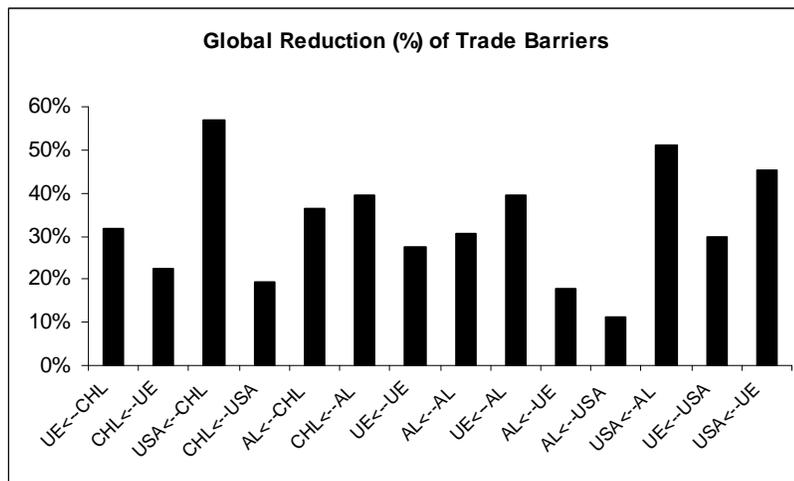


Figure 1.11. Changes in border effects

Chapter 2

Trade Liberalisation and Heterogeneous Within-Firm Productivity Improvements¹⁰

2.1 Introduction

Empirical works at the firm level have shown that trade policy shapes the evolution of firm productivity. This *within-firm* effect of trade, however, can not be reproduced by the wave of the recent heterogeneous firms' models. In these models, trade induces aggregate productivity improvements as a consequence of the exit of the least productive firms and the reallocation of market shares towards the most productive ones. This *between-firm* effect of trade is in line with stylised facts provided by firm-level data. Nonetheless, the understanding of the effect of trade on productivity calls for further analysis of the mechanisms explaining firm's productivity improvements.

This Chapter investigates the relationship between trade liberalisation, technology investment and productivity gains at the firm level. We focus on developing economies, usually characterised as highly dependent on foreign technology. We propose an extension of Melitz (2003), by incorporating endogenous labour productivity gains determined by an initial investment in technologies embodied in imported capital goods. Indeed, one of the results of the previous Chapter is that the reduction of import barriers in the machinery industry is associated with significant firm productivity gains in all industries. While

¹⁰ This Chapter is based on Bas and Ledezma (2006). "The Impact of Trade Reforms on the Extensive Margin of Trade". PSE Working Paper N°2006-36

we assume an exogenous initial distribution of productivity levels, we allow for further modifications of the initial level as a consequence of firms' decisions. The main contributions of this Chapter to the existing literature can be summed up as follows. Firstly, the model allows for endogenous productivity gains. Thereby, it explains how trade policy shapes the incentives of firms to undertake investments to enhance their productivity gains, a topic that has received less attention in the theoretical literature of trade with heterogeneous firms. Secondly, the model sheds new light on the impact of trade liberalisation on the intensive and the extensive margin of trade. Actually, firms' productivity improvements are themselves heterogeneous. Initial productivity matters and self-selection mechanisms are emphasised. The result is that gains of trade are concentrated on a reduced number of exporters, meaning that the effect of trade policy mainly concerns its intensive margin.

Several empirical works have studied the impact of trade integration on industry productivity evolution. One of their contributions is to understand whether trade liberalisation influences aggregate productivity and by which mechanisms. By decomposing aggregate productivity (see Olley and Pakes, 1996; Foster, Haltiwanger and Krizan, 1998) or by comparing firm productivity evolution, these studies have stressed three main channels: (a) resources reallocation towards most productive firms (between-firm channel), (b) net-entry of productive firms and (c) improvements of firms' efficiency (within-firm channel). In general, these works use plant panel data to carry out study cases of countries which have experienced trade reforms. Results vary depending on countries and periods.

Pavcnik (2002) investigates the impact of trade liberalisation on firm productivity in Chile (1979-1986). In her aggregate productivity decomposition, a major role is played by

the reallocation process of inputs and production towards most productive firms. Bernard and Jensen (2001) estimate the determinants of aggregate productivity at the industry level in the US (1983-1992) and find similar results. In both studies, productivity improvements at the industry level are mainly explained by the between-firm channel.

On the other hand, other empirical works highlight the explanatory power of within-firm productivity improvements and the net-entry of more productive firms: De Loecker and Konings (2003) on Slovenia for 1994-2000; Aw, Chung and Roberts (2000) on Taiwan for 1986-1991; Bergoeing, Hernando and Repetto (2006) on Chile for 1979-2001 and Chapter 1 on Chile for 1979-1999. These studies confirm that firm productivity does evolve over the time and that this evolution is a key factor to explain aggregate levels.

Interestingly, concerning recent empirical works on Chile, one notes that the sample periods are larger than the one used by Pavcnik (2002). Using different estimates of firm productivity and capital series, both Bergoeing, Hernando and Repetto (2006) and Chapter 1 find that, between 1979 and 1986, aggregate productivity is mostly explained by the reallocation process. Nevertheless, as we showed in Chapter 1, the evolution of within-firm productivity plays an important role from 1986 to 1998, the same period in which Chile experienced stable macroeconomic growth (Figure 1.2 - Chapter 1). In Figure 2.1, we overlap the histogram of plant productivity of 1987 with the one of 1995, a period of within-firm productivity gains. First, we observe that distribution remains highly asymmetric. Since we only observe those firms that remain in the market, the reduction in the percentage at the lowest productivity levels reflects the exit of least productive ones (both histograms start at zero). Second, it is important to note that productivity improvements concern a much re-

duced number of plants (histogram for 1995 in gray). Thus, productivity improvements at the firm level are heterogenous and concern just a few firms.

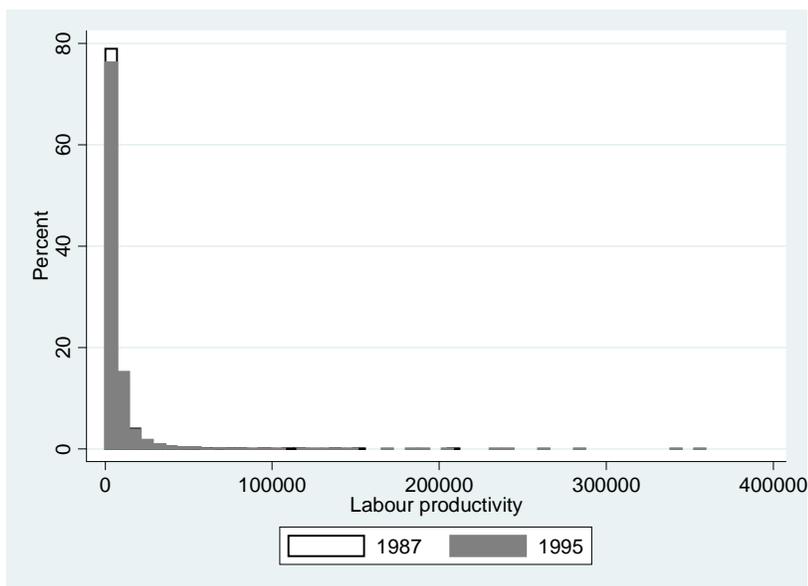


Figure 2.1. Histogram of labour productivity

On the theoretical ground, after the pioneer works of Melitz (2003) and Bernard et al. (2003), several trade models have been developed based on a microeconomic setup with heterogeneous firm productivity. This theoretical framework is able to reproduce the between-firm effect of aggregate productivity improvements. The reduction of trade frictions enhances aggregate productivity through two mechanisms. The increase in real wages and foreign competition leads to a reduction of domestic market shares of all firms and, thereby, the exit of the least productive ones. Consequently, there is also a reallocation process of resources towards the most productive firms, namely exporters. The second channel is characterised by the raise in market shares of exporters due to the increase in foreign demand.

An interesting contribution is the one of Baldwin and Robert-Nicoud (2006), which incorporates an innovative sector in the Melitz's model to explain the effects of trade on aggregate productivity growth. They combine the framework of heterogeneous firms with the endogenous growth theory. Dynamic effects are introduced thanks to knowledge spillovers associated to the production of successful varieties. In their model, trade liberalisation has two opposite effects on economic growth. The positive effect is based on the reduction of the marginal cost of innovation. Nevertheless, the selection of the most productive firms in the domestic market, generated by trade openness, increases the expected cost of production of new varieties and reduces the growth rate. The impact of trade on aggregate productivity is different depending on whether one focuses on static or dynamic effects. After trade liberalisation, industry productivity rises in level but the growth rate might decrease.

A key assumption of these models is that productivity at the firm level is exogenous. Therefore, they are not able to explain the evolution of industry productivity related to within-firm channels. Even in Baldwin and Robert-Nicoud (2006), innovation decisions do not change firms' productivity levels. Firm productivity is exogenously determined and it remains unchanged. This is a key motivation of this Chapter. While several theoretical works have explained why only the most productive producers can export and how trade induces a market share reallocation process, the determinants of these productivity differentials have not received enough attention. We contribute to this issue by introducing an endogenous mechanism of productivity divergence across firms which is reinforced by trade liberalisation.

In that sense our model is related to Yeaple (2005) who introduces a discrete technological choice. Firm heterogeneity arises endogenously from the allocation of heterogeneous skilled workers to different technologies. Homogeneous firms become heterogeneous due to the availability of more skilled workers. While Yeaple (2005) develops an explanation of firm heterogeneity, the static setup of his model does not allow for firms' decisions seeking to change their initial productivity. Based on Melitz (2003) and Yeaple (2005), Bustos (2005) builds a trade model of heterogeneous firms with homogeneous labour and fixed technology costs in order to investigate the relationship between the reduction of trade costs and firms' decision to upgrade technology. Bas (2008) puts this arguments in general equilibrium and obtain further insights concerning the effects of technology adoption on selection and on wage inequalities. In these models, productivity improvements due to technology adoption are homogeneous. In this Chapter, we represent technological choice as a continuous decision of the initial level of capital investment, which contributes to improve the productivity of a homogenous labour factor. While we assume an initial level of heterogeneity, we endogenously explain the change in the distribution of firms' productivity.

The setup of our model is as follow. We keep the intra-industry monopolistic competition framework with (initially) heterogeneous firms, and introduce an investment in technology embodied in imported capital goods. Once firms have paid a fixed-sunk entry cost, their initial productivity level is revealed. Afterwards, depending on their profitability, firms have the possibility to improve even more their efficiency through capital investment.

Since the initial level of productivity is heterogeneous, the productivity gains coming from capital-labour substitution are also heterogeneous across firms.

Trade policy is represented by fixed export costs and variable trade costs. The latter includes tariffs of imported capital goods. As usually, only most productive producers are able to pay the fixed export cost and to reach the foreign market. Trade liberalisation affects firms' investment decisions on both the supply and the demand sides. On the supply side, a decrease in tariffs of imported capital goods implies a heterogeneous increase in capital-labour substitution. On the demand side, the reduction of variable trade costs enhances foreign demand of domestic producers. The anticipation of a greater demand also increases heterogeneously capital investment because producers know the impact of their investment on prices and profits. The role of monopolistic competition is crucial to create the demand channel. Firms not only set a mark-up over marginal costs, but they can also reduce their marginal costs depending on their productivity advantages relative to the economy. As in a Dixit-Stiglitz framework, each firm competes with the whole economy. Most productive firms boost up the average productivity of the economy and deter the least productive ones to undertake technology investments. At the end, trade liberalisation is biased towards the initially high-productivity firms that become even more efficient after trade liberalisation. This theoretical prediction is consistent with the above-shown evidence and with empirical works at the firm level (Aw, Chung and Roberts, 2000; Trefler, 2004; De Loecker and Konings, 2003).

Hence, both "between" and "within" mechanisms are present in the model to explain how the trade frictions reduction positively contributes to aggregate productivity. The

between-firm effect works through the standard selection channel in the domestic market. The novel within-firm channel is interesting because productivity improvements are heterogeneous across firms. Indeed, the model predicts that only a small fraction of firms will become more efficient after a reduction of trade costs. Hence, the initial distribution of productivity is modified. Initially-high-productive firms capture most of technological productivity improvements. This result explains why there is a minor change in the extensive margin of trade, since gains from trade are concentrated in the most productive firms, those that more likely already export. Actually, after comparing the histogram of exports over gross output for 1990 (white color) and 1999 (gray color), one observes that the skewness increases (Figure 2.2). The graph considers only plants reporting a positive amount of exports.

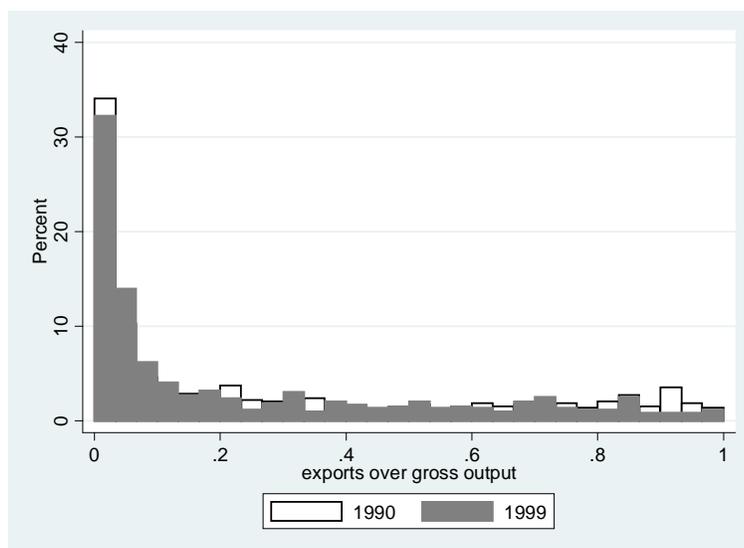


Figure 2.2. Histogram of exports over gross output

The rest of the Chapter is organised as follows. In Section 2.2 the set-up of the model is presented. Section 2.3 and 2.4 explain the main results. Section 2.5 concludes.

2.2 The model

2.2.1 Households consumption

There are two countries: home h and foreign f . They represent two small open economies. Households allocate consumption between the set of available domestic varieties Ω_h and the imported one Ω_f^x . Both sets are endogenously determined by the entry and the exit of firms. Whether domestic varieties are exported or not depends on their profitability. Consumers' preferences across varieties are given by a standard CES utility function. All variables with an circle (\circ) represent the foreign market and all round brackets ($()$) are reserved to specify the arguments of functions. Let C_h be the aggregate CES index in the home country. Domestic preferences are then summarised by:

$$C_h = \left[\int_{i \in \Omega_h} d_h(i)^{\frac{\phi-1}{\phi}} di + \int_{i' \in \Omega_f^x} d_f(i')^{\frac{\phi-1}{\phi}} di' \right]^{\frac{\phi}{\phi-1}} \quad (2.1)$$

Where $d_h(i)$ and $d_f(i')$ are the consumption of home and foreign varieties, respectively. The elasticity of substitution, $\phi > 1$, is the same in both countries. Denoting $p_x(i)$ the price of variety (i) produced in country x and P_h the aggregate price in the home country, this formulation implies the following optimal inverse demand functions:

$$d_h(i) = \left[\frac{P_h}{p_h(i)} \right]^{\phi} C_h \quad (2.2)$$

$$d_f(i') = \left[\frac{P_h}{p_f^\circ(i') [1 + \tau] e} \right]^{\phi} C_h \quad (2.3)$$

Where e is the nominal exchange rate quoted in the home currency relative to the foreign one and τ the variable trade costs, modeled as "iceberg costs". Consequently, the CES price index is given by:

$$P_h = \left[\int_{i \in \Omega_h} p_h(i)^{1-\phi} di + \int_{i' \in \Omega_f^x} [p_f^\circ(i') [1 + \tau] e]^{1-\phi} di' \right]^{\frac{1}{1-\phi}} \quad (2.4)$$

2.2.2 Producers

Each firm i faces the following schedule. First it enters the market. To do so, before knowing its initial productivity level, $\alpha_h(i)$, the firm has to pay a start-up cost f_e . After paying this sunk entry cost, $\alpha_h(i)$ is revealed from a common distribution density $g(\alpha_h)$, with support $[0, \infty]$ and cumulative distribution $G(\alpha_h)$. Second, once the firm knows its initial productivity level, but still before production, it decides its investment in technology embodied in imported capital goods. This technology choice allows it to improve its initial level of productivity. Finally, due to the presence of a fixed production cost f paid at every period, the firm decides whether it stays or exits the market. It might be the case that, even if a firm invests to enhance its efficiency, the expected profitability is not high enough to produce. In that case, the firm exits the market. Otherwise it stays and produces with an improved productivity level until economic conditions change and its revenues become insufficient to pay the permanent fixed cost.

Firms enter the market if their expected value allows, at least, to pay the entry cost. Thus, they anticipate their expected discounted of profits. This also includes the expected

gains from investment. We then analyse each step of the schedule and solve the model in backward induction.

Technology

Producers compete within a monopolistic competition framework. When a firm is active in the market, it produces a specific variety by using labour with constant returns to scale. Focusing on the home country, the production function $Y_h(i)$ of producer i is given by:

$$Y_h(i) = A_h(i) l_h(i) \quad (2.5)$$

Labour productivity $A_h(i)$ depends on an initial investment in foreign technology $I_{h0}(i)$. This investment has a different impact depending on the initial productivity level of each firm $\alpha_h(i)$.

$$A_h(i) = \alpha_h(i) [I_{h0}(i)]^\lambda \quad (2.6)$$

Where $0 < \lambda < 1$. The technology choice of firm i is made once it knows its initial productivity level $\alpha_h(i)$ and before it starts producing. This initial investment represents a specific fixed technological cost incurred by the firm in order to improve its efficiency when it enters the market. If it decides to stay, the firm produces using only labour with constant returns to scale, but with an improved productivity level.

Thus, the firm's investment I_{h0} is a decision, which is endogenously determined in the model. Since this decision depends on the heterogeneity α_h , the level of investment

will be heterogeneous across firms. Firms endowed with a higher initial productivity level, will be able to reinforce even more their efficiency through an “investment channel”.

As we focus on developing economies, we think in technology as embodied in imported capital goods. The elasticity λ , which is homogeneous across firms, captures the extent to which labour productivity reacts to this type of technology in the industry. If $\lambda = 0$ one finds a Melitz-type model. If $\lambda > 0$ further decisions take place and, as we will see, the initial distribution of productivity is modified. In this sense, the model seeks to understand the evolution of firm productivity in capital intensive industries.

One key assumption is that capital goods are supplied to both countries by the rest of the world in perfect competition. Implicitly, the model considers two small economies and a third country that represents the rest of the world. Since the investment is paid with profits, the trade balance condition between the two small economies does not take into account imported capital goods. Thus, we solve the model for the partial equilibrium between these two small economies.

Price setting and profits

As we mentioned, during production, firms behave as if they have constant returns on labour with a given level of productivity. Hence, first order conditions imply that firm set prices as a mark-up over marginal costs (wages over labour productivity):

$$p_h(i) = \frac{\phi}{[\phi - 1]} \frac{W_h}{A_h(i)} \quad (2.7)$$

Where W_h is the wage rate in the home country. The price of home goods sold in the foreign markets p_h° is higher due to variable trade costs (represented by τ).

$$p_h^\circ(i) = \frac{\phi}{[\phi - 1]} \frac{W_h}{A_h(i)} \frac{[1 + \tau]}{e} \quad (2.8)$$

Assumption 1: *Countries h and f are symmetric.*

We can now simplify our notation. Assumption 1 ensures equal wage rates (normalised to 1: $W_h = W_f = 1$) and equal aggregate prices ($P_h = eP_f = P$). Then, hereafter we drop country subscripts. Since heterogeneity is totally captured by α , we also drop firm subscripts and identify firms by α .

Firms' revenues can be divided into those earned from domestic sales r_d and those earned from export sales r_x . Using (2.7) and (2.6) the former can be written as:

$$r_d(I_0) = \left[\frac{P}{p(I_0)} \right]^{\phi-1} R \quad (2.9)$$

Where R is the aggregate revenue of the country ($R = PC$). We write revenues as a function of the initial investment in order to highlight the decision schedule. Using (2.8), export revenues are given by:

$$r_x(I_0) = r_d(I_0) [1 + \tau]^{1-\phi} \quad (2.10)$$

Total revenue $r(I_0)$ of a firm with initial productivity α depends on its export status:

$$\begin{aligned} r(I_0) &= r_d(I_0) && \text{if the firm does not export} \\ r(I_0) &= r_d(I_0) + r_x(I_0) = r_d(I_0) \left[1 + (1 + \tau)^{1-\phi} \right] && \text{if the firm exports} \end{aligned}$$

Similarly, profits can also be divided into domestic profits $\pi_d(I_0)$ and export profits

$\pi_x(I_0)$:

$$\pi_d(I_0) = \frac{r_d(I_0)}{\phi} - \delta\psi(\tau)I_0 - f \quad (2.11)$$

Where f represents fixed production costs that are paid in every period. We assume that technology investment is paid with profits to the country supplying capital goods (the rest of the world). $\delta\psi(\tau)I_0$ is the amortised investment. $\psi(\tau) \equiv (1 + \tau)p_k e_w$ is the final price of imported capital in home currency. e_w is the nominal exchange rate between any of the two symmetric small economies and the rest of the world. The price of imported capital goods p_k is taken as given since both economies are supposed to be small enough to have any impact on world prices. Export profits $\pi_x(I_0) = \frac{r_x(I_0)}{\phi} - \delta f_x$ are then:

$$\pi_x(I_0) = \frac{r_d(I_0)}{\phi} (1 + \tau)^{1-\phi} - \delta f_x \quad (2.12)$$

Firms having a higher productivity, which depends on the initial technology investment, will charge a lower price, have a higher demand and earn higher profits than less productive ones.

2.2.3 Technology choice: Initial investment

Using backward induction, firms set optimal prices taking I_0 as given (equations (2.7) and (2.8)) and decide the level of I_0 that maximises the present value v of their domestic profits.

Using δ as the time discounting factor.¹¹

$$v(I_0) = \frac{1}{\delta} \frac{r_d(I_0)}{\phi} - I_0\psi(\tau) - f \quad (2.13)$$

¹¹ As in Melitz (2003), the time discounting parameter δ , represents also the exogenous probability of exit.

The first order condition implies an optimal investment which depends on the initial productivity:

$$I_0(\alpha) = [P\alpha]^{\frac{\phi-1}{\beta}} \left\{ \frac{\lambda R}{\delta\psi(\tau)} \left[\frac{\phi-1}{\phi} \right]^\phi \right\}^{\frac{1}{\beta}} \quad (2.14)$$

Where $\beta \equiv 1 - \lambda(\phi - 1)$. We assume that $\frac{1}{(\phi-1)} > \lambda$ in order to ensure non-explosive returns of investment. The power $\frac{\phi-1}{\beta}$ gives the concavity of the effect of α on firm's investment. This term comes from the fact that, when maximising the discounted value of profits flows, the effect of demand is taken into account twice. First, when setting their price, firms know that their demand is a decreasing function of their price relative to the aggregate one. This leads to the mark-up price rule. Second, when entering the market they also know that their demand can be enhanced by decreasing their marginal costs through the investment channel. As we will see this anticipation mechanism implies that the effect of the initial heterogeneity is not linear.

2.2.4 Thresholds of production and export status

Since there is a fixed production cost (paid in units of labour), there exists a marginal firm, α^* , whose domestic profits are equal to zero: $\pi_d(\alpha^*) = 0$. This is equivalent to state:

$$\frac{r_d^I(\alpha^*)}{\phi} = f \quad (2.15)$$

Where $r_d^I(\alpha) \equiv r_d(\alpha) - \delta I_0(\alpha) \psi(\tau)$ are domestic revenues net of amortisation of initial investment in technology. The value α^* is the production cutoff. It defines the threshold corresponding to the minimum level of productivity that allows to produce. Some firms

decide to exit the market because, even after investment, they are not profitable enough to pay the fixed production costs.

Similarly, the tractability condition implies that only those firms with operating profits that counterweight the fixed export costs δf_x , also paid in units of labour, will be able to export. Again, this defines a marginal firm, α_x^* , whose export profits are zero: $\pi_x(\alpha_x^*) = 0$

$$\frac{r_d(\alpha_x^*)}{\phi} (1 + \tau)^{1-\phi} = \delta f_x \quad (2.16)$$

From this condition we can derive the export cutoff α_x^* : the threshold corresponding to the minimum level of productivity which ensures just enough revenues to pay δf_x .

2.2.5 Aggregation

After applying trade balance condition for symmetric countries, the index price over the support of α leads to:

$$P^{1-\phi} = \int_{\alpha^*}^{\infty} Np(\alpha)^{1-\phi} \frac{g(\alpha)}{[1 - G(\alpha^*)]} d\alpha + \int_{\alpha_x^*}^{\infty} N_x [p(\alpha) [1 + \tau]]^{1-\phi} \frac{g(\alpha)}{[1 - G(\alpha_x^*)]} d\alpha \quad (2.17)$$

From the left to the right, the integrals represent domestic and imported varieties, respectively. The assumption of symmetric countries implies that the characteristics of imported varieties are identical to those of exported ones. Thus, the number of exporters in both countries is the same $N_{hx} = N_{fx} = N_x$. The total number of varieties available for consumption in a country is then $N_T = N + N_x$. It is composed of N domestic varieties, including exported and non-exported goods, and N_x imported varieties.

The price index P takes into account that prices are a function of the random variable α . Consequently, the domestic component considers the distribution of α conditional on having entered the market $\frac{g(\alpha)}{1-G(\alpha^*)}$, and the import component the one conditional on having the export status $\frac{g(\alpha)}{1-G(\alpha_x^*)}$.

Trade balance accounting concerns two components: consumption goods and capital goods. The former are considered in the standard export-import balance accounting between the two symmetric countries and the latter in the amortisation of the initial investment in capital, imported from the rest of the world and paid by revenues coming from sales. Since both components are supplied and paid independently their accounting can also be done independently. Hence, the index price takes only into account consumption goods. Using the assumption of symmetry and the standard results of CES demand formulation, one obtains directly the aboved-presented expression.

Plugging the optimal prices set by the firm into the price index we obtain:

$$P = \frac{\phi}{\phi - 1} \left[\int_{\alpha^*}^{\infty} \frac{NA(\alpha)^{\phi-1}g(\alpha)}{[1 - G(\alpha^*)]} d\alpha + (1 + \tau)^{1-\phi} \int_{\alpha_x^*}^{\infty} \frac{N_x A(\alpha)^{\phi-1}g(\alpha)}{[1 - G(\alpha_x^*)]} d\alpha \right]^{\frac{1}{1-\phi}}$$

Defining the domestic average productivity $\widetilde{A}_d^{\phi-1} \equiv \int_{\alpha^*}^{\infty} A(\alpha)^{\phi-1} \frac{g(\alpha)}{[1-G(\alpha^*)]} d\alpha$ and that of the traded varieties $\widetilde{A}_x^{\phi-1} \equiv \int_{\alpha_x^*}^{\infty} A(\alpha)^{\phi-1} \frac{g(\alpha)}{[1-G(\alpha_x^*)]} d\alpha$, we can express the average productivity and the price index as

$$\widetilde{A}_T^{\phi-1} = \frac{1}{N_T} \left[N \widetilde{A}_d^{\phi-1} + N_x (1 + \tau)^{1-\phi} \widetilde{A}_x^{\phi-1} \right] \quad (2.18)$$

$$P = N_T^{\frac{1}{1-\phi}} \frac{\phi}{\phi-1} \frac{1}{\widetilde{A}_T} \quad (2.19)$$

This is the Melitz's (2003) aggregate price summarised by the average productivity \widetilde{A}_T . In our framework, productivity is determined by the optimal technology choice (2.14), which depends on the index price. This leads to an externality of investment. Thanks to investment, the economy becomes more productive and the aggregate price P is reduced. As in this Dixit-Stiglitz framework each firm competes with the whole economy, the average productivity improvement induces firms to invest more in order to set a competitive price. However, firms do not take into account that their behavior determines the average productivity of the economy.

After plugging (2.19) into (2.14) and the result into (2.6) and (2.18), we obtain:

$$\widetilde{A}_T = \frac{\kappa(\lambda, \tau) \widehat{\alpha}}{N_T} \quad (2.20)$$

Where the following definitions apply:

$$\begin{aligned} \kappa(\lambda, \tau) &\equiv \frac{\lambda R}{\delta \psi(\tau)} \left[\frac{\phi-1}{\phi} \right] \\ \widehat{\alpha}^{\frac{\phi-1}{\beta}} &\equiv \frac{1}{N_T} \left[N \widehat{\alpha}_d^{\frac{\phi-1}{\beta}} + [1+\tau]^{1-\phi} N_x \widehat{\alpha}_x^{\frac{\phi-1}{\beta}} \right] \\ \widehat{\alpha}_d^{\frac{\phi-1}{\beta}} &\equiv \frac{1}{[1-G(\alpha^*)]} \int_{\alpha^*}^{\infty} \alpha^{\frac{\phi-1}{\beta}} g(\alpha) d\alpha \\ \widehat{\alpha}_x^{\frac{\phi-1}{\beta}} &\equiv \frac{1}{[1-G(\alpha_x^*)]} \int_{\alpha_x^*}^{\infty} \alpha^{\frac{\phi-1}{\beta}} g(\alpha) d\alpha \end{aligned} \quad (2.21)$$

The average defined by $\hat{\alpha}$ aggregates heterogeneity after taking into account optimal decisions of investment. Similarly, $\hat{\alpha}_d$ and $\hat{\alpha}_x$ are the domestic and export counterparts of $\hat{\alpha}$. This average gives a measure of the reaction of labour productivity in the industry to the technology choice.

Proposition 1: *Firm's investment is a function of its (exogenous) initial heterogeneity α relative to the (endogenous) aggregate of the industry ($\hat{\alpha}$). The investment function is given by:*

$$I(\alpha) = \frac{\kappa(\lambda, \tau)}{N_T} \left[\frac{\alpha}{\hat{\alpha}} \right]^{\frac{\phi-1}{\beta}} \quad (2.22)$$

Proof: Plugging the global average productivity (2.20) into the optimal investment (2.14) gives (2.22). ■

Equation (2.22) gives further insights concerning the above-mentioned externality of investment. Since $\hat{\alpha}_d$ and $\hat{\alpha}_x$ are endogenously determined by productivity cutoffs, $\hat{\alpha}$ is modified by firms' decisions. Producers drawing a high initial productivity level will bias the initial distribution since they will concentrate most of investment gains. This occurs because firms anticipate the impact of their investment decisions on their demand. The decision of high productive firms will deter the least productive ones to undertake a large amount of investment because they compete with the average firm which has become more productive. As a consequence, firms' decisions are particularly sensitive to the expected relative advantages. As the average productivity gains are reinforced, the effectiveness of investment is reduced for firms with a low α . This induces the exit of the least productive firms and as a consequence an increase in $\hat{\alpha}$.

Proposition 2: *Global productivity \widetilde{A}_T can be summarised as the productivity of a representative firm whose initial productivity can be improved, through investment, by a factor of $\widehat{\alpha}$: $\widetilde{A}_T = A(\widehat{\alpha})$. More generally, a firm with an initial level of heterogeneity α will obtain after investment decision a productivity level of :*

$$A(\alpha) = \alpha I(\alpha) = \alpha \frac{\kappa(\lambda)}{N_T} \left[\frac{\alpha}{\widehat{\alpha}} \right]^{\frac{\phi-1}{\beta}} \quad (2.23)$$

Proof: Substitution of (2.22) into firm productivity (2.6) leads to equation (2.23).

Evaluating (2.23) for $\alpha = \widehat{\alpha}$ gives (2.20) ■

The optimal investment defines profits and revenues as functions of the exogenous initial productivity α . Plugging (2.22) into (2.9) gives:

$$r_d(\alpha) = \frac{1}{N_T} \left[\frac{\alpha}{\widehat{\alpha}} \right]^{\frac{\phi-1}{\beta}} R \quad (2.24)$$

Export revenues and profits are pin down by $r_d(\alpha)$ (see equations (2.10) and (2.12)).

The industry can be aggregated using the weighted averages $\widehat{\alpha}$, $\widehat{\alpha}_d$ and $\widehat{\alpha}_x$. Average revenue \widetilde{r} (net of investment), stem from average revenues earned from domestic sales $r_d^I(\widehat{\alpha}_d)$ and from export sales $r_x(\widehat{\alpha}_x)$

$$\widetilde{r} = r_d^I(\widehat{\alpha}_d) + \rho_x r_x(\widehat{\alpha}_x) \quad (2.25)$$

A similar statement applies for average profits $\widetilde{\pi}$, which can be decomposed into domestic $\pi_d(\widehat{\alpha}_d)$ and export $\pi_x(\widehat{\alpha}_x)$ average profits.

$$\widetilde{\pi} = \pi_d(\widehat{\alpha}_d) + \rho_x \pi_x(\widehat{\alpha}_x) \quad (2.26)$$

Where the probability of exporting, $\rho_x = \frac{1-G(\alpha_x^*)}{1-G(\alpha^*)}$ is the probability of having an α higher than the export cutoff α_x^* , conditional on having entered the market. Applying (2.22), domestic revenues net of amortised investment $r_d^I(\alpha) = r_d(\alpha) - \delta I_0(\alpha) \psi$ can be expressed as:

$$r_d^I(\alpha) = \beta r_d(\alpha) \quad (2.27)$$

Hence, $r_d^I(\hat{\alpha}_d) = \beta r_d(\hat{\alpha}_d)$.

2.2.6 Macro Balance

In this subsection we analyse global conditions of stability and macroeconomic balance to close the model.

Entry-Exit

The first group of conditions relates to the entry-exit process. The mass of prospective entrants is unbounded, they decide to enter depending on the firm's value and before knowing their initial productivity level α . Hence, in order to decide whether they enter the market, firms calculate the expected value of the average profit flows $\tilde{v} = \frac{[1-G(\alpha^*)]\tilde{\pi}}{\delta}$ and compare it to the sunk entry cost f_e . As usual, firms enter the market until the expected value of firms \tilde{v} is equalised to the sunk entry cost. This equality ($\tilde{v} = f_e$) states the free entry condition (FE):

$$\tilde{\pi} = \frac{\delta f_e}{[1 - G(\alpha^*)]} \quad (\text{FE})$$

Among firms that enter the market N_e , only a fraction $\rho = 1 - G(\alpha^*)$ will decide to stay. These firms are those whose technical conditions allow enough revenues to pay the fixed costs of production. On the other hand, among active firms N , some of them will exit the market with an exogenous probability δ (the death shock of Melitz, 2003). The stability condition of entry and exit implies:

$$\delta N = N_e \rho \quad (2.28)$$

Labour Market and Global Accounting

The labour factor is inelastically supplied in perfect competition. Total labour L_T is composed of production workers L_p (including labour used to pay the fixed production and export costs) and also workers allocated to pay the sunk cost to enter the market L_e :

$$L_T = L_p + L_e \quad (2.29)$$

The N_e firms that enter the market incur a labour cost of start-up equal to

$$L_e = N_e f_e \quad (2.30)$$

The labour market clearing condition is ensured by the global accounting condition. Recalling that wage rate is normalised to 1:

$$L_p + N\tilde{\pi} = R \quad (2.31)$$

Using (2.30), the free entry condition (FE) and the stability condition (??) one easily obtains $L_e = N\tilde{\pi}$. Using (2.29) yields:

$$L_T = R \quad (2.32)$$

Number of Domestic Firms

Starting from the previous conditions we can express average revenues \tilde{r} as

$$\tilde{r} = \frac{R}{N} \quad (2.33)$$

We can write average profits as $\tilde{\pi} = \frac{\tilde{r}}{\phi} - f - \rho_x \delta f_x$. After multiplying both sides by N and rearranging terms, we obtain the aggregate revenue:

$$R = N\tilde{r} = N[\tilde{\pi} + f + \rho_x \delta f_x] \phi \quad (2.34)$$

Replacing R in labour market clearing condition (2.32) and applying the free entry condition (FE) one gets the number of active domestic firms:

$$N = \frac{L_T}{\left[\frac{\delta f_e}{\rho} + f + \rho_x \delta f_x \right] \phi} \quad (2.35)$$

After considering revenues net of investment, the expression defining the number of firms looks similar to the standard Melitz's framework. However, the outcome is different. In this model, the probabilities defined by ρ and ρ_x are determined by the cutoffs α_x^* and α^* , which at equilibrium are influenced by the endogenous investment decision.

2.2.7 Equilibrium

The equilibrium can be solved using the Free Entry condition (FE) once we have determined its left-hand-side: the average profits $\tilde{\pi}$. The latter can be related to the minimum level of initial productivity that allows enough revenues to stay in the market (the production cutoff α^* defined by equation (2.15)). This relationship is what Melitz (2003) calls the Zero Cutoff Profit condition (ZCP). Hence, the equilibrium is jointly determined by both the FE condition (FE) and the ZCP condition. The intersection of both curves, gives α^* at equilibrium, which will then pin down the rest of endogenous variables of the model.

Starting from equation (2.26) we need to derive the ZCP in order to express $\tilde{\pi}$ as a function of the cutoff α^* . A convenient treatment is to exploit the aggregation properties of the model. To obtain the domestic average profit in (2.26), we start from the domestic average revenue (2.24). In order to simplify $\hat{\alpha}$, we express the ratio of the revenue of the representative domestic firm $\hat{\alpha}_d$ over the one earned by the cutoff firm α^* . Applying this to equation (2.27) gives:

$$r_d^I(\hat{\alpha}_d) = \left[\frac{\hat{\alpha}_d}{\alpha^*} \right]^{\frac{\phi-1}{\beta}} r_d^I(\alpha^*)$$

From equation (2.15) we know that operating profits of the production cutoff firm equals the fixed production cost: $\frac{r_d^I(\alpha^*)}{\phi} = f$. Hence, the domestic profits of the representative domestic firm $\pi_d(\hat{\alpha}_d) = \frac{r_d^I(\hat{\alpha}_d)}{\phi} - f$ can be written now as a function of the production cutoff α^* and the average $\hat{\alpha}_d$, which only depends on α^* . This leads to:

$$\pi_d(\hat{\alpha}_d) = \left\{ \left[\frac{\hat{\alpha}_d}{\alpha^*} \right]^{\frac{\phi-1}{\beta}} - 1 \right\} f$$

In the case of the average export revenues we proceed in a similar way. This time, we divide the export revenue of a representative exporter $\hat{\alpha}_x$ by the one earned by the export cutoff firm α_x^* . We also know that the export operating profits of the export cutoff firm equals the fixed cost to reach the foreign market: $\frac{r_x(\alpha_x^*)}{\phi} = \delta f_x$. Then, export profits of the representative exporter are give by:

$$\pi_x(\hat{\alpha}_x) = \left\{ \left[\frac{\hat{\alpha}_x}{\alpha_x^*} \right]^{\frac{\phi-1}{\beta}} - 1 \right\} \delta f_x$$

Therefore, the ZCP condition defines the average profit per firm as:

$$\tilde{\pi} = \left\{ \left[\frac{\hat{\alpha}_d}{\alpha^*} \right]^{\frac{\phi-1}{\beta}} - 1 \right\} f + \rho_x \left\{ \left[\frac{\hat{\alpha}_x}{\alpha_x^*} \right]^{\frac{\phi-1}{\beta}} - 1 \right\} \delta f_x \quad (\text{ZCP})$$

This condition is entirely determined by the production cutoff level. We know that $\hat{\alpha}_d = \hat{\alpha}_d(\alpha^*)$ and $\hat{\alpha}_x = \hat{\alpha}_x(\alpha_x^*)$. Thus, we just need to find $\alpha_x^* = \alpha_x^*(\alpha^*)$. In order to find this relationship, we plug the optimal investment (2.22) into equations (2.15) and (2.16). Then, we take the ratio of the resulting equations and we find:

$$\alpha_x^* = \alpha^* \gamma(\tau) \quad (2.36)$$

If $\gamma(\tau) \equiv [1 + \tau]^\beta \left[\frac{\beta \delta f_x}{f} \right]^{\frac{\beta}{\phi-1}} > 1$ there will be exported varieties at the equilibrium ($\alpha^* < \alpha_x^*$)¹². At the end, the ZCP condition depends only on α^* and the exogenous para-

¹² This occurs when $\delta f_x (2 - \phi) (1 + \tau)^{\phi-1} > f$

eters. In order to get a closed solution we solve the model using a Pareto distribution for the initial productivity draws.

2.3 Analytical solution

Following Ghironi and Melitz (2005) and Melitz and Ottaviano (2005), we parametrise the productivity draws to get tractable solutions of the model.

Assumption 2: *Productivity draws are distributed according to a Pareto distribution*

$$g(\varphi) = \frac{k\varphi_{\min}^k}{\varphi^{k+1}} \text{ with a lower bound } \varphi_{\min} = 1 \text{ and a shape parameter } k > \frac{\phi-1}{\beta}.$$

When this shape parameter increases there is a reduction of the technological dispersion, which will be concentrated towards the lower bound. As usual, this distribution density requires $k > \frac{\phi-1}{\beta}$ in order to ensure finite means. The parameter $\alpha_{\min} = 1$ implies that the corresponding cumulative distribution function is given by $G(\alpha) = 1 - \left[\frac{1}{\alpha}\right]^k$.

We can easily verify that $\rho = 1 - G(\alpha^*) = \alpha^{*-k}$ and $\rho_x = \frac{1-G(\alpha_x^*)}{1-G(\alpha^*)} = \left[\frac{\alpha^*}{\alpha_x^*}\right]^k$. After solving the integrals defining $\hat{\alpha}_d, \hat{\alpha}_x$ we obtain:

$$\hat{\alpha}_d = \alpha^* \eta \tag{2.37}$$

$$\hat{\alpha}_x = \alpha_x^* \eta \tag{2.38}$$

Where $\eta \equiv \left[\frac{-k\beta}{\phi-1-k\beta}\right]^{\frac{\beta}{\phi-1}}$

Proposition 3: *Under Assumption 2, there exists a unique equilibrium production cutoff α^* determined by the ZCP and FE conditions. This cutoff is given by:*

$$\alpha^* = \left[\frac{\left[\eta^{\frac{\phi-1}{\beta}} - 1 \right] \left[f + \delta f_x \gamma (\tau)^{-k} \right]}{\delta f_e} \right]^{\frac{1}{k}} \quad (2.39)$$

Proof. Equalising the equations of average profit stated by the *ZPC* and the *FE* leads to the equilibrium production cutoff (2.39). ■

Proposition 4: *Under assumption 2, the production cutoff is a decreasing function of variable trade costs ($\frac{\partial \alpha^*}{\partial \tau} < 0$).*

Proof. From (2.39) we obtain: $\frac{\partial \alpha^*}{\partial \tau} = -\beta \alpha^{*1-k} \frac{\left[\eta^{\frac{\phi-1}{\beta}} - 1 \right] \delta f_x \gamma (\tau)^{-k}}{\delta f_e [1+\tau]}$. Since $\beta > 0$, as long as $\eta^{\frac{\phi-1}{\beta}} > 1$, we verify $\frac{\partial \alpha^*}{\partial \tau} < 0$. Note that $\eta^{\frac{\phi-1}{\beta}} = \frac{1}{1 - \frac{1}{k} \left[\frac{\phi-1}{\beta} \right]}$. Thus, if $k > \frac{\phi-1}{\beta}$, clearly $\eta^{\frac{\phi-1}{\beta}} > 1$. This is exactly what the condition restricting k states in order to get finite means. ■

Melitz (2003) explains this result as a general equilibrium consequence of the increase in the number of potential entrants. After a reduction of variable trade costs, export demand increases. The value of firms is higher in the new equilibrium, which implies a higher number of entrants. This in turn increases labour demands and also real wages $\frac{1}{P}$. To be able to pay the fixed production cost, the marginal firm needs to be more productive than before.

In our model, the reduction of variable trade costs also enhances investment demand. As we saw, investment is more significant when the initial heterogeneity induces higher productivity gains from technology. The externality of investment reinforces the selection process. After a reduction of trade costs, investment remains low for initially-low-productive firms. Consequently, they end-up with a lower productivity relative to the

economy. Therefore, these firms will be forced to exit the market after a reduction of trade frictions.

Proposition 5: *Under assumption 2, the export cutoff is an increasing function of variable trade costs: $\left(\frac{\partial \alpha_x^*}{\partial \tau} > 0\right)$.*

Proof. Applying (2.39) to the export cutoff equation (2.36) gives the cutoff α_x^* which verifies: $\frac{\partial \alpha_x^*}{\partial \tau} = \gamma \left[\frac{\partial \alpha^*}{\partial \tau} + \frac{\alpha^* \beta}{(1+\tau)} \right]$. Since $\frac{\partial \alpha^*}{\partial \tau} < 0$, we need to prove $\left| \frac{\partial \alpha_x^*}{\partial \tau} \right| < \left| \frac{\alpha^* \beta}{(1+\tau)} \right| \Leftrightarrow -\frac{\partial \alpha_x^*}{\partial \tau} < \frac{\alpha^* \beta}{(1+\tau)}$. After using $\frac{\partial \alpha^*}{\partial \tau}$ obtained in the proof of proposition 4, this condition is similar to state $\frac{1}{\left[\frac{f}{f_x \gamma^{-k}} + 1 \right]} < 1$. Since $\frac{f}{f_x \gamma^{-k}} > 0$, this proposition is unambiguously verified. ■

Since productivity $A(\alpha)$ increases monotonically with α , a reduction of variable trade costs will decrease the export cutoff productivity level. Hence, more firms are able to acquire the export status. On the demand side, variable trade costs reduction leads to a decrease in the price of home goods sold in the foreign market. This price reduction accounts for an increase in foreign demand, which in turn raises export profits. In this new equilibrium firms need a lower level of productivity to pay the fixed export costs and to sell in the foreign market.

Note that these properties $\left(\frac{\partial \alpha^*}{\partial \tau} < 0; \frac{\partial \alpha_x^*}{\partial \tau} > 0\right)$ imply directly that higher variable trade costs increases the ex-ante probability of staying in the market $\left(\frac{\partial \rho}{\partial \tau} > 0\right)$ and reduces the probability of exporting $\left(\frac{\partial \rho_x}{\partial \tau} < 0\right)$. Intuitively, if the reduction of trade costs increases the minimum level of productivity required to stay in the market, the probability of a successful entry is reduced. Similarly, if less costly trade induces a lower threshold of productivity to export, it also implies a higher probability to reach the foreign market.

2.4 The reduction of variable trade costs

2.4.1 Within-firm productivity

The standard results presented in the previous Section are reinforced by the investment channel introduced in this model. The impact of trade liberalisation can be separated into two channels whether one observes the supply or the demand effects of trade variable costs. The former is related to the reduction of the cost of capital equipment, while the latter is based on the anticipation of an increase in final goods and factor demands which induces capital-labour substitution. In this Section we analyse these channels in more detail.

Consider firm productivity at equilibrium. Investment (2.22) applied to productivity (2.23), after global accounting states:

$$A(\alpha) = \alpha \left[\frac{\phi - 1}{\phi} \right] \left[\frac{L_T}{N_T(\tau)} \frac{\lambda}{\delta \psi(\tau)} \right] \left[\frac{\alpha}{\hat{\alpha}(\tau)} \right]^{\frac{\phi-1}{\beta}} \quad (2.40)$$

$N_T(\tau)$ highlights the dependency of the number of varieties on trade costs. The latter affects the probabilities of staying in the market and of exporting (see equation (2.35)). Applying the aggregation of heterogeneity for domestic (2.37) and exported (2.38) varieties to the global one (2.21) gives $\hat{\alpha}$ as function of τ . The reason is that this aggregation depends on the cutoffs of production and export, which are in turn determined by τ .

On the supply side, the effect of trade costs on the final capital price is captured by the final price of imported capital in home currency $\psi(\tau) = (1 + \tau) p_k^* e_w$. Clearly $A(\alpha)$ increases when ψ decreases and its impact (in absolute value) is higher for high values of initial productivity gains α . On the demand side, foreign consumption increases after a

reduction of variable trade costs. The intuition is that firms anticipate a greater demand and, as a consequence, more requirement of labour. Hence, labour productivity gains become more profitable, which leads to a raise in investment demand. While the supply channel is homogeneous across firms, the demand channel depends on α . Thus, the latter generates heterogeneous firms' productivity improvements.

We find these results with the help of numerical simulations. The parameters used are: $f_e = 15$, $\delta = 10\%$, $f_x = 20$, $f = 1$, $\phi = 1$, $\lambda = 2/3$, $k = 4$. This setting verifies both $k > \frac{\phi-1}{\beta}$ and the following condition $\gamma(\tau) \equiv [1 + \tau]^\beta \left[\frac{\beta \delta f_x}{f} \right]^{\frac{\beta}{\phi-1}} > 1$, ensuring exported varieties at equilibrium.

Result 1: *Firm productivity increases with the reduction of trade variable costs τ . The impact of τ on productivity gains is non-linear and it is more significant when α is higher.*

We illustrate this mechanism in Figure 2.3. It shows the plot of $A(\alpha)$ on τ for a high ($\alpha = 2$) and a low ($\alpha = 1$) levels of initial draws. In both cases a reduction of variable trade costs enhances labour productivity, but this improvement depends positively on the initial productivity level. Moreover, in the graph one clearly observes a steeper slope for the higher α .

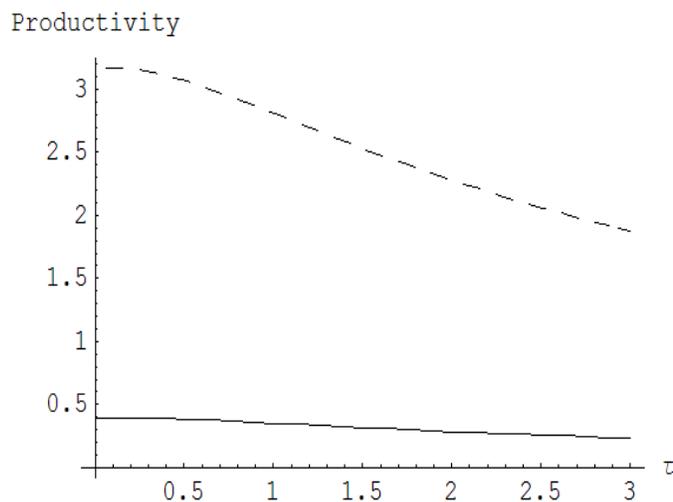


Figure 2.3. The effect of trade cost on firm productivity

$$f_e = 15, \delta = 10\%, f_x = 20, f = 1, \phi = 1, \lambda = 2/3, k = 4$$

More interestingly, there is a change in the distribution of initial productivity levels. This result is illustrated in Figure 2.4. We plot both the initial productivity draws (dashed line) and the equilibrium-level of productivity after investment (solid line). Firms can decide to modify their initial productivity level by the means of technological investments, but these decisions depend on their initial profitability. Thus, technological improvements are biased towards initially high-productive firms. In an heterogeneous firms model with fixed-exogenous productivity draws, the levels of firm productivity will be simply represented by α . This is the 45° dashed line¹³. The heterogeneous effect of investment is captured by the concavity of the productivity level at equilibrium (solid line). It might be the case that, as in Figure 2.4, the productivity level is even reduced. The fixed-exogenous productivity model can be seen as a model in which initial investment is homogenous and normalised to 1. Allowing for a continuous technology choice with investment externalities reinforces the

¹³ Scales of axis are assymmetric.

effect of market selection. Firms drawing a low α will be deterred to undertake a significant level of investment.

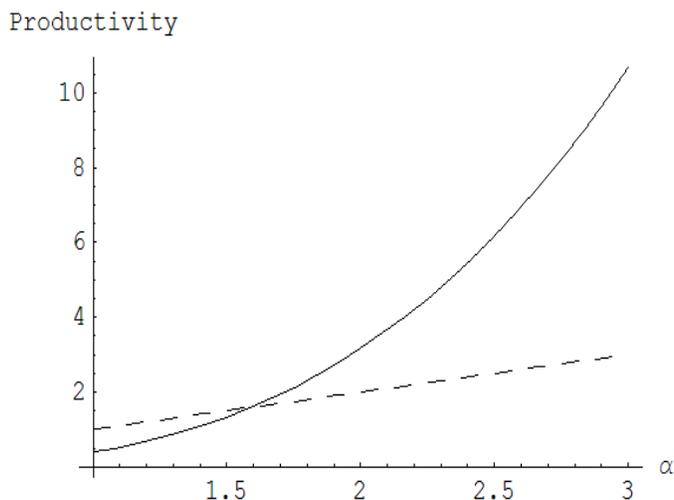


Figure 2.4. Modification of initial labour productivity

$$f_e = 15, \delta = 10\%, f_x = 20, f = 1, \phi = 1, \lambda = 2/3, k = 4$$

2.4.2 The intensive and the extensive margin of trade

One implication of the previous results is that trade liberalisation, in countries highly dependent on imported technologies, improves mainly the volume of exports of initially high-productive firms. Namely those that already export before trade reform (intensive margin). Foreign demand (2.3), using the properties of aggregation $\tilde{A}_T = A(\hat{\alpha}(\tau))$, can be expressed at equilibrium as:

$$d_f = \alpha \left(\frac{\phi - 1}{\phi} \right) \left[\frac{\alpha}{\hat{\alpha}(\tau)} \right]^{\frac{1}{\beta}} \frac{L_T}{N_T(\tau)} (1 + \tau)^{-\phi} A(\hat{\alpha}(\tau))$$

We know that a fall of trade variable costs forces the least productive firms to exit the market. Thus, the average $\hat{\alpha}(\tau)$ increases. We observe again differentiated effects

of trade policy depending on the impact of foreign technology on labour productivity. A reduction of variable trade costs induces a positive income effect through an increase in the average productivity of the economy, which boosts up global consumption. However, the demand of each firm (in monopolistic competition) depends on their technology relative to the average of the economy (the by $\frac{\alpha}{\bar{\alpha}(\tau)}$), the latter being endogenously determined. The initially high-productive firms will become even more efficient after trade liberalisation and thereby they will enlarge their export demand.

Result 2: *A reduction of trade barriers has a higher impact on the intensive margin of trade relative to the extensive one.*

To illustrate this point, we simulate the relationship between foreign demand and initial productivity of firms, for two different levels of variable trade costs. Figure 2.5 plots foreign demand $d_f(\alpha)$ on α . In the plot, the economy changes from a iceberg cost level of 80% (solid line) to a one of 20% (dashed line). Foreign demand curve increases more for high levels of α , where the slope is steeper.

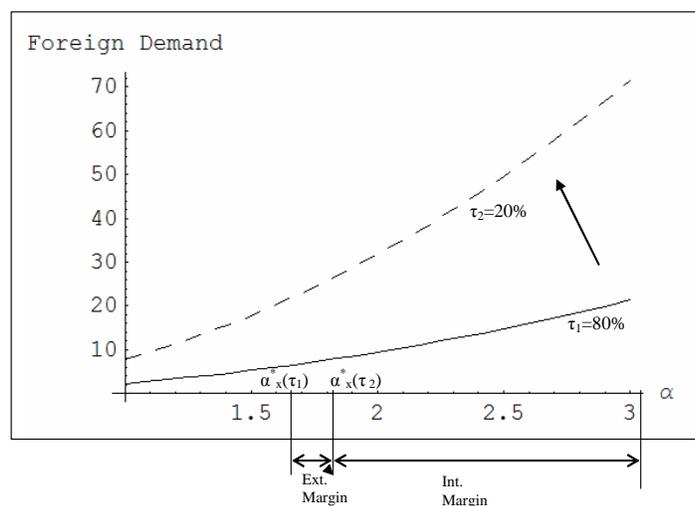


Figure 2.5. Extensive and intensive margin of trade

$$f_e = 15, \delta = 10\%, f_x = 20, f = 1, \phi = 1, \lambda = 2/3, k = 4$$

While there is a huge increase in the intensive margin of trade, there is only a minor one in the extensive margin. Indeed, the reduction of the export threshold α_x^* is small. It will only allow for few firms to become exporters. Therefore, gains from trade are concentrated on continuing exporters.

2.5 Conclusion

This Chapter has addressed the impact of trade on the evolution of within-firm productivity gains in countries highly dependent on technologies embodied in imported capital goods. We proposed an intra-industry trade model of heterogeneous firms which are able to change their initial efficiency level. The main contribution of this study is to introduce endogenous

productivity gains determined by an initial investment in foreign technology, a mechanism supported by our findings in Chapter 1.

The model introduces several results consistent with the empirical findings of firm-level studies. These results are also in line with Chilean plant-level data concerning the change in the distribution of labour productivity and the change in the distribution of export intensity.

Firstly, trade liberalisation induces a profitability bias towards the initially more productive firms. These firms are able to improve easily their efficiency by foreign technology adoption after a reduction of trade variable costs.

Secondly, contrary to the standard vision that supports the idea of a tariffs reduction in order to foster export diversification, this work argues that, in the case of a country highly dependent on foreign technology, trade variable costs reduction will have a minor impact on the extensive margin of trade.

Finally, the model is able to reproduce a new important channel through which trade liberalisation affects aggregate productivity growth. Besides the standard mechanism of selection and reallocation of resources (between- firm channel), the model also encompasses aggregate productivity gains related to improvements inside the firm (within-firm).

Further research should be oriented to analyse the specific pattern of the distribution of productivity levels at equilibrium and to compare it to firm level data. This can be made by the means of stochastic simulation. It seems clear for us that the link between trade and productivity asks for further research on stochastic dynamic issues.

II.- MARKET REGULATION, COMPETITION AND INNOVATION

In the previous chapters, we studied the outward dimension of market structure and its effect on productivity. We explicitly analysed the reaction of firm productivity to changes in trade policy in the context of an open developing economy. In this part of the thesis, we focus on the form of domestic competition, what we have called the "inward" dimension of market structure. More precisely, we address the question about how market regulation and competition shape firm's incentives to engage in innovation, a key productivity engine highlighted in endogenous growth literature.

Recent debates, in developed economies, emphasise the role of market competition on firm's incentives to innovate. The particular attention devoted by policy-makers to innovation is reflected in two important examples: the so-called Bush Policy Agenda (A New Generation of American Innovation) and the Lisbon Objective set in 2000 in Portugal by the European Council. Europe should become, by 2010, the most competitive and dynamic knowledge-based economy in the world. In both examples, firm's incentives to undertake R&D investments are seen as the outcome of .

Theoretically, we concentrate on the strategic concerns of innovation in a closed economy, although the arguments are extensive to the case of foreign competition. Empirically, we use international industry-level data in order to compare different regulatory environments. Chapter 3 revisits the arguments linking competition and innovation when producers move closer to the technological frontier. Results highlight an active role of mar-

ket regulation at the leading edge. This is analysed in more detail in Chapter 4 in which we study the strategic behaviour of competitors in R&D races. Here again, heterogeneity and asymmetries among competitors are key elements to understand empirical findings.

Chapter 3

Product Market Competition and Innovation at the Leading Edge¹⁴

3.1 Introduction

Concerns about the lack of convergence of Europe's productivity level vis-à-vis the US over the past decade have been expressed not only in academic circles but also among policy makers and politicians. As numerous reports have shown (Kok, 2004; Sapir, 2004), Europe seems to be losing ground, not because of an insufficient rate of capital accumulation, but for lack of innovation capability. The so-called Lisbon Strategy, which aims at fostering innovation and productivity, proposes a series of structural reforms for labour, financial and product markets. Regarding the latter, a link between competition and innovation underlies the whole Lisbon Strategy: more product market competition should bolster innovation and thus productivity and growth.¹⁵

According to economic theory, the relation between competition and innovation is ambiguous. For Schumpeter (1934), monopoly profits are rewards to innovators; the appropriability of innovation output is thus a crucial incentive issue. A rise in competition is expected to decrease rents stemming from innovation and thus incentives to innovate. This traditional "Schumpeterian effect" of competition is featured in numerous innovation-based

¹⁴ This Chapter is based on Amable, Demmou and Ledezma (2007). "Competition, Innovation and Distance to Frontier". Cepremap Docweb N°0706.

¹⁵ e.g. the Integrated Guidelines 12 to 16 (European Commission, 2005).

endogenous growth models, in particular Aghion and Howitt (1992) where innovation effort increases with the Lerner index.

On the other hand, competition may encourage innovation. Incumbents may innovate to keep their market power and fend off new entrants, or potential entrants may hope to capture the market position of incumbents by surpassing them with new and better products. In both cases, innovation would be the means for a firm to get the upper hand over its competitors. Extensions of the Schumpeterian innovation-based endogenous growth model allow to take into account differentiated influences of competition on innovation. The situation analysed in Aghion et al. (2005) is that of a competition between rivals with different productivity levels. Firms innovate to decrease their production costs "step by step": a technological laggard has to catch-up with the technological level of the leader before having the possibility of becoming itself a leader in the industry. The risks for the leader to lose its position are therefore increased when the competitor is only one step away from catching-up. When competitors have comparable productivity levels, i.e. the so-called "neck and neck" competition, a stronger competition will induce firms to increase their innovative investments in order to acquire a competitive lead over rival firms. This pro-innovation effect of competition is less prominent in industries where the leader has a marked advantage over its competitor. The incorporation of both innovation-inducing and innovation-deterring effects of competition into a single model leads to a nonlinear, inverted U-shaped, relation between product market competition and innovation (Aghion et al., 2005).

The link between competition and innovation has been investigated primarily at the firm level. The possible existence of an effect of the firm's size or market power on its

innovative activity is a well-known topic in the innovation literature (Baldwin and Scott, 1987; Cohen and Levin, 1989; Geroski, 1995). Although both pro- and anti-innovation effects of competition may be found in the empirical literature, the recent contributions tend to establish contrasted results differencing firm size effects from more general competition influences. Using a sample of French firms, Crépon, Duguet and Kabla (1995) found that market power stimulates innovation, although this effect seems to be small in magnitude. Crépon, Duguet and Mairesse (1998), in a four equation model for French manufacturing firms taking into account the firm's decision to engage in R&D activities, the R&D intensity, the effects of R&D on patenting and the effects of patenting on productivity, confirmed the existence of a size effect in the decision to engage in R&D activity but not the R&D intensity. On the other hand, market share and diversification affect positively both the decision to undertake R&D and R&D intensity. Competition may also exert negative effects such as those found in Crépon and Duguet (1997): competitors' R&D may have a negative impact on a firm's own innovation effort, indicating the existence of a rivalry externality that acts as a disincentive to innovate.

On the other hand, Nickell (1996) showed with a panel of 670 UK firms that competition, measured by a high number of competitors or low levels of rents, is associated to high rates of TFP growth. Whether this reveals a direct effect of competition on productivity, through a slack-reducing effect for instance, or an indirect effect through innovation is undecided. Blundell, Griffith and vanReenen (1999) used a panel of 340 British manufacturing firms between 1972 and 1982 and showed that the relation between competition and innovation possesses contrasted features. Industries where concentration is higher and im-

port penetration lower have fewer innovations. This finding tends to support the existence of a positive relationship between competition and innovation. However, within industries, firms with a higher market share tend to commercialise more innovations. They also showed that larger firms produce innovations of a greater commercial value than smaller firms.

The duality of competition's effects on innovation is summarised in the findings of Aghion (2003) and Aghion et al. (2005). With the help of firm-level data and US Patent Office data quoted on the London Stock Exchange between 1968 and 1997, they presented evidence of an inverted U-shaped relationship between the Lerner index and the number of patents granted. The "Schumpeterian effect" of competition should dominate when the level of competition is high whereas the 'escape competition' effect should be prominent at low levels of product market competition. Moreover, following the prediction of the theoretical model, the inverted U-shaped relationship was found to be steeper for firms that are closer to the leading edge in their industry.

Empirical evidence at the industry level is far less abundant than at the firm level. Industry-level studies have the advantage of allowing to escape from the limits of the proxies for competition usually taken into account by micro-level studies such as firm size, market power or profitability level, and consider actual industry-specific or macroeconomy-wide competition policy measures. Griffith, Harrison and Simpson (2006) measured innovation by Business Enterprise R&D expenditure for 12 industries and nine countries over the 1987-2000 period and investigated the effect of the Single Market Programme. Using a dummy variable for the post-SMP years, they found that the SMP had a positive impact on

innovative activity in affected industries and countries. They interpreted their results as a support for the competition-enhancing reforms advocated within the Lisbon Agenda. Nicoletti and Scarpetta (2003) considered a sample of 23 industries for 18 OECD countries over the period 1984-1998. They tested a model of TFP growth using product market regulation indicators devised by the OECD both alone and in interaction with a technology gap variable. They found statistically significant positive coefficients on the interacted variables, a result they interpreted as a catch-up slowing-down effect of product market regulation. Conway et al. (2006) tested a similar model of labour productivity with interaction terms between product market regulation indicators and a technology gap measure on a slightly extended sample of OECD countries. They found a significantly positive coefficient on the interacted variables too, which they interpreted as a catch-up slowing-down effect.

The differentiated effect of product market competition according to the distance to the technological frontier is a central issue of the whole competition and innovation debate. The received argument is that the economic costs of product market regulation increase the closer an economy is to the technological frontier (Aghion, 2006). For Aghion et al. (2006), increased competition, represented by a higher entry threat, spurs innovation incentives in sectors close to the technological frontier, whereas it discourages innovation in laggard sectors through a traditional Schumpeterian rent-diminishing effect. Testing a model of TFP growth and a model of innovation (patenting) with foreign entry and distance to the technological frontier variables included both alone and interacted along with other competition variables on micro-level data for the UK, they concluded that, as an economy moves closer to the technological frontier, the competitiveness of all industries in a

high-cost high-productivity economy depends on the ability to innovate. This applies to all sectors of the economy, "high-tech" or not, since the R&D intensity of all industries increases when economies move closer to the technological frontier (Acemoglu, Aghion and Zilibotti, 2006).

Concerning the inverted U-shape pattern, Tingvall and Poldahl (2006) find that, for Sweden firms, the support for this pattern depends on the indicator. While the Herfindal-index gives support to the inverted U-shape, the price cost margin does not allow to fit this pattern. Moreover, the use of time-series estimators reduces considerably the significance of results. Askenazy, Cahn and Irac (2007), using a panel of French firms, find that the concavity of the courbe linking competition and innovation is substantially reduced when the size of firms is small relatively to the cost of innovation. For the authors, this type of firms represents 85% of the sample.

The aim of this Chapter is to assess the validity of the argument according to which competition spurs innovation, and that this effect is all the more important that an economy is close to the technological frontier. A dynamic model including variables for the distance to the frontier, competition, as well an interaction term between them is estimated. The empirical strategy of this Chapter differs from the existing academic literature on three levels. First, the analysis is conducted at the industry level, while most empirical evidence focuses on micro studies. To the best of our knowledge, this is the first work testing the impact of competition on *innovation* at the industry level with a cross-country panel. Second, we use not only indicators for observed measures of competition but also indicators of regulation policy (institutional indicators, and output measure of competition). Finally, we

run regressions using different estimators (OLS, fixed effects and system GMM) in order to take into account the dynamic nature of the innovative process and propose different extensions of the baseline model. The use of different variants of the model, different estimators and different indicators to measure the intensity of competition helps to assess the robustness of our findings. The evidence does not give support to an innovation-bolstering effect of product market competition at the technological frontier. Moreover, the marginal effect of regulation, conditional on the closeness to the technological frontier, tends to be upward sloping, meaning that regulation might indeed foster innovation at the leading edge. The measure of observed competition (relative number of firms) presents a positive effect only for laggard industries and it vanishes close to technological frontier. These results along with previous micro evidence, suggest that deregulation policy does not seem to be a substitute for active science and technology policies, which do present a significant impact on technical change (Guellec and de la Potterie, 2003)

The Chapter is organised as follows. Section 3.2 discusses the theoretical argument relating innovation with competition. The inclusion of innovative leaders into the Aghion et al.'s (2005) model makes the relationship between the innovation-fostering effect of competition and distance to frontier more complex. Empirical tests are performed in the rest of the Chapter. Section 3.3 presents the empirical strategy and the problems related with the estimations. Section 3.4 presents the data used in the empirical analysis. The following Section presents the results of the baseline model. Section 3.6 proposes extensions and robustness tests of this model. A brief conclusion follows.

3.2 Theoretical framework

Recent works have undertaken the attempt to reconcile the traditional Schumpeterian view of a negative effect of competition on innovation and the idea according to which competition may push firms to reduce their inefficiencies in order to keep their market position. Aghion et al. (2005) present a theoretical basis enabling to encompass both arguments. The rationale consists in considering that innovation is carried out by incumbents that take into account not only post-innovations rents but the difference between post- and pre-innovation rents. The inclusion of positive and negative effects of competition leads to the inverted U-shape pattern depicting the relationship between competition and innovation.

One important prediction of Aghion et al. (2005) is that, for those firms competing at the leading edge, it is the pro-innovation effect of competition that dominates. We show in this Section that the validity of this prediction depends on the extent to which leaders are absent in the R&D contest. Results are different if leaders do carry out R&D and if they can limit knowledge diffusion. For a sake of presentation, we slightly modify the Aghion et al.'s (2005) model to include this possibility. In the next Chapter we go in more detail on the interactive behaviour in R&D races.

3.2.1 The baseline setup

Consider Aghion et al.'s (2005) economy composed of a unit mass of identical consumers. Each consumer supplies a unit of labour inelastically and has a logarithmic instantaneous utility function $u(y_t) = \ln y_t$ with a constant discount rate of r . The consumption good is produced with intermediate goods according to the following production function:

$$\ln y_t = \int_0^1 \ln x_{jt} dj \quad (3.1)$$

In each industry j , there are two duopolists, A and B. At each date, the final consumption good needs, as input, an aggregate good of each industry with the form $x_j = x_{Aj} + x_{Bj}$. Because of the utility function's specification (3.1), each individual spends the same amount on each good. Total spending is normalised to unity, so that the budget constraint is $p_{Aj}x_{Aj} + p_{Bj}x_{Bj} = 1$.

Each intermediate firm produces with constant returns to scale using labour as the only input. Denoting k the technology level of the duopoly firms in industry j , one unit of labour generates an output flow equal to:

$$A_i = \gamma^{k_i} \quad i = A, B \quad (3.2)$$

The baseline model assumes that, in any intermediate industry, the largest gap between the leader and the follower is one technological step because of knowledge externalities. If the leader innovates, the follower immediately moves one step up the quality ladder so that the relative positions of the two firms is not altered.

At any point in time, there will be two types of sectors in the economy: leveled industries where both firms are at the same technological level and unleveled industries where the technological leader is one quality step above its competitor. Thus, three types of firms are possible $i \in \{-1, 0, 1\}$: the follower ($i = -1$); the firm in a level sector ($i = 0$), the leader firm ($i = 1$). Depending on innovation firms A and B transit among these different states.

Product market competition is modelled in the following way. The degree of collusion ϵ of the two firms in a leveled industry will measure the degree of product market competition. Firms do not collude when the industry is unleveled. In this case, the leader applies a limit pricing rule, setting a price equal to the marginal cost of the laggard. The latter makes then zero profit while the leader makes a profit equal to one minus its production cost (wages are normalised to 1):

$$\pi_{-1} = 0 \quad \pi_1 = 1 - \frac{1}{\gamma} \quad (3.3)$$

In a leveled industry, if firms do not collude, Bertrand competition brings profits to zero. At a maximum level of collusion, firms split the leader profits between themselves (one half for each). Thus the model summarises in $\Delta = 1 - \epsilon$ ($0 \leq \epsilon \leq 1/2$) the degree of competition. Profits in leveled sectors are then given by:

$$\pi_0 = (1 - \Delta) \pi_1 \quad (3.4)$$

If a firm moves one technological step ahead at a Poisson hazard rate of n it incurs in a R&D cost $\frac{c n^2}{2}$. The follower can move one step ahead at a hazard rate h even without spending anything on R&D. One note n_0 the R&D intensity of each firm in leveled industries, n_{-1} that of the follower firm and n_1 that of a leading firm in an unleveled industry. A particular characteristic of the baseline model is that $n_1 = 0$ since the leading firm has no incentive to innovate because of the knowledge externality assumption. It is this feature that we modify.

3.2.2 A leader reducing knowledge diffusion

The assumption of a non-innovative technological leader appears to contradict casual evidence in a large number of activities.¹⁶ We therefore slightly modify the baseline setup exposed above to allow for leader innovation. We keep the assumption restricting the maximum sustainable productivity gap to be one step. As before, in an industry in which the leader has succeeded in innovating, its rival will immediately be upgraded one step. However, we consider that the leader's R&D effort n_1 makes it more difficult for the follower to innovate and move one step ahead, i.e. it reduces the catch-up probability to $h - \lambda n_1$, with λ a parameter capturing the ability of the leader to limit knowledge diffusion. This type of effect is supported by the empirical evidence provided by Crépon and Duguet (1997): in narrow defined industries, they find a negative externality of R&D between competitors. One may suppose that the engagement of the leader in a new discovery induces a change in the technological paradigm. Even if the quality difference is still one step, the leader's innovation makes this last step harder to climb for the follower.¹⁷

The steady state Bellman equations can be expressed as:

$$rV_1 = \pi_1 + (n_{-1} + h - \lambda n_1)(V_0 - V_1) + n_1(V_1 - V_1) - \frac{cn_1^2}{2} \quad (3.5)$$

$$rV_{-1} = \pi_{-1} + (n_{-1} + h - \lambda n_1)(V_0 - V_{-1}) - \frac{cn_{-1}^2}{2} \quad (3.6)$$

¹⁶ One may for instance check the R&D expenditure of industry leaders given in Table 1 of Segerstrom (2007).

¹⁷ The very closely related quality ladder model of Grossman and Helpman [1991] also assumes that leaders do not innovate. Rewards of a new improvement in quality are not profitable enough to incitate the leader to engage in R&D. Nevertheless, as pointed out in Chapter 4, Footnote 4, leaders might have other reasons, namely to deter the innovation of their rivals. This case is excluded in the standard quality ladder framework.

$$rV_0 = \pi_0 + n_0(V_1 - V_0) + \bar{n}_0(V_{-1} - V_0) - \frac{cn_0^2}{2} \quad (3.7)$$

Where V_i is the value of each type of firm $i \in \{-1, 0, 1\}$. The R&D effort of the competitor in a leveled sector is denoted by \bar{n}_0 . In a symmetric Nash equilibrium both R&D intensity are equal. Hence, the baseline model of Aghion et al. (2005) might be interpreted as a particular case in which $\lambda = 0$. Using the maximum principle, first order conditions on the right-hand-side lead to:

$$cn_1 = \lambda(V_1 - V_0) \quad (3.8)$$

$$cn_{-1} = V_0 - V_{-1} \quad (3.9)$$

$$cn_0 = V_1 - V_0 \quad (3.10)$$

Recalling that $\pi_0 = (1 - \Delta)\pi_1$ and solving for n_1 and n_{-1} leads to the reduced system:

$$0 = \Delta\pi_1 - \frac{\rho cn_1}{\lambda} + \frac{cn_1^2}{2} \left(1 - \frac{1}{\lambda^2}\right) \quad (3.11)$$

$$0 = -(1 - \Delta)\pi_1 - \frac{1}{\lambda^2} \frac{cn_1^2}{2} + \left(\rho + n_1 \left[\frac{1}{\lambda} - \lambda\right]\right) cn_{-1} + \frac{cn_{-1}^2}{2} \quad (3.12)$$

Where $\rho \equiv h + r$. These equations give the solution for the leader R&D effort n_1 and for that of the follower n_{-1} , respectively. The following propositions analyse the properties of stationary R&D efforts in this jump-stochastic process.

Proposition 1. *The possibility of two stationary R&D effort of the leader firm depends on λ .*

(a) *For $\lambda < 1$ there is one relevant stationary strategy for the leader:*

$$n_{1a} = \lambda \frac{\rho c - \sqrt{D_1}}{c(\lambda^2 - 1)} \quad (3.13)$$

Where $D_1 \equiv \rho^2 c^2 - 2c(\lambda^2 - 1)\Delta\pi_1$. For this strategy, competition increases R&D effort.

(b) *For $\lambda > 1$ and $\lambda^2 - 1 < \frac{\rho^2 c}{2\Delta\pi_1}$ there exists two relevant stationary strategies for the leader: n_{1a} and*

$$n_{1b} = \lambda \frac{\rho c + \sqrt{D_1}}{c(\lambda^2 - 1)} \quad (3.14)$$

For strategy n_{1b} , competition discourages R&D effort.

Proof. This result relies on the possibility of one or two positive roots of (3.11). First, we solve the quadratic equation (3.11). This gives n_{1a} and n_{1b} . For $\lambda < 1$ the coefficient multiplying the squared term in (3.11) is negative: $\frac{c}{2} \left(1 - \frac{1}{\lambda^2}\right) < 0$. The discriminant D_1 is positive when $\lambda^2 - 1 < \frac{\rho^2 c}{2\Delta\pi_1}$, which is always ensured for $\lambda < 1$. Hence the function first increases and then decreases (inverted U-shape). The intercept is positive ($\Delta\pi_1$), so only one solution is positive. Clearly, for $\lambda < 1$ the term $(\lambda^2 - 1) < 0$ so that n_{1a} is the positive root in this case. One immediately verifies that for $\frac{\partial n_{1a}}{\partial \Delta} < 0$ (innovation-inducing effect of competition). A similar reasoning applies for $\lambda > 1$. The coefficient multiplying the squared term in (3.11) is now positive: $\frac{c}{2} \left(1 - \frac{1}{\lambda^2}\right) > 0$. Since the intercept is positive, for $\lambda^2 - 1 < \frac{\rho^2 c}{2\Delta\pi_1}$ D_1 is also positive and the curve depicted by (3.11) intercepts twice the n_1

axis in the positive side. These roots are given by n_{1a} and n_{1b} . For $\lambda > 1$ one immediately verifies that for $\frac{\partial n_{1b}}{\partial \Delta} < 0$ (innovation-detering effect of competition). ■

Proposition 2. *The possibility of two stationary R&D effort of a leveled firm depends on λ .*

(a) *For $\lambda < 1$ there is one relevant stationary strategy for a leveled firm:*

$$n_{0a} = \frac{\rho c - \sqrt{D_1}}{c(\lambda^2 - 1)} \quad (3.15)$$

Where $D_1 \equiv \rho^2 c^2 - 2c(\lambda^2 - 1)\Delta\pi_1$. For this strategy competition increases R&D effort.

(b) *For $\lambda > 1$ and $\lambda^2 - 1 < \frac{\rho^2 c}{2\Delta\pi_1}$ there exists two relevant stationary strategies for a leveled firm: n_{0a} and*

$$n_{0b} = \frac{\rho c + \sqrt{D_1}}{c(\lambda^2 - 1)} \quad (3.16)$$

For strategy n_{0b} competition discourages R&D effort.

Proof. This result follows immediately from Proposition 2 and the first order conditions (3.8) and (3.10) by which one deduces $n_1 = \lambda n_0$. ■

Proposition 2. *For any value of λ , competition discourages the stationary R&D effort of the follower firm. The follower's stationary strategy is given by:*

$$n_{-1} = \frac{-(\rho + n_1 [\frac{1}{\lambda} - \lambda]) c + \sqrt{D_{-1}}}{c} \quad (3.17)$$

Where $D_{-1} \equiv [(\rho + n_1 [\frac{1}{\lambda} - \lambda]) c]^2 + 2c \left[(1 - \Delta) \pi_1 + \frac{1}{\lambda^2} \frac{cn_1^2}{2} \right]$.

Proof. This result comes from the solution of the quadratic equation (3.12). The coefficient multiplying the squared term in (3.12) is positive: $\frac{c}{2} > 0$. The discriminant D_{-1} is always positive too. Thus, the polynomial function first decreases and then increases (U-shape). Since its intercept is negative ($-(1 - \Delta) \pi_1 - \frac{1}{\lambda^2} \frac{c(n_1)^2}{2} < 0$) one solution lies on the negative side of the n_{-1} axis and the other on the positive one. Therefore, only the latter is relevant and is given by (3.17). ■

The two possible stationary strategies of the leader will imply two type of equilibrium since n_0 and n_{-1} are functions of n_1 . As in Aghion et al. (2005), the steady state equilibrium is defined in terms of the structure of the sector. If μ_1 is the probability in steady state of being in an unleveled sector, the probability that a sector moves from an unleveled state to a leveled one is then $\mu_1 (n_{-1} + h - \lambda n_1)$. The transition in the opposite direction is made with probability $2\mu_0 n_0$, where μ_0 denotes the steady-state probability of being in a leveled sector. The steady state equilibrium is given by equalising inward- and outward-flows:

$$\mu_1 (n_{-1} + h - \lambda n_1) = 2\mu_0 n_0 \quad (3.18)$$

Where the condition $\mu_1 + \mu_0 = 1$, of course, must hold . This implies:

$$\mu_1 = \frac{2n_0}{[(n_{-1} + h - \lambda n_1) + 2n_0]} \quad (3.19)$$

$$\mu_0 = 1 - \mu_1 \quad (3.20)$$

The R&D effort of the leader does not change the structure of the industry, but it contributes to the aggregate flow of innovation, which can be expressed as:

$$I = \mu_1 (n_{-1} + h - \lambda n_1 + n_1) + 2\mu_0 n_0 \quad (3.21)$$

The implication of the stationary R&D effort of the leader n_{1b} is that the steady state proportion of unlevelled sectors can be important, because the leader innovates and the follower has a lower probability to catch-up. In this type of sectors, if n_{1b} applies, both leader's and follower's R&D are deterred by competition. Thus, the aggregate effect of competition may be in fact negative. This is what Figures 3.1 to 3.3 show. For the sake of brevity, only numerical simulations are reported. The Figures display the aggregate flow of innovation I as function of competition Δ . Figure 3.1 considers the stationary strategy n_{1a} for $\lambda < 1$, which is the only possible outcome in this case. With use a value of λ very close to 0 ($\lambda = 0.001$). As expected, for very low values of λ , the model reproduces the standards results: the effects of competition on innovation are given by an inverted U-shape pattern.

In Figure 3.2 we consider the stationary strategy n_{1a} for $\lambda > 1$. Since for this case ($\lambda > 1$) there is also a second stationary strategy, Figure 3.3 plots aggregate innovation when the optimal R&D effort of firms at the leading edge is given by n_{1b} . Hence, when the ability of the leader to reduce knowledge diffusion is important enough ($\lambda > 1$) one has two possible equilibriums. When the stationary strategy of the leader is given by n_{1a} , the inverted U-shape no longer holds and innovation appears as monotonically increasing with competition. On the other hand, when the leader innovates at the (numerically) higher

rate n_{1b} exactly the opposite occurs: competition is uniformly *detrimental* to innovation. As $n_{1b} > n_{1a}$ one might interpret this results as the outcome of fierce rivalry in high technology industries.

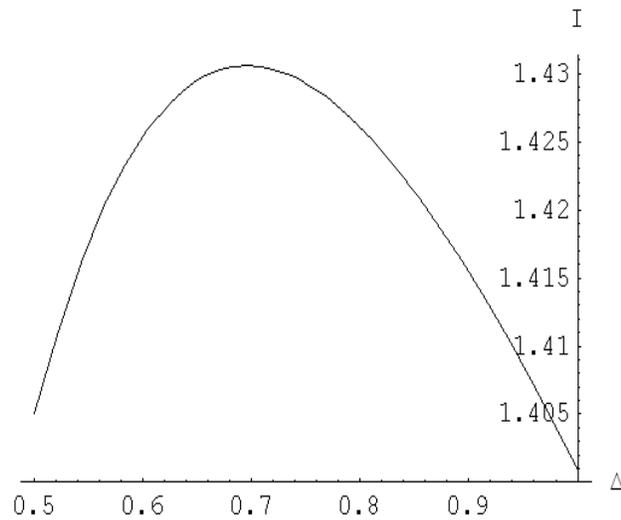


Figure 3.1. The effect of competition (Δ) on aggregate flow of innovation (I) using n_{1a}

$$h = 0.5, r = 0, c = 0.5, \pi_1 = 0.8, \lambda = 0.001$$

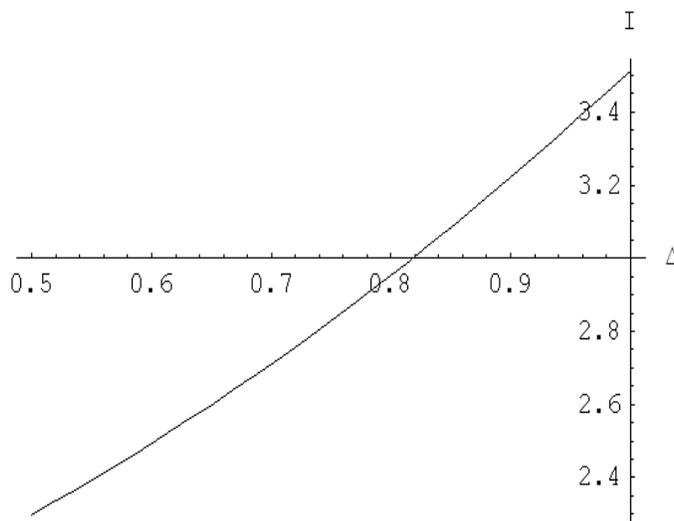


Figure 3.2. The effect of competition (Δ) on aggregate flow of innovation (I) using n_{1a}

$$h = 0.5; r = 0; c = 0.5; \pi_1 = 0.8; \lambda = 1.01$$

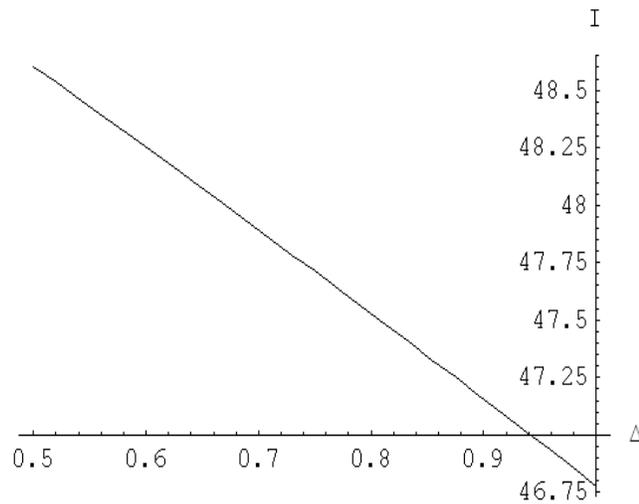


Figure 3.3. The effect of competition (Δ) on aggregate flow of innovation (I) using n_{1b}

$$h = 0.5; r = 0; c = 0.5; \pi_1 = 0.8; \lambda = 1.01$$

Since our modification of the baseline model modifies the most well known prediction of Aghion et al. (2005), namely that competition fosters innovation in industries that are close to the technological frontier, we now turn to empirical tests of the robustness of this argument. The next Section describes the empirical strategy adopted in the rest of the Chapter.

3.3 Empirical strategy

3.3.1 Dynamic issues

Our purpose is to test the impact of competition on innovation with a time-series-cross-section data at the industry level for OECD countries. This structure has two particularities. First, information on innovation is aggregated and belongs to individuals which represent

different activities performed in different countries. Second, a plausible model of the innovation process should exploit this panel structure and allow for a dynamics in which past innovations help to explain current ones. These particularities imply a non-negligible unobserved heterogeneity among individuals that will be present in both past and current innovation. More specifically let p_{it} be our proxy of innovation activity in natural log and summarise, for the moment, our explanatory covariates (in log) on the vector x_{it} . Our problem can be formulated as the estimation of the following dynamic multivariate model:

$$p_{it} = \alpha p_{it-1} + \beta x_{it} + \epsilon_{it} \quad (3.22)$$

Where $\epsilon_{it} = \eta_i + \mu_{it}$

The main issue is that the past realisation of our dependent variable is endogenous to the fixed effect in the error term. In this framework, the estimates of α provided by OLS are upward biased and those coming from the Within-group estimator are downward biased (Bond 2002; Benavente et al. 2005). While the former neglects the unobserved time-invariant heterogeneity η_i , which is the source of correlation between p_{it-1} and ϵ_{it} , the latter includes past values of p_{it} since it subtracts the mean to eliminate η_i . Although these estimators are biased, they are useful because they give an interval in which a consistent estimation of α should lie.

Several strategies can be adopted to face these dynamic concerns. They go from the estimation of the model in differences, by instrumenting Δp_{it-1} with p_{it-2} using a two stage least squares (Andersen and Hsiao 1981), to different techniques based on the generalised method of moments (GMM). GMM-based methods improve efficiency by exploiting

the moment conditions that relate deeper lags of the dependent variable, some times transformed, to the error term. Among GMM techniques we are particularly interested in the one suggested by Arellano and Bover (1995) and fully developed by Blundell and Bond (1998), usually called system GMM (S-GMM). The difference GMM (D-GMM) proposed by Arellano and Bond (1991), which applies a transformation in differences and uses the orthogonality conditions of available lags of p_{it-1} , is augmented by S-GMM under the assumption that first differences of the instrumenting variables are uncorrelated to the error in levels. Thanks to this assumption, one can include the original equation in levels and use Δp_{it-2} and deeper as instruments for p_{it-1} . The transformed equation and the one in levels make a system in which more instruments can be exploited.

The use of a new set of instruments in differences improves efficiency as it deals with the problem of weak instruments of D-GMM in persistent series. Note that equation (1) is equivalent to state $\Delta p_{it} = (\alpha - 1)p_{it-1} + \beta x_{it} + \epsilon_{it}$. Hence Δp_{it} is weakly correlated with p_{it-1} if α is close to 1. Intuitively, in the case of a process close to a random walk, past values will not predict current changes as good as past changes can predict current values. In that sense, one can expect that instrumenting p_{it-1} with Δp_{it-s} ($s = 2..T$) should give more accurate estimates. On the other hand, the inclusion of the equation in levels will be useful to keep the information of variables that do not change too much during time. This is namely the case of our proxies of regulation.

It should be stressed that our measure of innovation is based on the aggregation of patents at the country level and distributed at the industry level according to a transformation matrix linking technology and industry classification. In addition, to take into account

fixed effects related to size and economic activity we normalize this measure dividing by the hours worked. In this context, it seems reasonable to treat this aggregated normalised measure of innovation as a continuous variable rather than counts coming from independent experiments.

3.3.2 Specifying regressors x_{it}

One advantage of GMM techniques is that they allow the other regressors x_{it} to be predetermined (explained by their past realisations) or endogenous (explained by current and past realisations of other variables and by their own autoregressive process). In our basic estimation, we consider as explanatory variables x_{it} the closeness to the frontier cl_{it} , the product market competition proxy mc_{it} and their interaction $mc_{it} * cl_{it}$. As elemental controls we also include in all regressions the capital intensity kl_{it} and the externalities ex_{it} arising from the innovative activity of the same industry in the rest of the world. The interaction term will capture the extent to which product market competition influences the innovative process conditional to the proximity to the technological frontier. We also include year dummies d_t in order to control for macroeconomic shocks homogeneous across individuals. The following baseline model is estimated:

$$p_{it} = \alpha p_{it-1} + \beta_1 cl_{it} + \beta_2 mc_{it} * cl_{it} + \beta_3 mc_{it} + \beta_4 kl_{it} + \beta_5 ex_{it} + \beta_6 d_t + \epsilon_{it} \quad (3.23)$$

Even though the S-GMM estimator deal with the potential endogeneity of the regressors, as a robustness check, to reduce the risk of reverse causality, we also estimate the model considering the explicative variables lagged once:

$$p_{it} = \alpha p_{it-1} + \beta_1 cl_{it-1} + \beta_2 mc_{it-1} * cl_{it-1} + \beta_3 mc_{it-1} + \beta_4 kl_{it-1} + \beta_5 ex_{it-1} + \beta_6 d_t + \epsilon_{it} \quad (3.24)$$

Aiming at getting further insights about the concavity of the effect of competition, we augment the reduced form of the interaction and include the squares terms of the closeness to the frontier and product market competition:

$$p_{it} = \alpha p_{it-1} + \beta_1 cl_{it} + \beta_2 mc_{it} * cl_{it} + \beta_3 mc_{it} + \beta_4 kl_{it} + \beta_5 ex_{it} + \beta_7 cl_{it}^2 + \beta_8 mc_{it}^2 + \beta_6 d_t + \epsilon_{it} \quad (3.25)$$

This specification is equivalent to consider a translog approximation of a constant elasticity function between both variables that can be more precise to capture an eventual complementarity between them. A similar equation is also estimated for the model with all regressor in lag 1. Finally, we test an extended version of (3.23) and (3.25), including further controls such as import penetration, financial deepness and labour market regulation.

In all S-GMM regressions the set of instruments is composed of the dependent variable p_{it} , the closeness to the frontier cl_{it} , the product market competition mc_{it} , and their interaction $mc_{it} * cl_{it}$, all in lag two or deeper. We also use as instrument the externalities ex_{it} in lag 1 (or deeper) as we can exploit its expected exogeneity. Since the Sargan-Hansen test for overidentifying restriction, which tests the exogeneity of instruments, becomes less rigorous as the number of instruments increases, the recommendation is to have less instruments than individuals (Roodman, 2006), a rule that is in line with evidence provided by simulation (see Windmeijer 2005). Since the number of instrument is quadratic in time di-

mension and S-GMM generates not only a set of instrument for the transformed equation but also for the equation in levels, this rule, for our sample size, is some what constraining. We overcome this difficulty by using limited lags, by considering most informative instruments and by collapsing in some cases the matrix of an instrumenting variable into a vector. The latter strategy is equivalent to sum up independent moment conditions in one equation. Examples of this strategy are Calderon et al. (2002) or Beck and Levine (2004). In each case, the main criterion to accept the instrumentation strategy is the Sargan-Hansen test and its version in difference which allows to test a subset of instruments. In addition, we pay special attention to the autocorrelation of the error term, a crucial assumption for the validity of instruments in lag 2. To do so, use is made of the Arellano-Bond test for serial correlation in differences. Since by construction first order correlation is expected we only focus on the test for second order correlation in difference, which relates ϵ_{it-1} with ϵ_{it-2} by looking at the correlation between $\Delta\epsilon_{it}$ and $\Delta\epsilon_{it-2}$.

3.3.3 The marginal effect of competition on innovation

Since we have included an interaction term between product market competition and the closeness to technological frontier ($mc_{it} * cl_{it}$), the assessment concerning the expected overall effect of product market competition mc_{it} needs the computation of its marginal effect conditional on specific values of the closeness to technological frontier cl_{it} (Braumoeller 2004):

$$\frac{\partial E(p_{it}/x_{it})}{\partial mc_{it}} = \widehat{\beta}_2 cl_{it} + \widehat{\beta}_3 \quad (3.26)$$

For the translog version:

$$\frac{\partial E(p_{it}/x_{it})}{\partial mc_{it}} = \widehat{\beta}_2 cl_{it} + \widehat{\beta}_3 + 2\widehat{\beta}_8 mc_{it} \quad (3.27)$$

Similar expressions hold for (3.24) and the lagged version of (3.25). It is easy to see, for instance, that a positive and significant $\widehat{\beta}_2$ means nothing but that competition increases innovation activity *only* for an individual completely far away the technological frontier ($cl_{it} = 0$). That is for the unrealistic case of zero labour productivity. Notice that for the augmented version (3.25), the calculation of the marginal effect of competition depends on the level of competition itself mc_{it} in (3.27).

As each of these linear combinations is computed using the estimated values of β_2, β_3 and β_8 , one still needs to determine their significance, which in turn will depend on the variance of estimates and the value at which cl_{it} is evaluated (Friedrich 1982). For the (3.26), this significance is given by the ratio

$$\frac{\widehat{\beta}_2 cl_{it} + \widehat{\beta}_3}{\sqrt{\widehat{\sigma}_{\beta_3 \beta_3} + cl_{it}^2 \widehat{\sigma}_{\beta_2 \beta_2} + 2cl_{it} \widehat{\sigma}_{\beta_2 \beta_3}}}$$

Where $\widehat{\sigma}_{\gamma\delta}$ is the sample covariance between γ and δ . Hence, statistically insignificant coefficients may combine to produce statistically significant conditional effects. In our regression we evaluate the marginal effect and its significance for the minimum, one deviation under the mean, the mean, one deviation over the mean and the maximum sample values of cl_{it} . For the translog version we take the mean value of mc_{it} .

3.3.4 Testing for unit root

The validity of lagged differences as instruments for levels depends on whether this lagged differences are uncorrelated with the error term. Blundell and Bond (1998) state this assumption in terms of the stationarity of the initial conditions of the autoregressive process.

Let us consider the reduced AR(1) version of our model:

$$p_{it} = \alpha p_{it-1} + \epsilon_{it} \quad \epsilon_{it} = \eta_i + \mu_{it} \quad (3.28)$$

If the initial conditions do not deviate systematically from their long term stationary value $E \left[\left(y_{i1} - \left(\frac{\eta_i}{1-\alpha} \right) \right) \eta_i \right] = 0$, it follows that the deviation itself will be uncorrelated with the fixed effect. Thus, for the second period onwards the difference of the dependent variable will be also uncorrelated with the fixed effect. In other words, under this assumption, a first difference transformation of the instrument will be enough to purge η_i . If there is no serial correlation of μ_{it} , then $E [\Delta p_{it-1} \epsilon_{it}] = 0$.

As a consequence, we verify the risk of unit root of our main time series variables by the means of the Fisher test developed by Maddala and Wu (1999) for panel data. Alternative tests such as Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) seem less convenient for our case as they need a balanced panel data, which reduces the size of the sample and the efficiency of the test. Results are reported in Table 3.14 (appendix). In order to allow for serial correlation in the error term we consider one and two lags of Δy_{it} for each individual Augmented Dickey-Fuller test. We do not take a risk rejecting the null hypothesis of non stationary of our series.

3.4 Data

We collected information for 17 OECD countries and 15 manufacturing industries at two-digit ISIC-Rev3 from 1979 to 2003 (Table 3.8). Original data come from OECD-STAN, GGDC-ICOP project¹⁸ and EUROSTAT databases. From OECD-STAN we use trade indicators and investment series. Starting from OECD-STAN, the GGDC-ICOP data complete the information with surveys and their own estimations, consistent with national accounts.¹⁹ This data is our original source for value added series, implicit deflators and hours worked. Patent series were obtained from EUROSTAT, which distribute by industries the number of patents granted according to a matrix relating technology and industry classification.

3.4.1 Distance to frontier

Labour productivity (value added per hour worked) is used as the main measure of efficiency. The technological frontier is defined as the most productive available technology for each ISIC-Rev3 Industry at every period. The individual (country-industry couple) having the maximum labour productivity among all countries in a given year is identified as the technological leader for that year. The closeness to the frontier is measured as the ra-

¹⁸ The International Comparisons of Output and Productivity (ICOP) project of the Groningen Growth & Development Centre (GGDC)

¹⁹ GGDC-ICOP estimate OECD-STAN missing information going to alternative sources and applying different estimation methods. However, the resulting dispersion is considerably bigger (See GGDC rows in Table 3.9 in appendix). We drop GGDC-ICOP estimations of industry 30 (office machinery) because of its high dispersion and keep the OECD-STAN values for GGDC-ICOP outliers when OECD information exists. The global dispersion considerably diminishes (Filtered Data). With this filter we get 6098 observation instead of 4129, with series quite comparable to those available in OECD-STAN.

tio of labour productivity relative to that of the frontier.²⁰ For instance, the closeness to the frontier of Spain in chemical industry in 1994 is the labour productivity of the Spanish chemical industry in 1994 divided by the highest labour productivity level for chemicals among all countries in that year. We consider a moving average of three year in order to smooth the series.

All nominal series were deflated to 1997 in their national currency. However, in order to make an international comparison at the industry level, we need to take into account price differences among countries at the industry level (cross section deflation). This is particularly important for value added series since we base our productive measure on them. Use is made of the industry purchasing power parities (I-PPPs) provided by Timmer, Ympa and van Ark (2006) for 1997. The authors consider a mix between purchasing power parities based on two points of the productive process: consumer expenditure and production. Expenditure PPPs are computed from ICP index and production PPPs from average producer prices, which are calculated at the industry level dividing output values by quantities. While the former includes only final goods and must be adjusted for taxes, distribution margins and trade costs, the latter needs to face the problem of matching varieties of goods that may differ in quality and product definition among countries. The selected PPPs measure (adjusted-expenditure or production) depends on the specificity of each industry. The authors propose a harmonised dataset of purchasing power parities disaggregated at the industry level (I-PPPs) for a wide sample of developing countries. Aiming at getting comparable series, they apply the multilateral weighted aggregation method proposed by Elteto

²⁰ The distance to frontier is the inverted ratio.

and Koves (1964) and Szulc (1964) (EKS). This method allows to obtain transitivity in multilateral comparisons starting from binary comparisons.

Table 3.10 (appendix) shows the average labour productivity of each country for the full sample period and compares the values whether one uses the standard (non-adjusted) expenditure PPPs at the country level or the industry-PPP computed by Timmer, Ympa and van Ark (2006). Table 3.11 (appendix) presents similar figures at the industry level (world sample average). At the country level the average of labour productivity for the full sample period seems similar among countries. However, the variation induced by both measures increases if one considers the industry level. This issue is important because the hierarchy in terms of productivity and namely the identification of the frontier level might change. This is what Table 3.12 (appendix) shows using the number of times a country is at the frontier level in some of its industries.

3.4.2 Innovation

As a proxy of innovation we consider the number of patents. At the industry level, they are provided by EUROSTAT. In this database the applications at the European Patents Office (EPO) are linked to industry standard classifications by the means of a detailed matrix of weights. This matrix builds on firm data allowing to relate ISIC industries to the subclasses of International Patent Classification (IPC) categories. The US counterpart of the EPO is the United States Patents and Trademarked Office (USPTO). Both series are not directly comparable since the EPO system informs about applications and the USPTO about patent granted. We consider the EPO system as it is more representative for the countries present

in our sample. Aiming at controlling for market size effects, patents are normalised by the hours worked of the industry. At the end we get a continuous aggregated measure of innovation that enables international comparisons at the industry level.

Information on R&D expenditure, disaggregated at the industry level, is available from the OECD ANDBERD database. Nevertheless, the intersection between R&D information and the availability of the rest of variables leads to a significant reduction of the number of observations (mainly Austria, Greece, Ireland and Portugal) and the data is only available from 1987.

3.4.3 Competition and regulation measures

Five indicators have been selected to capture product market competition. On order to capture the extent of competition, we use both input (*de jure*) and output (*de facto*) measures of the competitive environment. Within the first group of proxies, we consider four indicators of market regulation: (1) the global product market regulation PMR provided by the OECD and documented by Conway, Janod and Nicoletti (2005); (2) the size of the public enterprise sector PMR(public), a component of PMR that focuses on state control; (3) the regulatory provisions in non-manufacturing sectors (telecoms, electricity, gas, post, rail, air passenger transport, and road freight) summarised by the REGREF indicator, also provided by the OECD (Conway and Nicoletti, 2006) and (4) the corresponding effect of these regulatory provisions on the manufacturing sector given by the REGIMP indicator, which is also documented by (Conway and Nicoletti, 2006). REGIMP is based on an input/output matrix defining the use of non-manufacturing sectors as inputs in manufacturing. Thus, it

aims at capturing the "knock-on" effect of regulation in selected non-manufacturing sectors on manufacturing.

On the other hand, we also consider a measure of the outcome of competition, namely the number of firms per value added (N-FIRMS/VA), which is a proxy of market atomicity (or the inverse of the average size), usually expected to be the result of the reduction of market barriers.

The scope of these indicators is as follows. REGIMP and N-FIRMS/VA are consistent with our time-series-cross-section data structure. REGREF is a time series at the country level reflecting the evolution of the economy-wide competitive environment. Finally, PMR and PMR(public) are computed at the country level for two point times (1998 and 2003). They have been distributed for two periods: before and after 2000. Since PMR is based on a collection of private and governmental practices, this distribution should be in line with the evolution of European market reforms. Figure 3.4 gives a picture of the hierarchy of countries depending on their regulatory environments.

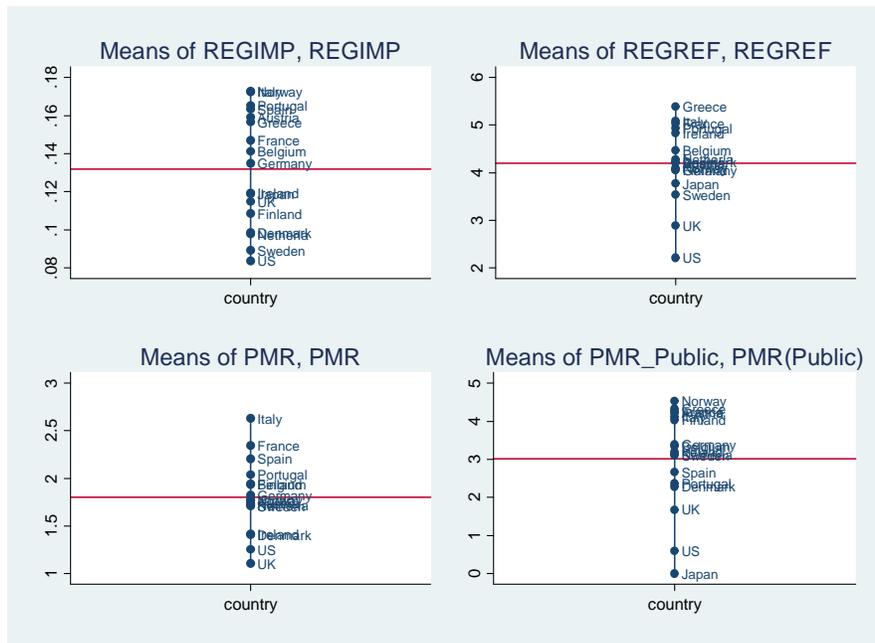


Figure 3.4. Hierarchy of regulatory environments

3.4.4 Controls

We use two elemental controls: capital intensity and innovation spillovers. Capital series were constructed using investment series and the standard Perpetual Inventory Method (PIM). This method uses the dynamic rule by which current capital stock equals the stock of the preceding period after depreciation plus current investment. To compute the initial stock, the PIM method supposes that pre-sample investment grows at a constant rate. Under the assumption of steady state this rate equals the one of value added. After applying this result to the dynamic rule, the initial stock becomes a function of initial investment, the global depreciation rate and the steady state growth rate of value added. We proxy the latter with the mean of the sample period and use a depreciation rate of 7.5%, the standard assumption. To capture innovation spillovers, we consider patenting activity of the rest

of the world in the same manufacturing industry (the number of patents per hour worked produced by the same industry in the rest of the world).

As additional controls, we also include indicators of foreign competition, labour market regulation and financial deepness: the import penetration ratio MPEN available in OECD-STAN at the industry level, the employment protection indicator EPLBLD proposed by Amable, Demmou and Gatti (2007) at the country level, which updates the EPL indicator of the OECD, and the financialisation ratio defined as the total assets of institutional investors relative to GDP. Table 3.13 (appendix) summarises the main descriptive statistics.

3.5 Results

3.5.1 OLS and Within-group regressions

Table 3.1 presents OLS and Within-group estimates of the effects of competition on patenting using *de facto* and *de jure* measures of competition: the number of firms relative to value added (N-FIRMS/VA in columns [1] to [3]) the "knock-on" effect of regulation in non-manufacturing sectors (REGIMP in columns [4] to [6]), the indicator of competition in non-manufacturing sectors (REGREF in columns [7] to [9]), the economy-wide indicator of product market regulation (PMR in [10] to [12]) and the indicator for public sector (PMR(Public) in [13] to [16]). The models differ with the inclusion of the lagged dependent variable and the estimator: OLS or Within-group panel estimator. Models [3], [6], [9], [12] and [15] are first difference equations with no lagged dependent variable. This

amounts to forcing the coefficient of the lagged dependent variable in level to be equal to one.

As expected, the coefficient on the lagged dependent variable differs greatly between the OLS and fixed-effect estimator, being greater for the former model. Also the signs of the coefficients for the externality effect and the capital/labour ratio are mostly significantly positive. For each regression, the lower panel of the Table presents the estimated marginal effects of the competition indicator for different levels of the relative productivity level (the closeness to the frontier). The first line of the lower panel gives the value of the marginal effect when the relative technological level is at its minimum (min), i.e. when the distance to frontier is at its maximum. The last lines give the marginal effects and standard errors when the relative productivity level is at the maximum of the sample, i.e. at the technology frontier. Marginal effects coefficients are also presented for the mean value of the relative technological level, the mean value minus one standard deviation and plus one standard deviation. Therefore, reading a column of the lower panel of the Table shows how the marginal effect of competition changes as the distance to the technological frontier decreases and vanishes.

The interpretation of the marginal effect for regressions [1] to [3], with the relative number of firms indicator, differs from the interpretation for the other indicators. A higher relative number of firms is a direct measure competition since it informs about the number of competitors that share the same market. It can also be interpreted as an inverse measure of the average firms' size in the industry, related to the level of concentration in the industry. If competition is more favourable to innovation near the technological frontier,

Dependent Variable: Patenting (patents decomposition /hours worked) - OLS and Within Group Estimators
 Regressions for Competition ([1] to [3]) and Regulation ([4] to [15])

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
	N-FIRMSVA			REGIMP			REGREF			PMR			PMR(Public)		
Patenting (t-1)	0.974*** (0.009)	0.328*** (0.072)		0.961*** (0.006)	0.557*** (0.032)		0.960*** (0.006)	0.599*** (0.029)		0.961*** (0.007)	0.637*** (0.029)		0.944*** (0.007)	0.596*** (0.030)	
Closeness to Frontier	-0.030 (0.027)	-0.096* (0.056)	0.003 (0.054)	0.026 (0.089)	-0.181 (0.161)	-0.077 (0.151)	-0.021 (0.042)	-0.001 (0.045)	0.062 (0.048)	0.001 (0.029)	0.013 (0.038)	0.068* (0.038)	0.028 (0.038)	0.082** (0.039)	0.027 (0.043)
Closeness x Competition (Regulation)	-0.010 (0.016)	-0.089*** (0.028)	-0.006 (0.026)	0.012 (0.042)	-0.075 (0.078)	-0.043 (0.069)	0.023 (0.034)	-0.011 (0.041)	-0.047 (0.047)	-0.027 (0.052)	-0.069 (0.071)	-0.131* (0.079)	-0.007 (0.030)	-0.084*** (0.032)	-0.013 (0.037)
Competition (Regulation)	0.059 (0.065)	0.402*** (0.117)	0.060 (0.107)	-0.024 (0.174)	-0.514 (0.348)	0.568* (0.312)	-0.026 (0.142)	-0.138 (0.189)	0.187 (0.219)	0.228 (0.220)	0.322 (0.341)	1.070*** (0.358)	0.114 (0.125)	0.064 (0.285)	0.573* (0.333)
Externalities	0.032*** (0.009)	0.330*** (0.088)	-0.066 (0.100)	0.039*** (0.006)	0.419*** (0.065)	-0.021 (0.062)	0.041*** (0.006)	0.351*** (0.061)	0.005 (0.062)	0.038*** (0.007)	0.306*** (0.059)	0.013 (0.059)	0.057*** (0.007)	0.327*** (0.060)	0.011 (0.061)
Capital Intensity	0.011 (0.011)	0.537*** (0.083)	0.103 (0.072)	0.002 (0.009)	0.254*** (0.031)	0.087** (0.036)	0.002 (0.009)	0.246*** (0.031)	0.082** (0.036)	0.000 (0.009)	0.233*** (0.031)	0.082** (0.036)	0.004 (0.009)	0.249*** (0.031)	0.081** (0.035)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Obs	1352	1352	1352	2646	2646	2646	2646	2646	2646	2521	2521	2521	2646	2646	2646
Individuals	1352	133	133	148	148	148	148	148	148	134	134	134	148	148	148
Estimator	OLS	Within	Within	OLS	Within	Within	OLS	Within	Within	OLS	Within	Within	OLS	Within	Within

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
	N-FIRMSVA			REGIMP			REGREF			PMR			PMR(Public)		
Closeness (sample values)	0.039 (0.035)	0.233*** (0.064)	0.048 (0.059)	-0.001 (0.095)	-0.655*** (0.219)	0.487** (0.195)	0.016 (0.078)	-0.158 (0.116)	0.099 (0.134)	0.176 (0.123)	0.190 (0.224)	0.820*** (0.226)	0.101 (0.069)	-0.094 (0.245)	0.549* (0.280)
Mean less one standard deviation	0.021** (0.010)	0.080*** (0.019)	0.037** (0.018)	0.019 (0.028)	-0.781*** (0.137)	0.415*** (0.118)	0.054** (0.026)	-0.177*** (0.061)	0.020 (0.068)	0.127*** (0.037)	0.066 (0.145)	0.586*** (0.140)	0.089*** (0.020)	-0.236 (0.216)	0.527** (0.240)
Mean	0.017*** (0.006)	0.043*** (0.013)	0.035*** (0.012)	0.025 (0.017)	-0.815*** (0.130)	0.395*** (0.110)	0.065*** (0.018)	-0.182*** (0.052)	-0.001 (0.057)	0.117*** (0.025)	0.039 (0.138)	0.535*** (0.135)	0.086*** (0.010)	-0.274 (0.211)	0.522** (0.231)
Mean plus one standard deviation	0.013* (0.007)	0.006 (0.016)	0.032** (0.015)	0.030 (0.022)	-0.849*** (0.133)	0.376*** (0.110)	0.075*** (0.022)	-0.187*** (0.049)	-0.022 (0.052)	0.106*** (0.027)	0.013 (0.135)	0.485*** (0.136)	0.083*** (0.014)	-0.312 (0.206)	0.516** (0.222)
Maximum	0.011 (0.009)	-0.008 (0.019)	0.031* (0.017)	0.032 (0.026)	-0.859*** (0.136)	0.370*** (0.112)	0.078*** (0.025)	-0.188*** (0.049)	-0.028 (0.052)	0.102*** (0.031)	0.002 (0.136)	0.465*** (0.138)	0.082*** (0.017)	-0.323 (0.204)	0.514** (0.220)

Note: Hubert-White corrected standard errors in parentheses
 * p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.1.

the marginal effects should increase as the relative technological level augments from its minimum to its maximum. Indeed, if one follows strictly the predictions of Aghion et al. (2005), Aghion (2006), one should expect a negative marginal effect of competition far from the technological frontier (the Schumpeterian effect) and a positive effect close to the frontier (the 'escape competition' effect). Results reported in Table 3.1 show that, while the relative number of firms is positively correlated with innovation in laggard industries, its effect decreases as the industry moves closer to the technological frontier. At the leading edge the effect of competition given by this indicator loses its significance. Having a less concentrated industry seems to matter more when the industry is far from the leading edge than when it is near. This result is true whatever the estimator or specification, only the magnitude of the effects and their significance change. This result could be compared with the positive size effect found in many micro studies of innovation. If the firm size is a positive influence on innovation, one may suppose that it will be all the more important that the technological competition is fierce, i.e. that the industry is close to the leading edge.

Using a proxy for size or concentration in the industry is subject to the usual limitations: it measures the outcome of the competition process, not so much the competitive environment. In this respect, the use of indicators of regulation will make it possible to avoid ambiguous interpretations of the results. The interpretation of the marginal effects of regulation according to the proximity to the frontier is straightforward. Again, if competition is good for innovation, product market regulation should exert a negative influence on patenting, all the more so that the distance to frontier diminishes. Indeed, for Conway, Janod and Nicoletti (2005) and Conway and Nicoletti (2006), these regulation proxies re-

flect ant-competitive market barriers. Following Aghion et al.'s (2005) predictions, regulation could be good when the industry is far from the frontier, but should gradually become detrimental as the distance to frontier is reduced. One observes contrasted results in regressions using the REGIMP indicator (columns [4] to [6] in Table 1), which is provided in panel-data-like structure (times-series-cross-section data). The OLS regression gives marginal effects non significantly different from zero, i.e. no impact of product market regulation on innovation whatever the distance to frontier. The fixed effect regression gives a statistically negative impact of regulation, which is increasing with the relative technological level. On the other hand, considering the model without the lagged dependent variable gives significant positive marginal effects of regulation.

Looking at the results documented in Table 3.1 (columns [4] to [15]), three configurations emerge. The most frequent case is that of a positive impact of regulation policy, which is decreasing as the industry approaches the technological frontier but remains significantly positive even at the frontier ([6], [10],[12],[13] and [15]). In regression [7], this positive marginal effect appears on the contrary to increase as the industry moves closer to the frontier. On the other hand, regulation policy turns out to have a negative significant marginal effect in regressions [5] and [8]. Although this effect is decreasing with the closeness to the frontier, it appears significantly negative for laggard industries. Furthermore, in some cases regulation turns out to have non significant marginal effects, no matter what the distance to the frontier is ([4],[9],[11] and [14]). Interestingly, even if these regressions do not allow to conclude to a single pattern of the relationship between competition and innovation, none of them reproduce the predictions of the baseline model.

3.5.2 Addressing dynamics (System-GMM regressions)

As argued in the previous Section, OLS and Within-group estimators may not be appropriate for the problem considered here. The use of the S-GMM estimator will allow us to deal with the lagged dependent variable bias and the potential endogeneity of several of the regressors. One may indeed suppose that the competition indicators taken into account here are endogenous. For instance, lagging firms or industries may pressure for protection from competition in exchange for political support, whereas the support for regulation would be less pronounced in the vicinity of the technological frontier. Other variables may also be endogenous to the growth process itself. For these reasons, the competition indicators and the capital/labour ratio will be considered as endogenous in the S-GMM estimations.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations
Regressions for Competition ([1]) and Regulation ([2] to [5])

	N-FIRMS/VA [1]	REGIMP [2]	REGREF [3]	PMR [4]	PMR (Public) [5]
Patenting (t-1)	0.896*** (0.064)	0.903*** (0.032)	0.843*** (0.049)	0.922*** (0.022)	0.887*** (0.033)
Closeness to Frontier	-0.013 (0.126)	1.924** (0.972)	-0.284 (0.230)	0.003 (0.053)	0.046 (0.129)
Closeness x Competition (Regulation)	-0.113* (0.067)	0.936** (0.469)	0.494** (0.198)	0.020 (0.114)	0.068 (0.096)
Competition (Regulation)	0.509* (0.280)	-3.794** (1.909)	-1.926** (0.823)	0.257 (0.450)	-0.144 (0.397)
Externalities	0.177* (0.105)	0.116** (0.046)	0.219*** (0.064)	0.084*** (0.024)	0.114*** (0.036)
Capital Intensity	0.032 (0.057)	-0.032 (0.041)	0.122 (0.079)	-0.041 (0.039)	0.118** (0.055)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1352	2646	2646	2521	2646
Sargan-Hansen p	0.387	0.164	0.117	0.187	0.224
AR(2)p	0.522	0.908	0.919	0.654	0.946
Instruments	122	136	131	106	142
Individuals	133	148	148	134	148
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM
Marginal effect of competition ([1]) and Regulation ([2] to [5])					
Closeness (sample values)	N-FIRMS/VA [1]	REGIMP [2]	REGREF [3]	PMR [4]	PMR (Public) [5]
Minimum	0.294* (0.153)	-2.033** (1.027)	-0.997** (0.455)	0.294 (0.264)	-0.017 (0.217)
Mean less one standard deviation	0.100** (0.045)	-0.451* (0.240)	-0.162 (0.150)	0.330* (0.175)	0.098 (0.063)
Mean	0.053* (0.028)	-0.028 (0.062)	0.061 (0.105)	0.338* (0.183)	0.128*** (0.038)
Mean plus one standard deviation	0.006 (0.035)	0.395** (0.200)	0.284** (0.125)	0.345* (0.199)	0.159*** (0.052)
Maximum	-0.012 (0.042)	0.516** (0.258)	0.348** (0.141)	0.348* (0.208)	0.167*** (0.062)

Note: Hubert-White corrected standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.2.

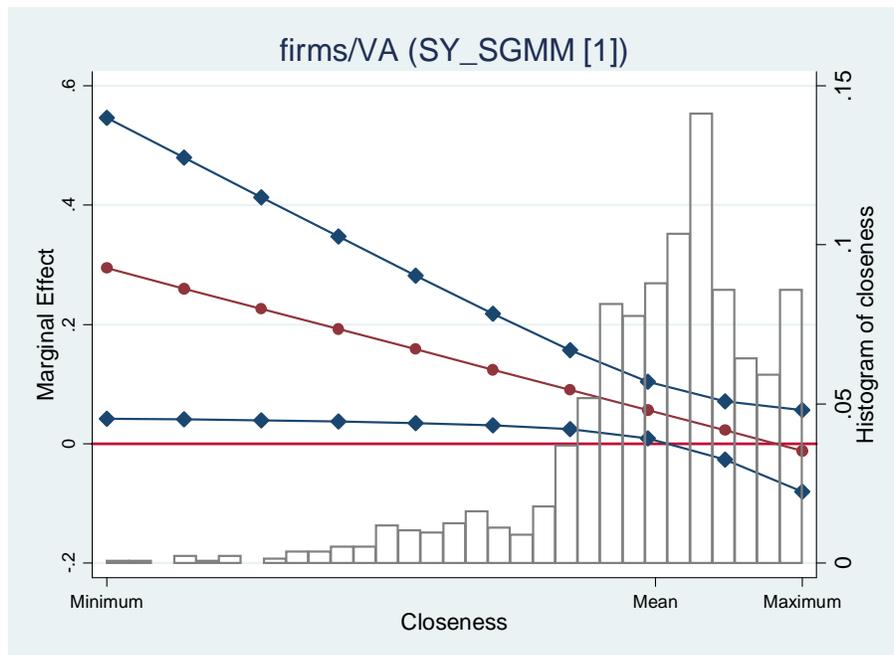


Figure 3.5. Marginal effect of N-Firms/VA on patenting

Table 3.2 presents the S-GMM estimations of the effects of competition on innovation. As in our previous results, the number of firms plays a positive role for innovation, but only when industries are far from the technological frontier (Column [1]). This effect vanishes once the relative productivity level rises above the mean. Figure 3.5 presents the plot of the marginal effect against the closeness to the technological frontier. As one notices clearly with the confidence intervals, a significant innovation-boosting effect exists only for industries under the mean relative productivity. The Figure displays also the histogram of the relative productivity levels. One notices that only a limited number of industry laggards are likely to benefit from increased competition while the bulk of the industries would benefit very little if anything.

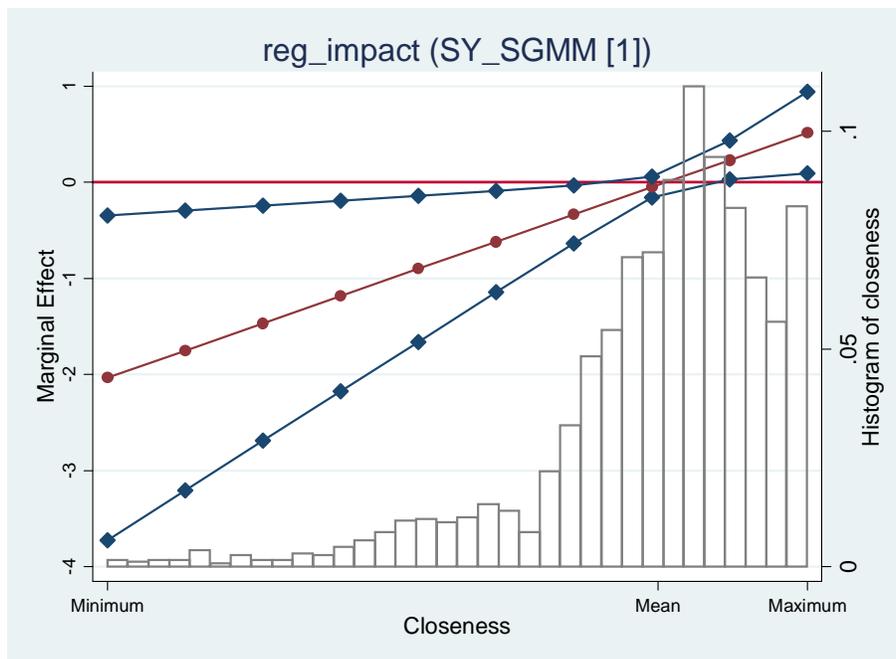


Figure 3.6. Marginal effect of REGIMP on patenting

This effect of competition is broadly confirmed by the results obtained using the indicators of regulation. For the regulation impact (Column [2] and Figure 3.6) and regulation in non-manufacturing activities (Column [3] and Figure 3.7) indicators, competition regulation has a negative impact on innovation far from the frontier. This effect becomes gradually positive as the relative productivity level increases above the mean and turns out to be significantly positive at the frontier. The results for the economy-wide product market regulation indicators (Columns [4] and [5], Figures 3.8 and 3.9) are in line with those just mentioned. Product market regulation has no impact on innovation far from the frontier, and an increasingly positive effect as the productivity level rises.

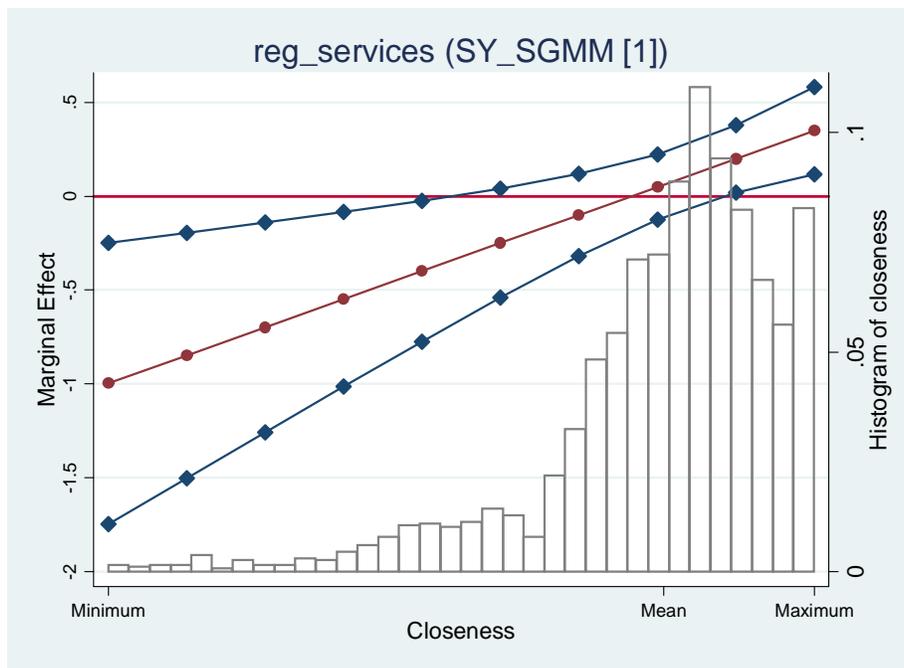


Figure 3.7. Marginal effect of REGREF on patenting

On the whole, the use of an estimator well-suited to a dynamic specification allows to depict a clearer picture about the marginal effect of competition and regulation according to the proximity to the technological frontier: product market regulation has an increasingly positive impact on innovation as the industry moves closer to the frontier, i.e. the marginal effects of regulation indicators display a positive slope. The findings with the relative number of firms as a proxy for the outcome of market competition are consistent with this result. The next Section checks the robustness of these results by considering alternative specifications under system GMM.

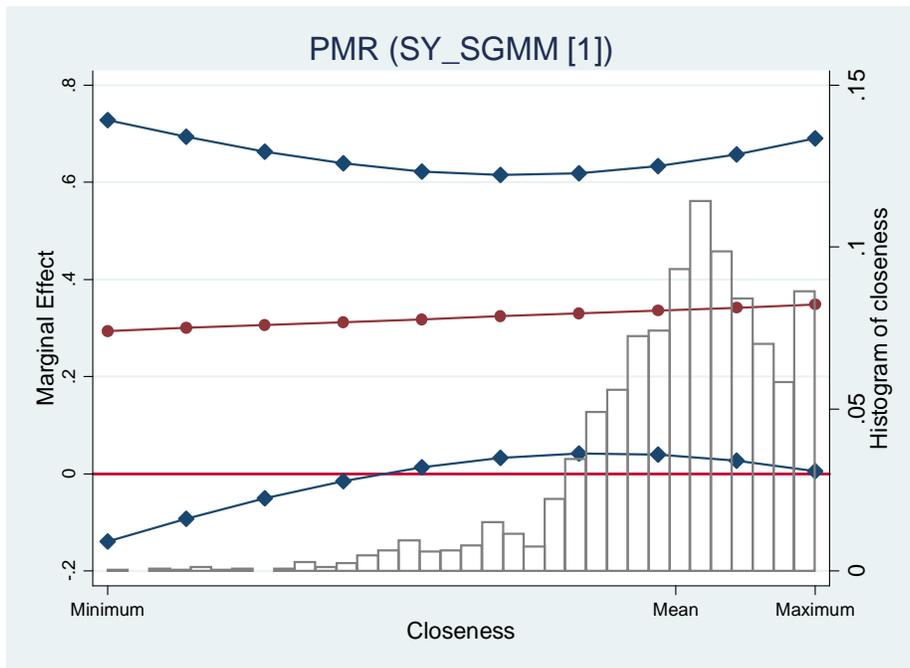


Figure 3.8. Marginal effect of PMR on patenting

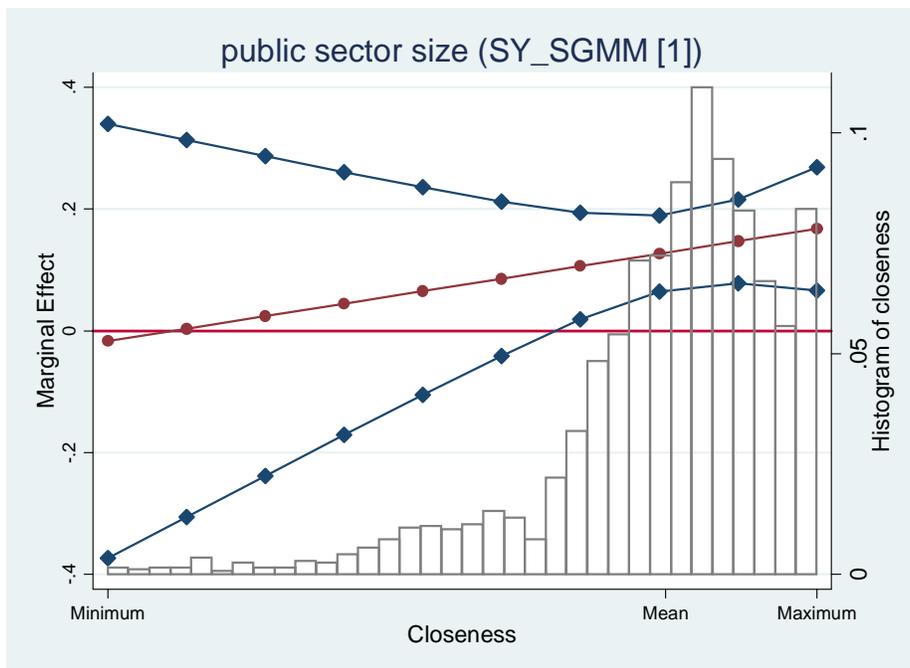


Figure 3.9. Marginal effect of PMR(Public) on patenting

3.6 Robustness tests

3.6.1 Additional controls

The model considered in the preceding Section is now extended to include other variables. The competition indicators considered previously referred to the domestic situation only. However competition from foreign firms can be important in some industries. In order to control for this effect, the import penetration ratio is included in the regressions. Other institutional variables may have an influence too. The literature on competition and innovation refers particularly to labour and financial markets (Aghion, 2006). More labour market flexibility is supposed to favour restructuring and hasten the decline of sunset industries, allowing factors to be transferred to sunrise industries (Saint-Paul, 2002). Also, more developed financial markets are expected to boost innovative investment since credit-constrained firms may not be able to finance the fixed costs necessary to develop new product or processes. For these reasons, two variables were introduced in the regression: a measure of employment protection and the ratio of total financial assets of institutional investors to GDP (OECD). Results for the extended models are presented in Table 3.3.

Import penetration turns out to have significant coefficients for models [1] and [4]. Each time, the coefficient is positive, which means that the innovation-boosting effect of foreign competition is present. However, changing the competition indicator leads to non significant coefficients in models [2], [3] and [5]. The labour market legislation (employment protection) variable obtains significant coefficients with all regulation indicators. However, the impact is negative with the economy-wide product market regulation indi-

cators ([4] and [5]) but positive with the non-manufacturing regulation indicators ([2] and [3]). One cannot therefore conclude to the existence of an innovation-hindering effect of employment legislation. Finally, the financial variable obtains significant, positive, coefficients with the economy-wide indicators ([4] and [5]).

The extension of the model with the three variables do not significantly change the results concerning the marginal effect of product market regulation or competition. The magnitude of the effect is sometimes changed (for instance with the "knock-on" effect of non-manufacturing regulation REGIMP) but the positively-sloped relationship of the regulation effect with the relative productivity level is maintained. The same applies for the negative slope of the marginal effect of the relative number of firms ([1]) The only change worth mentioning takes place with the REGREF indicator([3]), usually used as proxy of the evolution of regulation at the national level. Using this indicator, regulation now fails to have a positive impact on innovation even at the frontier. However, since REGIMP seems more suited to the industry-level data used in the estimations, the results of model [2] are supposed to be more accurate. One can also note that the positive impact of the PMR variable restricted to the Public Sector [5] turns now significant far from the technological frontier whereas it was not the case in the baseline model (Table 3.2, column [5]).

We also consider a translog-like specification to test the effect of the interaction between competition and proximity to the frontier. To this effect, quadratic terms for the distance to frontier and the competition indicators were introduced in the regressions. This more flexible function should make it possible to estimate more accurately the effects of regulation. Results are presented in Table 3.4. Once again, nothing substantial is altered in

comparison with the results in Tables 3.2 or 3.3. The slopes of the marginal effects remain the same and the magnitude of the effects is not changed very much. However, this time, regulation fails to have a positive innovation effect at the frontier even with the REGIMP indicator.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations					
Regressions for Competition ([1]) and Regulation ([2] to [5]) (Full set of controls)					
	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Patenting (t-1)	0.919*** (0.027)	0.857*** (0.044)	0.840*** (0.044)	0.835*** (0.051)	0.693*** (0.082)
Closeness to Frontier	-0.125 (0.133)	1.411*** (0.516)	-0.031 (0.125)	-0.117 (0.106)	-0.027 (0.111)
Closeness × Competition (Regulation)	-0.104 (0.069)	0.665*** (0.257)	0.065 (0.115)	0.265 (0.163)	0.059 (0.086)
Competition (Regulation)	0.469 (0.289)	-2.814*** (1.067)	-0.780 (0.551)	-0.010 (0.927)	0.775 (0.485)
Externalities	0.061* (0.035)	0.156*** (0.041)	0.152*** (0.043)	0.106* (0.062)	0.282*** (0.086)
Capital Intensity	0.168** (0.070)	-0.069 (0.074)	0.033 (0.054)	0.015 (0.063)	0.119** (0.057)
Import Penetration	0.109* (0.062)	-0.054 (0.047)	0.015 (0.060)	0.239** (0.118)	0.052 (0.092)
Labour Market Regulation	-0.045 (0.033)	0.118* (0.069)	0.169* (0.098)	-0.444** (0.207)	-0.278* (0.153)
Financial Assets/GDP	-0.019 (0.051)	-0.001 (0.060)	-0.012 (0.055)	0.293** (0.117)	0.518** (0.207)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1154	2110	2110	2110	2110
Sargan-Hansen p	0.378	0.148	0.125	0.128	0.117
AR(2)p	0.823	0.920	0.885	0.900	0.873
Instruments	99	122	93	75	106
Individuals	125	126	126	126	126
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM
Marginal effect of Competition ([1]) and Regulation ([2] to [15])					
Closeness (sample values)	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Minimum	0.232* (0.134)	-1.425*** (0.534)	-0.644* (0.341)	0.545 (0.673)	0.899** (0.394)
Mean less one standard deviation	0.086** (0.042)	-0.349** (0.142)	-0.538** (0.222)	0.974* (0.545)	0.994*** (0.371)
Mean	0.045* (0.024)	-0.104 (0.091)	-0.513** (0.209)	1.072** (0.531)	1.016*** (0.373)
Mean plus one standard deviation	0.004 (0.029)	0.142 (0.119)	-0.489** (0.204)	1.171** (0.522)	1.038*** (0.377)
Maximum	-0.012 (0.037)	0.248* (0.150)	-0.479** (0.205)	1.213** (0.521)	1.047*** (0.380)

Note: Hubert-White corrected standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.3.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations
 Regressions for Competition ([1]) and Regulation ([2] to [5]) (Translog Model)

	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Patenting (t-1)	0.918*** (0.031)	0.836*** (0.041)	0.865*** (0.033)	0.913*** (0.024)	0.880*** (0.031)
Closeness to Frontier	0.891* (0.479)	0.385 (0.681)	0.674 (0.846)	0.115 (0.580)	0.301 (0.298)
Closeness x Competition (Regula	-0.061 (0.038)	0.396* (0.218)	0.505** (0.242)	0.042 (0.096)	0.052 (0.089)
Competition (Regulation)	0.295** (0.147)	-1.248 (1.070)	-4.420*** (1.406)	1.001* (0.514)	-0.132 (0.345)
Externalities	0.102** (0.047)	0.191*** (0.051)	0.180*** (0.042)	0.095*** (0.026)	0.119*** (0.035)
Capital Intensity	0.037 (0.046)	0.011 (0.041)	0.014 (0.038)	-0.033 (0.043)	0.103*** (0.036)
Closeness to Frontier ²	-0.139** (0.064)	-0.099 (0.113)	0.078 (0.082)	-0.014 (0.084)	-0.037 (0.041)
Competition ² (Regulation ²)	0.013 (0.010)	-0.095 (0.201)	-0.553*** (0.161)	-0.533*** (0.169)	0.087 (0.111)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1352	2646	2646	2521	2646
Sargan-Hansen p	0.556	0.185	0.211	0.288	0.117
AR(2)p	0.524	0.950	0.904	0.651	0.958
Instruments	121	142	144	106	143
Individuals	133	148	148	134	148
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM

Closeness (sample values)	Marginal effect of Competition ([1]) and Regulation ([2] to [15])				
	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Minimum	0.178** (0.076)	-0.765* (0.429)	-1.180** (0.542)	0.485* (0.286)	0.152 (0.263)
Mean less one standard deviation	0.073*** (0.021)	-0.096 (0.132)	-0.327** (0.147)	0.560** (0.234)	0.240 (0.160)
Mean	0.048** (0.020)	0.082 (0.137)	-0.098 (0.074)	0.576** (0.238)	0.263* (0.148)
Mean plus one standard deviation	0.022 (0.030)	0.261 (0.198)	0.130 (0.115)	0.592** (0.247)	0.286** (0.145)
Maximum	0.013 (0.034)	0.312 (0.221)	0.195 (0.141)	0.598** (0.252)	0.293** (0.147)

Note: Hubert-White corrected standard errors in parentheses
 * p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.4.

The two above-mentioned extensions can be combined to obtain a translog model with the full set of controls. Table 3.5 presents the estimations of this model with the various competition or regulation indicators. The results concerning the marginal effects are basically unchanged. The main result, i.e. the non existence of a significant negative effect of product market regulation at the technological frontier, is preserved. However, it should be also noticed that, relatively to the simple translog model, the extended one pro-

vides a better assessment of the impact of regulation. While in the previous table (Table 3.4, columns [2] and [3]) the marginal effects of regulation in services and their impact on industries were only significant far from the frontier, they are now significant for a larger interval. Concerning the effects of additional controls, results are not substantially modified. The positive effects of labour market legislation obtained with the *regimpact* and *REGREF* indicators now turn out to be insignificant (columns [2] and [3]) while the negative impact obtained with the economy-wide regulation indicators is maintained. The financial assets variable only obtains a significant coefficient with the *PMR* variable restricted to the Public sector (column [5]).

Besides some changes in the significance and magnitude of the marginal effect of regulation, the picture depicted in the system-GMM regressions (Table 3.2) remains qualitatively unchanged after this first robustness test. Indeed, most of the time, regulation policy improves innovative performances as one moves closer to the leading edge of technology (columns [2][4][5], Tables 3.2, 3.3 and 3.4). Only the model with additional institutional controls using the regulation in services indicator (column [3], Tables 3.3 and 3.5) delivers divergent results. Product market regulation turns out significantly detrimental to innovative performances near the frontier only in regression [3] in Table 3.3. Nevertheless, this adverse impact of services regulation is weaker the closer to the frontier an industry is.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations
 Regressions for Competition ([1]) and Regulation ([2] to [5]) (Full set of controls; Translog Model)

	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Patenting (t-1)	0.920*** (0.023)	0.950*** (0.031)	0.814*** (0.053)	0.927*** (0.040)	0.688*** (0.076)
Closeness to Frontier	0.344 (0.825)	1.632 (1.103)	1.495 (1.148)	-0.520 (0.599)	0.791 (0.817)
Closeness x Competition (Regulation)	-0.101 (0.066)	0.565** (0.276)	0.401 (0.246)	0.101 (0.143)	0.075 (0.076)
Competition (Regulation)	0.462* (0.274)	-4.143** (2.003)	-1.016 (0.860)	0.850 (0.951)	0.814 (0.529)
Externalities	0.066** (0.033)	0.062** (0.029)	0.165*** (0.052)	0.025 (0.036)	0.292*** (0.080)
Capital Intensity	0.154** (0.064)	0.006 (0.103)	0.087 (0.058)	0.032 (0.053)	0.127** (0.061)
Import Penetration	0.099* (0.054)	-0.023 (0.069)	0.073 (0.061)	0.205** (0.104)	0.032 (0.094)
Labour Market Regulation	-0.031 (0.036)	-0.026 (0.077)	0.058 (0.093)	-0.276* (0.161)	-0.308* (0.177)
Financial Assets/GDP	-0.000 (0.050)	-0.021 (0.060)	-0.017 (0.061)	0.088 (0.092)	0.490** (0.204)
Closeness to Frontier ²	-0.062 (0.107)	-0.046 (0.103)	-0.249 (0.182)	0.064 (0.093)	-0.113 (0.116)
Competition ² (Regulation ²)	0.008 (0.011)	-0.421 (0.300)	-0.391** (0.189)	-0.416 (0.429)	-0.057 (0.159)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1154	2110	2110	2110	2110
Sargan-Hansen p	0.294	0.137	0.219	0.231	0.210
AR(2)p	0.815	0.928	0.893	0.920	0.889
Instruments	103	95	88	77	110
Individuals	125	126	126	126	126
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM
	Marginal effect of Competition ([1]) and Regulation ([2] to [15])				
	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Closeness (sample values)					
Minimum	0.233* (0.125)	-1.222** (0.578)	-1.250* (0.651)	0.596 (0.501)	0.846** (0.348)
Mean less one standard deviation	0.091** (0.038)	-0.308* (0.187)	-0.601** (0.284)	0.759* (0.448)	0.967*** (0.351)
Mean	0.052** (0.023)	-0.099 (0.150)	-0.453** (0.216)	0.796* (0.452)	0.995*** (0.357)
Mean plus one standard deviation	0.013 (0.031)	0.109 (0.175)	-0.305* (0.172)	0.833* (0.462)	1.022*** (0.366)
Maximum	-0.003 (0.039)	0.199 (0.201)	-0.241 (0.164)	0.849* (0.468)	1.034*** (0.370)

Note: Hubert-White corrected standard errors in parentheses
 * p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.5.

3.6.2 The model with lagged regressors

To test further the robustness of the results, regressors are now included with a lag. This specification allow to further reduce the risk of reverse causality. Results for the base and for the translog models are presented in Tables 3.6 and 3.7 and are compared with those of the contemporaneous model (Tables 3.2 and 3.4).

Concerning the base model for the S-GMM estimates, two main differences arise. First, while the contemporaneous model account for a positive significant impact of regulation close to the frontier (Table 3.2, columns [2] and [3]), regulation policy in the lagged model does not have a significant impact near the frontier (Table 3.6, columns [2] and [3]). In contrast, the economy-wide regulation indicator for the Public sector turns out now to have a significant and positive impact for laggard industries, while they were non significant in the baseline model (Table 3.2 and 3.6, columns [4] and [5]). For all regulation indicators the main result obtained with system-GMM estimations is confirmed, i.e. a positively-sloped relationship for the marginal effect of regulation as the distance to the frontier decreases. Also, one should note that the negative slope for the relative number of firms is preserved.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations
Regressions for Competition ([1]) and Regulation ([2] to [5]) (Lagged Regressors)

	N-FIRMS/VA [1]	REGIMP [2]	REGREF [3]	PMR [4]	PMR (Public) [5]
Patenting (t-1)	0.875*** (0.054)	0.875*** (0.041)	0.863*** (0.041)	0.953*** (0.023)	0.705*** (0.061)
Closeness to Frontier (t-1)	-0.163 (0.112)	1.007** (0.490)	-0.173 (0.152)	0.048 (0.083)	0.207** (0.096)
Closeness x Competition (Regulation) (t-1)	-0.110* (0.066)	0.453** (0.229)	0.212 (0.131)	0.001 (0.110)	0.019 (0.067)
Competition (Regulation) (t-1)	0.476* (0.277)	-2.017** (0.988)	-1.072* (0.553)	0.194 (0.482)	0.292 (0.273)
Externalities (t-1)	0.140** (0.063)	0.128*** (0.044)	0.136*** (0.045)	0.062 (0.042)	0.374*** (0.084)
Capital Intensity (t-1)	-0.028 (0.075)	0.026 (0.054)	0.039 (0.053)	0.070 (0.053)	0.227*** (0.087)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1321	2649	2649	2455	2649
Sargan-Hansen p	0.565	0.143	0.130	0.284	0.146
AR(2)p	0.961	0.689	0.715	0.969	0.702
Instruments	93	143	134	131	136
Individuals	133	148	148	134	148
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM
Marginal effect of Competition ([1]) and Regulation ([2] to [15])					
Closeness (sample values)	N-FIRMS/VA [1]	REGIMP [2]	REGREF [3]	PMR [4]	PMR (Public) [5]
Minimum	(0.152)	(0.561)	(0.316)	(0.278)	(0.159)
Mean less one standard deviation	0.077* (0.043)	-0.394** (0.191)	-0.314** (0.136)	0.197* (0.112)	0.361*** (0.089)
Mean	0.031 (0.024)	-0.192 (0.119)	-0.219* (0.117)	0.198** (0.093)	0.369*** (0.088)
Mean plus one standard deviation	-0.014 (0.028)	0.010 (0.112)	-0.124 (0.126)	0.198** (0.092)	0.378*** (0.097)
Maximum	-0.031 (0.035)	0.068 (0.126)	-0.098 (0.133)	0.198** (0.097)	0.380*** (0.101)

Note: Hubert-White corrected standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.6.

Results for the translog model estimations are given in Table 3.7. Two main remarks can be made. First, for the impact of service regulation (REGREF) and Public sector indicators (PMR(public)), the magnitude of the marginal effect is higher in the translog lagged model than in contemporaneous one (see Tables 3.4 and 3.7). Second, the adverse impact of the REGREF and REGIMP indicators ([2] and [3]) appear significant for a wider interval, at least up to the mean value of the relative productivity level, whereas this effect

was only significant for small values in the translog contemporaneous model (Table 3.4). Most importantly, the upward slope of the marginal effect is still observed.

One should stress that here again the most interesting result is not substantially modified: there is no evidence of an adverse impact of regulation near the frontier and the marginal effects of regulation display a positively-sloped relationship against the relative productivity level of the industry. Similarly, the marginal effect of the number of firms per value added on patenting is significantly positive for laggard industries and decreases with the productivity gap, becoming non significant at the frontier.

Dependent Variable: Patenting (patents decomposition /hours worked) - System-GMM Estimations
Regressions for Competition ([1]) and Regulation ([2] to [5]) (Lagged Regressors; Model Translog)

	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Patenting (t-1)	0.915*** (0.032)	0.874*** (0.040)	0.861*** (0.041)	0.889*** (0.053)	0.688*** (0.064)
Closeness to Frontier (t-1)	1.112 (0.876)	1.213 (0.888)	-0.810 (0.708)	0.457 (0.674)	-0.861 (1.025)
Closeness x Competition (Regulation) (t-1)	-0.033 (0.035)	0.513** (0.244)	0.185 (0.136)	0.004 (0.172)	0.049 (0.093)
Competition (Regulation) (t-1)	0.189 (0.139)	-2.731* (1.482)	-0.649 (0.601)	0.299 (0.727)	0.012 (0.406)
Externalities (t-1)	0.112** (0.053)	0.131*** (0.044)	0.141*** (0.044)	0.134* (0.069)	0.397*** (0.089)
Capital Intensity (t-1)	-0.034 (0.038)	0.025 (0.057)	0.024 (0.056)	0.002 (0.055)	0.213** (0.087)
Closeness to Frontier ² (t-1)	-0.161 (0.115)	-0.011 (0.097)	0.096 (0.109)	-0.054 (0.099)	0.149 (0.141)
Competition ² (Regulation ²) (t-1)	0.009 (0.012)	-0.109 (0.180)	-0.134 (0.104)	0.061 (0.146)	0.181 (0.134)
Year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	1321	2649	2649	2455	2649
Sargan-Hansen p	0.671	0.136	0.147	0.244	0.197
AR(2)p	0.962	0.690	0.709	0.986	0.706
Instruments	116	143	134	82	136
Individuals	133	148	148	134	148
Estimator	SY_GMM	SY_GMM	SY_GMM	SY_GMM	SY_GMM
Marginal effect of Competition ([1]) and Regulation ([2] to [5])					
Closeness (sample values)	N-FIRMS/VA	REGIMP	REGREF	PMR	PMR (Public)
	[1]	[2]	[3]	[4]	[5]
Minimum	0.126* (0.074)	-1.318** (0.594)	-0.676** (0.309)	0.376 (0.398)	0.495* (0.262)
Mean less one standard deviation	0.069*** (0.025)	-0.445** (0.199)	-0.361** (0.143)	0.383* (0.204)	0.579*** (0.191)
Mean	0.056** (0.023)	-0.216* (0.121)	-0.279** (0.136)	0.384* (0.203)	0.601*** (0.191)
Mean plus one standard deviation	0.042 (0.029)	0.014 (0.116)	-0.196 (0.155)	0.386* (0.222)	0.623*** (0.199)
Maximum	0.037 (0.033)	0.078 (0.132)	-0.173 (0.164)	0.386* (0.234)	0.630*** (0.203)

Note: Hubert-White corrected standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01; All variables in log

Table 3.7.

3.7 Conclusion

This Chapter has examined the proposition according to which the impact of competition on innovative performance depends on the distance to the technological frontier. Basically, this proposition states that competition discourages innovation for laggard firms or industries but represents a major incentive to innovate as the economy moves closer to the

technological frontier. This is consistent with the idea of an inverted U-shaped relationship between competition and innovation that is steeper for economies at the leading edge of technology. To test the empirical validity of this proposition we used a panel of industries for OECD countries.

The outcome of the estimations presented in this Chapter do not support the existence of an innovation-bolstering effect of product market competition at the technological frontier. Concerning regulation, two main results arise depending on specifications and proxies. In the first case, regulation has a positive effect whatever the distance to the frontier and the magnitude of its impact is higher the closer the industry is to the frontier. This is the case when one considers the economy-wide indicators. In the second configuration, which is representative of time-varying indicators of regulation, the effect of regulation is negative far from the frontier and vanishes or becomes positive when the technology gap decreases. Based on these estimates, regulation, if anything, might foster innovation at the leading edge. Regarding the measure of the outcome of competition given by the relative number of firms, results reveals that the positive effect of competition is only observed for laggard industries and is non-significant at the top technological level.

These results, though contradicting the recent belief in the positive effects of competition on innovation, are compatible with previous theoretical work and micro empirical studies that emphasised the existence of a Schumpeterian effect or even a size effect in innovation. Similarly, results concerning the positive impact of the public sector on innovation are also consistent with arguments highlighting the suboptimality of the market equilibrium in the presence of technological externalities. At the end, the lack of evidence

supporting the benefits of market competition when industries come close to the technology frontier raises important questions concerning economic policy. Namely, strategies, such as those adopted in the Lisbon Agenda, strongly relying on a positive effect of product market deregulation on innovation seem weakly supported by the data. Competition policy does not seem to be a substitute for science and technology policy.

A possible explanation of our results, briefly illustrated in the theoretical Section, put forward the active presence of leaders in the innovative process. In the next Chapter we provide further insights on this argument and analyse the strategic behaviour in R&D races.

3.A Appendix to Chapter 3

	Industry	Country list
15-16	Food products, beverages and tobacco	Austria
17-19	Textiles, textile products, leather and footwear	Belgium
17	Textiles	Denmark
18	Wearing apparel, dressing and dyeing of fur	Finland
19	Leather, leather products and footwear	France
20	Wood and products of wood and cork	Germany
21-22	Pulp, paper, paper products, printing and publishing	Greece
24	Chemicals and chemical products	Ireland
25	Rubber and plastics products	Italy
26	Other non-metallic mineral products	Japan
27	Basic metals	Netherland
28	Fabricated metal products, except machinery and equipment	Norway
29	Machinery and equipment, n.e.c.	Portugal
30	Office, accounting and computing machinery	Spain
31	Electrical machinery and aPPPatus, nec	Sweden
32	Radio, television and communication equipment	UK
33	Medical, precision and optical instruments, watches and clocks	US
34	Motor vehicles, trailers and semi-trailers	

Table 3.8. List of industries and countries

Sample	N	mean	Std. Dev.	min	max
OECD-STAN	4129	28,73	19,68	2,82	309,13
GGDC	6345	37,58	216,74	-12,21	12233,91
GGDC Industry 30	423	198,40	818,60	-12,21	12233,91
Final Filtered Data	6099	25,73	23,85	0,02	581,73

Table 3.9. Descriptive statistics of labour productivity in I-PPPs for different samples

Country	Mean I-PPPs	CV I-PPPs	Mean PPPs	CV PPPs
Austria	23,19	0,80	25,98	0,60
Belgium	33,27	0,66	32,30	0,71
Denmark	23,44	0,55	23,60	0,46
Finland	26,87	0,73	25,86	0,76
France	28,01	0,99	29,79	0,88
Germany	28,61	0,74	28,19	0,85
Greece	12,24	0,66	13,51	0,68
Ireland	30,35	1,99	32,34	2,03
Italy	29,17	0,63	26,49	0,71
Japan	24,05	1,28	22,54	1,14
Netherland	31,84	0,63	32,86	0,44
Norway	25,42	0,49	26,64	0,45
Portugal	14,03	0,79	15,86	0,70
Spain	25,77	0,49	24,25	0,52
Sweden	27,98	0,58	26,88	0,52
UK	22,74	0,68	25,44	0,62
US	30,86	0,60	30,86	0,60
Total	25,73	0,93	26,07	0,91

Table 3.10. Mean values and coefficient of variation of Labour Productivity by country

Industry	Mean I-PPPs	CV I-PPPs	Mean PPPs	CV PPPs
Basic metals	29,21	0,39	28,36	0,38
Chemicals and ch	54,73	0,94	45,16	0,78
Electrical machi	22,93	0,47	25,00	0,45
Fabricated metal	20,53	0,42	19,50	0,36
Food products, b	24,20	0,44	25,41	0,37
Machinery and eq	23,02	0,36	23,57	0,32
Medical, precisi	19,97	0,50	24,08	0,46
Motor vehicles,	18,92	0,70	26,81	0,47
Office, accounti	29,69	1,49	27,68	1,41
Other non-metall	30,97	0,36	25,28	0,34
Pulp, paper, pap	26,80	0,35	28,27	0,34
Radio, televisio	26,20	1,78	35,74	1,90
Rubber and plast	32,02	0,44	23,26	0,35
Textiles, textil	12,89	0,39	15,64	0,35
Wood and product	16,25	0,43	18,25	0,37
Total	25,73	0,93	26,07	0,91

Table 3.11. Mean values and coefficient of variation of Labour Productivity by industry

Country	Frequency at the frontier (I-PPPs)	Frequency at the frontier (PPPs)
Austria	7	10
Belgium	59	56
Denmark	8	15
Finland	20	10
France	7	8
Germany	3	4
Greece	3	13
Ireland	24	42
Italy	55	1
Japan	35	23
Netherland	70	95
Norway	17	38
Portugal	6	7
Sweden	18	3
UK	10	22
US	33	28
Total	375	375

Table 3.12. Frequency at the frontier level by country

Variable	N	Mean	Std. Dev.	Min	Max
Labor productivity	6099	25,73	23,85	0,02	581,73
Closeness to the frontier (%)	6099	56,89	24,07	1,93	100
Patents over hour worked	6345	0,00165	0,00939	0,00000	0,39679
Capital intensity	2785	0,05	0,03	0,00	0,20
REGREF	6375	4,19	1,31	1,05	6,00
REGIMP	6375	0,13	0,04	0,05	0,22
PMR	5760	1,80	0,44	0,92	2,78
PMR (Public)	6375	3,01	1,28	0,00	4,61
N-FIRMS/VA	2599	2,06	3,67	0,00	37,70

Table 3.13. Global descriptive statistics

Variable	Model	χ^2	p-value
p_{it}	AR(1)	770.384	0.000
p_{it}	AR(2)	615.627	0.001

Table 3.14. Unit Root Test Maddala and Wu (1999) (Ho: Non Stationary)

Chapter 4

Market Regulation and Defensive Strategies in R&D Races²¹

4.1 Introduction

Innovation not only implies the discovery of a new "improved" product. It is also a process influenced by rent seeking strategies aiming at consolidating leading business positions. The so called Coca Cola "formula" or compatibility issues involved in ERP business applications and in operating systems are examples which testify to the fact that particular features of manufactured products are innovation strategies in themselves. Namely, the specific way in which a discovery is fabricated has consequences over the diffusion of knowledge. At least partially, a new product embodies the state-of-the-art information in itself. As shown by several R&D surveys, patent protection is not the only strategy allowing business appropriation. In fact, it is usually accompanied by secrecy, the use of lead time advantages and manufacturing complementarities (see for instance Cohen, Nelson and Walsh, 2000; Cohen et al., 2002; Levin et al., 1987).

The set of strategies among rivals in R&D activities has therefore multiple dimensions, including manufacturing. In this context, market regulation reforms aiming at exploiting the "trimming fat" effects of competition may trigger defensive reactions rather than pro-innovation ones. Thoenig and Verdier (2003) show how globalisation, by in-

²¹ This Chapter is based on Ledezma (2008). "Defensive Strategies in the Quality Ladders". Working Paper PSE N°2008-29

creasing the threat of leapfrogging, induces firms to adopt a technical bias in production. Firms introduce tacitness in the knowledge embodied in production, but they do it at the cost of increasing their skill-labour intensity. Closely related, Dinopoulos and Syropoulos (2007) highlight the role of "rent protecting activities" in quality upgrading innovation. Following this idea, incumbents spend resources in strategies allowing them to preserve their rents. These activities are at the centre of the innovative dynamics and include patent blocking, copyrights, limiting technology diffusion and the like. In line with these theoretical arguments and the evidence provided by R&D surveys, Crépon and Duguet (1997) find within-industry evidence of negative R&D externalities among French manufacturing firms. The authors interpret this result as the outcome of competitors' rivalry. Furthermore, in Chapter 3, we found no evidence concerning a positive effect of deregulation on innovation at the leading edge. On the contrary, in most of specifications, regulatory provisions exert a positive effect on innovation at the very top productivity level. As we noticed, if one includes active leaders in the model of Aghion et al. (2005), results are less conclusive.

This Chapter, focuses in more detail on this defensive strategic behaviour and its impact on R&D effort. We call defensive strategies those actions aiming at protecting the firm's current business position from the risk of loosing the innovation contest. Our main argument is that rivalry among firms, when a set of defensive strategies is available, may reduce the incentives to carry out R&D. This is specially the case when these strategies rely on manufacturing complexity. This kind of manufacturing strategies limiting knowledge spillovers is what we call "technological bias"²². In these circumstances, regulation can play

²² Thoenig and Verdier (2003) use the label of "technical" bias. This is appropriate in their setup since firms change their techniques of production. In our case, the properties of the good itself are at the core

a role in determining the possibilities of technological bias. Moreover, as new discoveries may represent new entrants, the way through which defensive strategies are constrained (*de jure*) has an impact on market structure (*de facto*). Besides antitrust institutions, some usually called "market barriers" may in fact limit the barriers constructed by incumbents to protect their rents. For instance, procedures of certification and regulation in services used as input in manufacturing (or using manufacturing as input) actually determine the set of possibilities of the manufactured product. These "rules of the game" are taken into account by the innovator when deciding the way in which its new discovery will be fabricated. Thus, they shape the visible properties containing the state-of-the-art knowledge and, as a consequence, the difficulties faced in R&D activities. The latter can be high enough to deter prospective innovators. Hence, the rules constraining the scope of possibilities of technological bias will determine how much R&D effort is performed and who does it. This is one important contribution of this Chapter since in most Schumpeterian models, incumbents do not innovate. We present a theoretical model featuring these mechanisms. Using time-series cross-section data of manufacturing industries from 17 OECD countries in the period 1987-2003, we provide evidence for this argument.

The model builds on a "quality-ladders" framework, which provides a useful baseline to analyse innovative behaviour. It encompasses, in a tractable manner, the Schumpeterian notion of creative destruction as modelled by Aghion and Howitt (1992) and Segerstrom, Anant and Dinopoulos (1990). In the pioneer model of Grossman and Helpman (1991), innovation improves the quality of goods. Outsider firms carry out risky R&D investment.

of the strategy. Thus the state-of-the-art technology is the object of bias. This is why we use the label of "technological" bias

The successful innovator replaces the current incumbent and becomes the new monopolistic leader, who remains in the market until the next innovation takes place. Each innovator "climbs" the quality-ladder in the industry. The discounted monopolistic profits are the reward for new innovators that "steal" the incumbent's rents.

Quality-ladders models have evolved to solve problems of scale effects in the steady state growth (Segerstrom, 1998; Young, 1998), a property strongly contradicting empirical evidence found by Jones (1995): while resources allocated to R&D increase exponentially in the long-run data, productivity growth remains almost constant. Based on this adapted setup, a new wave of models has recently revisited important issues such as North-South trade (Dinopoulos and Segerstrom, 2007), firm heterogeneity in the open economy (Segerstrom and Gustafsson, 2007) and the possibility of stable saddle path equilibrium with self-fulfilling beliefs about R&D intensity (Cozzi, 2007). The previously mentioned models of Thoenig and Verdier (2003) and Dinopoulos and Syropoulos (2007) are also built on a quality-ladders setup.

A few contributions in this literature introduce the possibility of innovative leaders (Segerstrom, 2007; Barro and Sala-i-Martin, 2004, Chapter 7; Etro, 2007). This is an important property for our argument since one of incumbent's strategies to keep its leading position is innovation itself. Because innovation for incumbents also translates into their self-replacement, they take into account the loss of their current state value. On the contrary, outsiders seeking to enter the market have nothing to lose and are willing to perform a higher R&D effort. This is the Arrow replacement effect. In most quality-ladders models,

it implies the absence of incumbents in R&D races. However, this result no longer holds true if the incumbent has enough technological advantages in R&D.

We address these technological R&D advantages endogenously. The model reproduces the underlying conditions of two types of steady state equilibrium. Equilibrium with a permanent monopolist arises if the possibilities of technological bias are sufficiently high. In this case the incumbent leader is able to introduce a complexity that renders outsiders' R&D hard enough to induce them to exit the R&D race. Conversely, Schumpeterian replacement equilibrium takes place if technological bias is limited. Differently from the standard case, in this continuous replacement, the incumbent firm will seek to delay its ending date. These results come from the introduction of two ingredients: (a) a Stackelberg type game in which the incumbent leader has the first mover advantage and (b) an endogenous choice of technological bias. For the sake of simplicity we formalise our argument using a semi-endogenous quality ladder model without scale effects. The basic setup is based on Li (2003), which generalises Segerstrom's (1998) framework to consider imperfect inter-industry substitutability. To remove steady state scale effects, Li (2003) assumes that as quality improves new discoveries need more R&D effort. At equilibrium the innovation rate will not depend on the size of labour allocated to R&D but on the rate of population growth.

The Stackelberg building block is based on Barro and Sala-i-Martin (2004). We introduce into their setup an endogenous R&D advantage explained by the privative knowledge in the hands of the current successful innovator. In the Stackelberg game, outsiders can be driven away from R&D races if the leader (incumbent) is able to make a commitment

of high R&D investment. In turn, this depends on R&D advantages. Thus the possibilities of technological bias determine whether the leader's commitment is credible. Thus, the model offers an endogenous threshold that defines who innovates. If the leader is not credible, the Arrow replacement effect holds in the usual way: outsiders carry out all R&D effort and a continuous replacement takes place (Schumpeterian replacement equilibrium). If the leader can make a credible commitment, it will do all R&D and will remain in the market indefinitely (permanent monopolist).

The way we model defensive strategies of technological bias also seeks to keep the dynamic of the model as tractable as possible. Quality is represented as a vector whose Euclidean norm is upgraded at each step of innovation. For a given level of the quality magnitude (the Euclidean norm), the firm chooses, among the multiple quality dimensions, the specific quality mix to be manufactured (the direction of the vector). The difference between the new quality mix and the former one gives to the incumbent the possibility of keeping private a part of the state-of-the-art knowledge. This change in the composition of goods captures the technological bias introduced, by the incumbent, in order to reduce spillovers.

Regulation is then modelled as the extent to which the cost of technological bias increases along with the change between the former and the new quality mix. The result is that the share of labour allocated to R&D increases with regulation enforcement in the Schumpeterian replacement equilibrium. Moreover, this effect depends positively on the size of the innovative steps.

The permanent monopolist equilibrium arises when the technological bias induced by the leader firm is big enough to ensure its credibility. In that case, the incumbent does not need further level of bias to deter its rivals because it can (potentially) do a high enough amount of R&D effort. This occurs when the level of regulation is low. In this equilibrium, if regulation increases, but not enough to avoid permanent monopolists, it reduces the R&D intensity since it induces an allocation of labour to defensive activities which is disconnected from costs.

In the model, the possibilities of positive R&D effort for all players (incumbent and outsiders) are ex-ante discarded by the linear form of R&D technologies (the standard assumption). We empirically test the predictions assuming a smoothing approximation in which monopolists are replaced, even if with a low probability. Using several indicators of market regulation provided by the OECD over a sample of 17 industries belonging to 17 OECD countries, we find a positive effect of regulation on R&D intensity that increases for high technological industries. Since the latter are supposed to perform bigger innovative jumps, we interpret this evidence as consistent with the model's predictions. The rest of the Chapter is organised as follows. Section 4.2 presents the model and Section 4.3 the empirical findings. Finally, we briefly conclude in Section 4.4.

4.2 The Model

4.2.1 Households

Instantaneous decisions

Per capita utility at each time t is given by the CES formulation:

$$u(t) = \left[\int_0^1 z(t, \omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad (4.1)$$

Where $z(t, \omega) \equiv \sum_j \gamma^j d(j, t, \omega)$ is the sub-utility function associated to each industry. The demand for the good of quality j at time t in industry ω is denoted by $d(j, t, \omega)$. The term γ^j captures the quality level j of a given good, where $\gamma > 1$ is a parameter representing the size of quality upgrade (see Section 4.2.3). Thus, for a given industry $z(t, \omega)$ captures a situation in which consumers preferences are ordered by the quality of the available varieties. To avoid confusions in notation, all round brackets, $()$, are reserved to the arguments of the functions of the model.

At any time, households allocate their consumption expenditure $E(t)$ seeking to maximise $u(t)$. This static problem can be separated in two components: a within-industry consumption decision and a between-industry one. Given the perfect substitutability among the quality varieties in each industry ω , all intra-industry expenditure will focus on the good j^* having the lowest quality-adjusted price

$$j^* = \arg \min_{(j)} \left\{ \frac{p(\gamma^j, t, \omega)}{\gamma^j} \right\}$$

The between-industry problem concerns the allocation of total expenditure $E(t)$ among all $\omega \in [0, 1]$. This consists of applying $z^*(t, \omega)$ to (4.1) and maximising $u(t)$ subject to $\int_0^1 p(j^*, t, \omega) d(j^*, t, \omega) d\omega = E(t)$, which leads to the well-known CES demands:

$$d(j^*, t, \omega) = \frac{\delta(j^*, t, \omega)}{p(j^*, t, \omega)^\sigma \int_0^1 \frac{\delta(j^*, t, \omega')}{p(j^*, t, \omega')^{1-\sigma}} d\omega'} E(t) \quad (4.2)$$

Where $\delta(j^*, t, \omega) \equiv \gamma^{j^*[\sigma-1]}$ is a quality level index. This demand function (4.2) reflects a key property of monopolistic competition: each firm (one by industry) is in competition with the whole economy. Indeed, using the utility based index price $P = \left[\int_0^1 \left[\frac{p(j^*, t, \omega')}{\gamma^{j^*}} \right]^{1-\sigma} d\omega' \right]^{\frac{1}{1-\sigma}}$ and noting $C(t) \equiv \frac{E(t)}{P} = u(t)$ the equivalent aggregate good accounting for $u(t)$, (4.2) is then equivalent to state:

$$d(j^*, t, \omega) = \delta(j^*, t, \omega) \left[\frac{P}{p(j^*, t, \omega)} \right]^\sigma C(t) \quad (4.3)$$

Hence, demand decreases along with the relative quality-adjusted price concerning a particular producer and the average of the economy summarised in P .

Intertemporal decisions

Households are considered as identical dynastic families whose number of members grows at the exogenous rate $n > 0$. Each member of a household supplies inelastically one unit of labour. Without loss of generality, initial population is set to 1, so that the population at time t is $L(t) = e^{nt}$. Using a subjective discount rate $\rho > n$, each dynastic family maximises its intertemporal utility

$$U = \int_0^{\infty} e^{-[\rho-n]t} \log u(t) dt \quad (4.4)$$

subject to the usual intertemporal budget constraint that links stock market gains, revenue and expenditure. Noting for any variable Δ its infinitesimal variation $\dot{\Delta} \equiv \frac{d\Delta}{dt}$, this constrain in flows implies:

$$\dot{a}(t) = w(t) + r(t)a(t) - E(t) - na(t) \quad (4.5)$$

Where $a(t)$ is the endowment of per capita financial assets and $w(t)$ the wage income of the representative household member. Since $u(t) = \frac{E(t)}{P}$ and each individual takes P as given, the intertemporal program is equivalent to the maximisation of $U = \int_0^{\infty} e^{-(\rho-n)t} \log E(t) dt$ subject to (4.5). Denoting μ the shadow price of the dynamic constraint, the Hamiltonian can be written as:

$$H = e^{-(\rho-n)t} \log E(t) + \mu [w(t) + r(t)a(t) - E(t) - na(t)]$$

As in most Ramsey-intertemporal consumption, this problem is solved with the help of the transversality condition $\lim_{t \rightarrow \infty} \mu(t)a(t) = 0$ and the optimality conditions $\frac{\partial H}{\partial E} = 0$; $\frac{\partial H}{\partial a} + \dot{\mu} = 0$. Differencing the resulting relationship leads to the well-known intertemporal optimal rule:

$$\frac{\dot{E}(t)}{E(t)} = r(t) - \rho \quad (4.6)$$

4.2.2 Producers and price setting

Labour is the only factor in production and is used in a technology with constant returns to scale. Each firm producing the variety ω sells its output to all members of the representative household. Thus, the firm produces a quantity of $d(j^*, t, \omega) L(t)$, sells at price $p(j^*, t, \omega)$ and incurs a production cost $w(t) d(j^*, t, \omega) L(t)$. After normalising wages ($w(t) = 1$), the profit of each producer is given by:

$$\pi(j^*, t, \omega) = [p(j^*, t, \omega) - 1] d(j^*, t, \omega) L(t) \quad (4.7)$$

Standard monopolist profit maximisation leads to a markup over marginal costs: $p(j^*, t, \omega) = \frac{\sigma}{\sigma-1}$. However, the monopolist is also in competition with firms offering lower quality goods. Consider, namely, the firm laying one step behind the leader in the quality-ladder. The lowest price that this firm is able to set equals its marginal cost $w = 1$. Thus, in any industry ω for which the quality level offered by the leader is j^* , the firm one step behind charge the adjusted price of $\frac{1}{\gamma^{j^*-1}}$. Given the perfect substitutability within industries, the strategy of the leader will be to charge a quality-adjusted price infinitesimally lower than the one of its competitor. By doing so, it gets all demands. Let be ε this infinitesimal price advantage. The leader will thus charge $p(j^*, \omega, t) = \gamma - \varepsilon$, implying a quality-adjusted price equal to $\frac{p(j^*, \omega, t)}{\gamma^{j^*}} = \frac{\gamma}{\gamma^{j^*}} - \frac{\varepsilon}{\gamma^{j^*}}$. This is the limit pricing rule.

An alternative solution, often used in the literature, is to assume a tie-break rule. For instance, suppose that a consumer facing similar quality-adjusted prices prefers the good with the highest quality. This means that the leader charges $p(j^*, \omega, t) = \gamma$ and gets all

demands. For the sake of simplicity we adopt the latter solution as it is "asymptotically" equivalent.

Another issue concerns the fact that price strategies depend on the size of innovation γ and the monopolist power $\frac{\sigma}{\sigma-1}$. If $\frac{\sigma}{\sigma-1} > \gamma$ firms will charge $p(j^*, \omega, t) = \gamma$. On the other hand, if $\frac{\sigma}{\sigma-1} \leq \gamma$ the leader is unconstrained to charge its optimal monopolistic price rule $p(j^*, \omega, t) = \frac{\sigma}{\sigma-1}$. This is an interesting point concerning usual distinctions of radical ($\gamma \geq \frac{\sigma}{\sigma-1}$) and non radical innovation ($\gamma < \frac{\sigma}{\sigma-1}$). What should be stressed is that this distinction depends on the elasticity of substitution. Empirically, it is not so clear what relevant elasticity of substitution should be considered since the national and international scope of the "relevant economy" may vary among goods. Moreover, one of the risk of defining radical innovation by using this criteria is that the distinction may come from a lower economy-wide competition rather than the size of each step of technological upgrade.²³

Innovation in our framework suppose further quality upgrades of the same good. In this sense, is more plausible to assume that the size of each upgrade is not as big enough to induce the innovator to adopt the same price behaviour than a monopolist having no outside competition. Therefore, we restrict $\frac{\sigma}{\sigma-1} > \gamma$ and consider the price setting $p(j^*, \omega, t) = p = \gamma$. Nonetheless, in order to separate the price effects of the size of innovation from those related to technological concerns, we keep p in the exposition of equations.

²³ Amable (1996) makes a deeper economic distinction between radical and incremental innovation that implies endogenous growth and irregular cycles.

Putting demands (4.2) into leader profits (4.7) and using the fact that p neither depends on j^* nor on ω yields:

$$\pi(j^*, \omega, t) = \frac{[p - 1] \delta(j^*, \omega, t)}{p Q(t)} E(t) L(t)$$

Where $Q(t) \equiv \int_0^1 \delta(j^*, \omega, t) d\omega = \int_0^1 \gamma^{j^*[\sigma-1]} d\omega$ is the average quality index. It arises from the monopolistic competition framework as firm's demands are related to the average quality-adjusted price of the economy.

4.2.3 R&D and quality improvements

As in the standard quality-ladders setup, at time $t = 0$, the state-of-the-art quality in each industry is $j = 0$. We suppose that, at this initial stage, in each industry some producer(s) has (have) the knowledge to fabricate a good of quality $j = 0$. Firms then engage in R&D races to discover a new version of the good ω that provides a level of quality $j = 1$. More generally, at each state-of-the-art quality level j , the successful innovator of the current R&D race improves quality to the level $j + 1$ and climbs the quality-ladder one step ahead. The above exposed framework implies that the successful innovator becomes the sole producer in the industry. Thus, each incumbent is also the monopolist and the leader of the industry. Differently from the standard setup, in our model the incumbent does not wait until the next innovator "steal" its rents, but seeks to deter its potential rivals and to remain in the market. This Section is devoted to set the underlying R&D framework allowing for these mechanisms.

Since at this point we know the determinants of our main variables, we can simplify our subscript notation. This simplification can be done thanks to three features of the model. First, the leader is the only firm producing a positive quantity in an industry. Second, the only difference among industries concerning state variables is the current state-of-the-art quality level j . Finally, all *endogenous* variables depend on t (except prices). Thus we summarise the couple (j^*, ω) into j_ω , which indicates the current state-of-the-art good produced by the leader of industry ω . In order to further facilitate notations, we drop the time index and keep in mind the time dependency of the model.

Quality dimensions

The quality provided by a firm producing in industry ω is given by the quality vector $\vec{q}(j_\omega) = \{q_1(j_\omega), q_2(j_\omega), \dots, q_m(j_\omega)\}$. The magnitude of quality is summarised by the euclidean norm of the vector $\|\vec{q}(j_\omega)\| = \sqrt{\sum_{k=1}^m q_k^2(j_\omega)}$ and the quality mix by its direction (the angle of the vector), which reflect the quality composition. The quality state j_ω is the outcome of step-by-step innovations. Different mix concerning the same industry are just perfect substitutable versions of the same product. Thus, consumers only care about quality magnitude. Two different quality mix provide the same utility if the magnitude is equal. However, as we will see, direction matters for the innovator.

The magnitude of the quality vector is upgraded at each step by a factor of γ , the size of innovations. The quality provided by the state-of-the-art j_ω is thus defined as $\|\vec{q}(j_\omega)\| = \gamma^{j_\omega}$.

Diffusion, R&D difficulty and technical bias

Why should we expect the manufacturing of different mix if the composition does not matter for consumers? Two assumptions allow to understand it: (a) while outsiders competing in a R&D race take the current quality mix as given, the current successful innovator can change it; and (b) the knowledge about the way in which new dimensions of quality can be incorporated into the state-of-the-art product does not diffuse instantaneously. Assumption (a) seeks to capture the innovator's advantages arising from its private knowledge about the new product. Once the new discovery come off, the new blueprint is certainly known by the innovator. The leader firm now has the choice about what "visible" properties the manufactured product should have. Assumption (b) allows for a lag in the way in which private knowledge becomes public knowledge. In a basic quality-ladders framework, outsiders *"via inspection of goods on the market, learn enough about the state of knowledge to mount their own research efforts, even if the patent laws (or the lack of complete knowledge about best production methods) prevent them from manufacturing the current generation products"* (Grossman and Helpman, 1991; pag. 47). With assumption (b) we are just specifying that the "lack of complete knowledge" also comes from new dimensions of quality. Current public knowledge may not be enough to allow outsiders to completely understand *all* via the simple "inspection of goods on the market". Rather than to the new dimension itself, the asymmetry of knowledge relates to the way this new dimension must be incorporated into the new product. These knowledge advantages will be used by the incumbent "to bias" its rivals.

Outsiders carry out R&D activities by using labour as input. R&D is governed by a Poisson stochastic process: ℓ units of labour allocated to research during an interval of time dt imply a probability of success $\Lambda_0(j_\omega + 1) \ell dt$ of a new up-grade. We call R&D productivity the augmenting factor of the probability of innovative success implied by one unit of labour in the R&D process. For the outsider, the R&D productivity is defined as

$$\Lambda_0(j_\omega + 1) \equiv \frac{hA^\xi}{\delta(j_\omega + 1)}$$

Where h is an exogenous technology parameter. Similarly to Li (2003), this R&D productivity is a function of the upgrade endeavoured ($j_\omega + 1$). The presence of $\delta(j_\omega + 1) = \gamma^{[j_\omega+1][\sigma-1]}$ in the denominator implies that, as the level of quality increases, the next improvement becomes harder and R&D more costly. The incidence of the quality mix on R&D is captured by A , the scalar product between the unitary vector \vec{u}_{j_ω} having the same direction than $\vec{q}(j_\omega)$ and the unitary vector $\vec{u}_{j_\omega-1}$, the one having the direction of the previous step $\vec{q}(j_\omega - 1)$.²⁴ Let θ_{j_ω} be the angle between vectors $\vec{q}(j_\omega)$ and $\vec{q}(j_\omega - 1)$ (and, consequently, between \vec{u}_{j_ω} and $\vec{u}_{j_\omega-1}$). The term A can be written as:

$$A \equiv \vec{u}_{j_\omega} \times \vec{u}_{j_\omega-1} = \cos(\theta_{j_\omega})$$

Recall that the $\cos(\cdot)$ function is symmetric and monotonically decreases from 1 to 0 along with $|\theta_{j_\omega}| \in [0; \Pi/2[$ (in Π radians). Hence the change in the quality mix involved in the upgrade of j_ω implies an increase in the R&D difficulty faced by outsiders. This

²⁴ The vector \vec{u}_{j_ω} is thus a vector of magnitude 1 whose angle (quality mix) equals the one of $\vec{q}(j_\omega)$.

increase is measured by $A^\xi = \cos^\xi(\theta_{j_\omega})$. The instantaneous probability of innovation I_i implied by the R&D effort of outsider i is then:

$$I_i = \ell_i \frac{h \cos^\xi(\theta_{j_\omega})}{\delta(j_\omega + 1)} \quad (4.8)$$

Any time an innovative firm succeeds, it can add a new quality dimension. Thus, we implicitly suppose that there will always be new dimensions available for the incumbent to bias the outsiders. Our vectorial representation allows to avoid the assumption of an exogenous rate of discovery of new dimensions. Instead, we suppose a certain degree of obsolescence of public knowledge: if during one wave of innovation a quality dimension have not been used, the old way to incorporate it into the product manufacturing no longer applies. Figure 4.1 illustrates this situation. Let us start from the quality level j , which is totally based on dimension q_1 (implying a horizontal vector). Once the next innovative firm has succeeded in upgrading the quality level to $j + 1$, it introduces a bias by including dimension q_2 . The firm then produces the new version of the product with a quality vector having a direction θ_{j+1} far away from the previous one. By doing so, it increases the difficulty of the next R&D race (the one leading to the $j + 2$ level) by a factor of $\cos^\xi(\theta_{j_\omega+1})$. Then, the next innovation occurs and improves the quality level to $j + 2$. If, as in the figure, the new biased mix lies completely on the plan q_2 and q_3 , dimension q_1 will be dropped ($q_1(j + 2) = 0$). Now, if some obsolescence arises after one step of innovation, the next incumbent ($j + 3$) can use again the quality dimension q_1 as a source of bias.

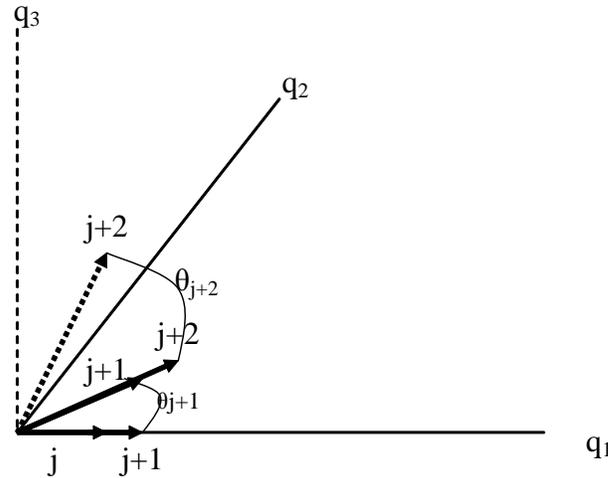


Figure 4.1. Quality dimensions and technological bias

This is one of the advantage of using the scalar product in a vectorial representation . Between two vectors of \mathbb{R}^n representing precedent and current innovation we just need to know the angle between them to model the technological bias.

Leaders' R&D technology and regulation

If the incumbent firm is willing to do positive R&D effort it will not face the difficulty coming from bias. Since this firm has discovered the current state-of-the-art product, it is the sole producer that knows how to incorporate the new dimension in the manufacturing of the good. Hence, the leader R&D productivity is just:

$$\Lambda_L(j_\omega + 1) = \frac{h}{\delta(j_\omega + 1)}$$

Any leader that changes the mix incurs a variable cost (in units of labour) of adapting the new version of the product with a new quality dimension. This cost is defined as:

$$c(\theta_{j_\omega}, \psi) \equiv \frac{f}{\cos^\psi \theta_{j_\omega} \Lambda_L(j_\omega)} \quad (4.9)$$

We summarise in $\psi > 1$ the extent to which regulation limits the new version of the product. Regulation implies a cost of technological bias that increases with the size of the bias (i.e. the change of the direction of the quality vector). This cost is all the more important that regulation is higher. Thus we modelise regulatory provisions as inducing fewer possibilities of complexity in the manufactured version of the improved product²⁵.

$\Lambda_L(j_\omega)$ is the R&D productivity of the leader firm in the former R&D race j_ω (the one that it has won). Thus, the cost of introducing a technological bias in the new manufacturing of a product diminishes with the R&D productivity involved in its discovery. This also means that higher quality goods are more difficult "to bias" since R&D productivity decreases with the quality level of the industry. Finally we include a non consequential cost parameter $f < 1$ to take into account the measure of units of labour required to activities relating to defensive strategies.

4.2.4 Strategic behaviour

Productive advantages obtained by the leader may allow it to deter any prospective entrant and become the only innovator. We now explore this possibility. In what follows, unless we explicitly specify the contrary, all R&D productivity functions concern the next R&D race $j_\omega + 1$. Thus we omit this index in the arguments of $\Lambda_o(\cdot)$ when dealing with $j_\omega + 1$ and write the outsider's R&D productivity as $\Lambda_o(\theta_{j_\omega}) = \Lambda_L \cos^\xi \theta_{j_\omega}$, where $\left(\frac{\partial \Lambda_o}{\partial \theta_{j_\omega}} < 0\right)$.

²⁵ Usual representations of regulation consider a fixed cost that limits the entry of firms. Here we are rather interested in regulatory barriers constraining the operation of firms.

Firm's value

In the outsider state a firm i gets no profits and incurs an R&D cost of ℓ_{io} . Its value is denoted by v_o . Thanks to its R&D effort, with instantaneous probability $\Lambda_o(\theta_{j_\omega}) \ell_{io}$, the outsider may become the leader of the industry and get an optimal value denoted by $v_L(j_\omega + 1)$. The Bellman equation of the outsider is then:

$$rv_o = -\ell_{io} + \Lambda_o(\theta_{j_\omega}) \ell_{io} [v_L(j_\omega + 1) - v_o] \quad (4.10)$$

Putting $v_o = 0$, one verifies that outsiders carry out a positive and finite amount of R&D only when:

$$v_L(j_\omega + 1) = \frac{1}{\Lambda_o(\theta_{j_\omega})} \quad (4.11)$$

This is equivalent to state the equality between the expected value of innovation $v_L(j_\omega + 1) \Lambda_o(\theta_{j_\omega}) \ell_{io} dt$ and the R&D investment during an infinitesimal interval of time $\ell_{io} dt$. This equality applies when free entry occurs. The R&D effort of the outsider for a given value of a successful innovation $v_L(j_\omega + 1)$ is then:

$$\ell_{io} = \left\{ \begin{array}{ll} 0 & \text{if } v_L(j_\omega + 1) < \frac{1}{\Lambda_o(\theta_{j_\omega})} \\ \infty & \text{if } v_L(j_\omega + 1) > \frac{1}{\Lambda_o(\theta_{j_\omega})} \\ \ell_{io} \in \mathbb{R}^+ & \text{if } v_L(j_\omega + 1) = \frac{1}{\Lambda_o(\theta_{j_\omega})} \end{array} \right\} \quad (4.12)$$

Let $\ell_0 = \sum_i \ell_{io}$ be the whole amount of R&D carried out by outsiders. The Bellman equation of a (potential) innovative leader is

$$rv_L(j_\omega) = \pi_L - \ell_L + \ell_L \Lambda_L [v_L(j_\omega + 1) - v_L(j_\omega)] + \ell_o \Lambda_o(\theta_{j_\omega}) [v_0 - v_L(j_\omega)] - c(\theta_{j_\omega}, \psi) \quad (4.13)$$

If the leader carries out R&D, with instantaneous probability $\ell_L \Lambda_L$ its optimal value $v_L(j_\omega)$ can jump to $v_L(j_\omega + 1)$ thanks to a new discovery. With instantaneous probability $\ell_o \Lambda_o(\theta_{j_\omega})$ the leader may be replaced by a successful outsider. In the meantime, the leader firm enjoys its monopolist profits π_L and pays ℓ_L unit of labour for new discoveries as well as $c(\theta_{j_\omega}, \psi)$ units of labour for defensive strategies.

The stackelberg game

Since a leader firm is active in the market, its actions such as technology adoption, advertising and, of course, the quality mix choice, are visible. In an strategic framework, these actions can be seen as a commitment of R&D effort. The consequence is that this commitment of the leader firm can be high enough to deter its rival. This structure is in line with a sequential stackelberg game in which the leader has the so called first mover advantage. Immediately after innovating, the leader sets the quality mix θ_{j_ω} in order to introduce a technological bias. This information is taken into account by outsiders in their decisions. Assume by the moment that the reaction function of outsiders respond negatively to the leader R&D signal. The credibility of the leader's commitment depends its R&D productivity advantages.

Proposition 1 *A necessary condition to ensure that outsiders can be driven out of the R&D race is given by*

$$\Lambda_L \left[\frac{1}{\Lambda_o(\theta_{j_\omega})} - \frac{\gamma^{-[\sigma-1]}}{\Lambda_o(\theta_{j_\omega-1})} \right] \geq 1 \quad (4.14)$$

This credibility condition implies that the leader's R&D effort is irrespective of outsider actions.

Proof. The necessity of this condition comes from the fact that any credible commitment of a high R&D effort depends on the capability of the leader to perform, at least, a positive amount of R&D when free entry is possible. Equation (4.13) shows that the leader firm does perform R&D when $\Lambda_L [v_L(j_\omega + 1) - v_L(j_\omega)] \geq 1$. If free entry applies, then $v_L(j_\omega + 1) = \frac{1}{\Lambda_o}$. Since $\Lambda_o(\theta_{j_\omega})$ is a function of $\delta(j_\omega + 1) \equiv \gamma^{[j_\omega+1][\sigma-1]}$, we can obtain $v_L(j_\omega)$ by adjusting for one step down in the quality-ladder: $v_L(j_\omega) = \frac{\gamma^{-[\sigma-1]}}{\Lambda_o(\theta_{j_\omega-1})}$. Putting these elements together yields the credibility condition (4.14). Moreover, because of constant returns to scale of the R&D investment, if (4.14) holds as a strict inequality, the optimal R&D effort for the leader is unbounded. If (4.14) holds as equality, the leader can perform any finite amount of R&D effort. In both cases it can invest a positive amount in R&D without taking into account outsiders menace. ■

Intuitively, this condition defines a threshold for the R&D productivity of the leader relative to that of the outsiders. Thanks to technological bias, this level can be attained. If this is the case, the constant returns of R&D investment imply that the leader can perform as much R&D effort to put outsiders out of competition²⁶. Thus, if (4.14) is ensured, the leading position value (4.13) can be written as:

²⁶ See Barro and Sala-i-Martin (2004) pp. 333-336 for this Stackelberg explanation.

$$v_L(j_\omega) = \frac{\pi_L - c(\theta_{j_\omega}, \psi) - \ell_L + \ell_L \Lambda_L v_L(j_\omega + 1)}{r + \ell_L \Lambda_L} \quad (4.15)$$

Setting $\frac{\partial v_L(j_\omega)}{\partial \ell_L} = 0$ allows to equating the marginal gain of the R&D effort to its marginal cost.

$$v_L(j_\omega + 1) - v_L(j_\omega) = \frac{1}{\Lambda_L} \quad (4.16)$$

As usually with constant returns, if (4.16) applies, the R&D investment of the leader can be positive and finite. Putting the value of $v_L(j_\omega + 1)$ implied by (4.16) into (4.15) yields the present optimal value of a permanent monopolist leader.

$$v_L(j_\omega) = \frac{\pi_L - c(\theta_{j_\omega}, \psi)}{r} \quad (4.17)$$

At equilibrium, the interest rate must verify (4.16) and (4.17), otherwise the leader carries out zero R&D effort or an unbounded amount. Using the monopolist profits equation (4.7) we obtain:

$$r = \frac{p-1}{p} \frac{E L [1 - \gamma^{-(\sigma-1)}] h}{Q} \quad (4.18)$$

We are mainly interested in the steady state properties of the model. For the sake of presentation in (4.18) we assume that a constant value of $\theta_{j_\omega} = \theta$ exists.²⁷ Now we can state the sufficiency of the credibility condition:

²⁷ We show later that $\theta_{j_\omega+1}$ is constant for a constant outsider menace, which is the standard steady state condition of this kind of model.

Proposition 2 *For a constant value of $\theta_{j_\omega} = \theta$ the credibility condition (4.14) is sufficient to ensure zero outsiders' R&D effort. This condition can be expressed as:*

$$\cos^\xi \theta \leq [1 - \gamma^{-[\sigma-1]}] \quad (4.19)$$

Proof. Recalling that $\frac{\Lambda_L}{\Lambda_o(\theta)} = \frac{1}{\cos^\xi \theta}$ and using (4.14) for $\theta_{j_\omega} = \theta$ immediately gives (4.19). Further, by equation (4.12), the absence of outsiders in R&D races requires $v_L(j_\omega + 1) < \frac{1}{\Lambda_o(\theta_{j_\omega})}$. Consider the optimal value of the next innovation $v_L(j_\omega + 1)$ by using (4.17), profits (4.7) and the definition of $\Lambda_o(\theta_{j_\omega})$. This inequality is then equivalent to: $\frac{\delta(j_\omega+1)-\Theta}{[1-\gamma^{-[\sigma-1]}]} < \frac{\delta(j_\omega+1)}{\cos^\xi \theta}$, where $\Theta \equiv \frac{c(\theta, \psi)}{\frac{p-1}{p} \frac{E(t)L(t)}{Q(t)}}$. Now consider condition (4.14) for a constant value of bias: $\frac{1}{[1-\gamma^{-[\sigma-1]}]} < \frac{1}{\cos^\xi \theta}$. After multiplying both sides of the latter inequality by $\delta(j_\omega + 1)$, since $\Theta > 0$ it immediately appears that credibility condition ensures the absence of outsiders in R&D races. ■

Thus, when the bias is strong enough, i.e. $\cos^\xi \theta \leq [1 - \gamma^{-[\sigma-1]}]$, the leader firm does carry out research effort and the outcome is that the value of the next quality improvement will be lower than the R&D cost incurred by outsiders. As a consequence, outsiders react by setting zero R&D effort, meaning no replacement menace: $I_o = \ell_o \Lambda_o(\theta_{j_\omega}) = 0$. In contrast, if credibility condition does not hold, the leader will do zero R&D effort and will not innovate. All innovation will be done by outsiders. Nevertheless, since the leader firm can render the next R&D race harder it can delay its own replacement, which increases its value. In our particular setup the R&D advantage is endogenously determined by the technological bias. The possibilities of each scenario are thus endogenously determined.

The choice of the bias

Once the new innovative firm has succeeded and before producing it decides the visible features of the new version of the product. This new version may incorporate a new dimensions of quality, which generate a gap between private and public knowledge about the design of the product. The differences in the quality mix between the new manufactured version and the previous one is what we have called the technological bias ($\theta_{j\omega}$). This bias determines whether the incumbent becomes an innovative permanent leader firm or a non-innovative monopolist that can delay to some extent its date of replacement. Hence, the value of the incumbent leader can be discomposed into both situations:

$$v_L(j\omega) = \left\{ \begin{array}{ll} \frac{\pi_L - c(\theta_{j\omega}, \psi)}{r + \ell_o \Lambda_o(\theta_{j\omega})} & \text{if } \cos^\xi \theta_{j\omega} > [1 - \gamma^{-(\sigma-1)}] \\ \frac{\pi_L - c(\theta_{j\omega}, \psi)}{r} & \text{if } \cos^\xi \theta_{j\omega} \leq [1 - \gamma^{-(\sigma-1)}] \end{array} \right\} \quad (4.20)$$

Note that before the leader takes the decision of bias, outsiders can potentially carry out research efforts and the free entry condition holds. Thus, the rationale of the decision of bias starts by considering the first case in (4.20). Since at this stage no technological advantage has been induced, the leader firm is not credible for the moment. The value is given by (4.13) for $\ell_L = 0$. Here, the leader firm waits until a new successful innovator replace it. But it can still do better. For a given value of outsider's R&D effort ℓ_o , the discounted expected value of the leader will increase with the technical bias $\theta_{j\omega}$. A higher R&D difficulty means a lower probability of replacement and then a higher expected monopolist life. This decision of bias implies a cost of $c(\theta_{j\omega}, \psi)$ units of labour which is increasing in ψ , the regulation parameter. Thus, the leader will choose a value of $\theta_{j\omega}$ as high as possible, depending on regulation ψ . For a certain "low" level of regulation, this bias can be high

enough to ensure the credibility condition as equality. In that case the economy jumps to a permanent monopolist framework.

Let us now derive this rationale analytically. Define $I_{oL} \equiv \ell_o \Lambda_L$ as the potential menace of outsiders, that is the probability of outsiders' innovative success in the absence of any bias ($\theta_{j_\omega} = 0$) (i.e. the same R&D productivity as the leader). We can then rewrite the bellman equation of the leader firm as

$$r v_L(j_\omega) = \pi_L - I_{oL} \cos^\xi \theta_{j_\omega} v_L(j_\omega) - c(\theta_{j_\omega}, \psi) \quad (4.21)$$

Proposition 3 *For a constant potential outsider menace I_{oL} , the optimal choice of θ_{j_ω} , is constant. Its value is given by*

$$\cos \theta = \left[\frac{\psi f}{\xi I_{oL}} \right]^{\frac{1}{\psi}} \quad (4.22)$$

Proof. By the maximum principle, the choice of θ_{j_ω} , is determined by the first order condition of the RHS of (4.21). To do so, we use $c(\theta_{j_\omega}, \psi)$ as defined by (4.9). Recall also that the free entry condition in the precedent R&D race (the one that the incumbent has won) states: $v_L(j_\omega) = \frac{1}{\Lambda_o(j_\omega, \theta_{j_\omega-1})} = \frac{1}{\Lambda_L(j_\omega) \cos^\xi \theta_{j_\omega-1}}$ where $\Lambda_o(j_\omega, \theta_{j_\omega-1})$ and $\Lambda_L(j_\omega)$ are the outsiders and the leader R&D productivity in the preceding R&D race, respectively. After applying this, first order condition can be written as $\cos \theta_{j_\omega} = \cos^{\frac{\xi}{\xi+\psi}} \theta_{j_\omega-1} \left[\frac{\psi f}{\xi I_{oL}} \right]^{\frac{1}{\xi+\psi}}$. Define now $q \equiv \left(\frac{\psi f}{\xi I_{oL}} \right)^{\frac{1}{\xi+\psi}}$; $\beta \equiv \frac{\xi}{\xi+\psi} < 1$; $a_{j_\omega} \equiv \cos \theta_{j_\omega}$. The sequence of a_{j_ω} can be expressed as $a_{j_\omega} = q^{z(j_\omega)}$ where $z(j_\omega) = \sum_{j=1}^{j_\omega} \beta^j$ is itself a geometric sequence that converges towards $\frac{1}{1-\beta}$. Thus, for a high enough level of j_ω , one has $a = q^{\frac{1}{1-\beta}}$. Putting back the definitions of a , q and β gives directly (4.22). ■

As expected $\cos \theta$ decreases with I_{oL} . A higher potential menace of replacement implies a higher defensive strategy. Recalling that $I_o = I_{oL} \cos^\xi \theta$, the probability of outsiders to succeed in innovation is then:

$$I_o = I_{oL}^{\frac{\psi-\xi}{\psi}} \left[\frac{\psi f}{\xi} \right]^{\frac{\xi}{\psi}} \quad (4.23)$$

Note that in the extreme case of $\psi \rightarrow \infty$, the outsiders' probability of innovation converges toward its potential $I_o \rightarrow I_{oL}$. Hence, a high level of regulation may (asymptotically) eliminate the bias ($\cos \theta \rightarrow 1$).

In particular, ψ can determine whether the credibility condition holds. Indeed, note that for a given value of I_{oL} regulation reduces the bias: $\frac{\partial \cos \theta}{\partial \psi} > 0$.²⁸ If ψ is particularly low, the technological bias implies that the R&D advantage of the leader firm relative to that of outsiders ($\frac{1}{\cos \theta}$) can be high enough to allow it a credible commitment. In this case, the second part of the discontinuous function of the leader value (4.20) applies. The leader now enjoys permanent profits as an innovative monopolist. Since $\frac{\partial c(\theta_{j\omega}, \psi)}{\partial \theta_{j\omega}} > 0$, a value of $\cos^\xi \theta_{j\omega}$ lower than $[1 - \gamma^{-[\sigma-1]}]$ will only reduce $v_L(j_\omega)$. Therefore, the leader does not need further R&D advantages beyond the credibility point. As a consequence the optimal choice will be given by

$$\cos^\xi \theta = [1 - \gamma^{-[\sigma-1]}] \quad (4.24)$$

²⁸ Taking I_{oL} as given, $\frac{\partial \cos \theta}{\partial \psi} = \cos \theta \left[\frac{1 - \log[\cos^\psi \theta]}{\psi^2} \right] > 0$ since $\log[\cos^\psi \theta] < 0$.

Equation (4.24), however, is not sufficient to analyse the regulation threshold allowing to separate both cases of (4.20). Actually $\cos \theta$ depends on the outsiders' potential menace. The latter needs to be computed at the steady state equilibrium.

Finally, it should be stressed that the reaction of zero R&D effort of outsiders is a direct consequence of the linear R&D technology. With decreasing returns in the R&D technology, one has both players active in R&D races (see Segerstrom, 2007). For the simplicity of the exposition we have adopted linear technologies.

4.2.5 Global accounting and steady state equilibrium

To sum up, the discontinuity of (4.20) implies two cases depending on the fulfillment of the credibility condition, which in turn depend on ψ . In the first case, outsiders do all R&D and the leader waits for its replacement (Schumpeterian replacement case). In the second situation, the leader may become the only innovator and enjoys permanent profits (permanent monopolist case). In this subsection we analyse the steady state macro equilibrium for each case.

The macro equilibrium for a continuum Schumpeterian replacement is given by the labour market clearing and the free entry condition. In a situation with a permanent monopolist, the free entry condition no longer holds. Instead, the steady state equilibrium condition arises from the interest rate (4.18) allowing a positive and finite amount of research.

The Schumpeterian replacement case

Labour market clearing needs the addition of labour used in research $L_r = \int_0^1 \ell_o (j_\omega + 1) d\omega$, manufacturing $L_y = \int_0^1 L d(j_\omega + 1) d\omega$ and defensive activities related to technological bias $L_f = \int_0^1 c(\theta, \psi) d\omega$. We focus on the symmetric steady state equilibrium in which expenditure E and outsiders innovative potential I_{0L} are constant. As a consequence, θ and I_0 are also constant. Using the probability of outsiders' innovative success (4.8), $I_{0L} = \ell_o \Lambda_L = \frac{I_o}{\cos^\xi(\theta)}$ and the definition the average quality Q and $\delta (j_\omega + 1)$, the demand for labour in research activities is given by:

$$L_r = \frac{I_{oL} \gamma^{\sigma-1}}{h} Q \quad (4.25)$$

After including consumers' demand $d(j_\omega + 1)$ (4.2), labour required for manufacturing is:

$$L_y = L \frac{E}{p}$$

To obtain the labour demand for defensive activities, we use the definition of $c(\theta, \psi)$ written in (4.9) and the average quality Q . This leads to²⁹:

$$L_f = \frac{f}{h \cos^\psi \theta} Q$$

We can now state the full employment condition clearing the labour market. This requires $L = L_y + L_r + L_f$, which is equivalent to:

²⁹ Because industries are symmetric in probabilities, $\cos^\psi \theta$ (which depends on I_{0L}) can be considered as a constant inside integrals.

$$1 = \frac{E}{p} + \frac{I_{oL} \gamma^{\sigma-1} Q}{h L} + \frac{f}{h \cos^\psi \theta} \frac{Q}{L} \quad (4.26)$$

Recall that $\cos^\xi \theta$ is stable when I_{oL} is stable. Thus, in a equilibrium in which I_{oL} and E are constant $x \equiv \frac{Q}{L}$ must also be constant. As mentioned, prices and the rest of exogenous parameters do not depend on time. Thus, like in the standard schumpeterian model without scale effects and exogenous rate of growth, the average quality and the population must grow at the same rate:

$$\frac{\dot{Q}}{Q} = \frac{\dot{L}}{L} = n \quad (4.27)$$

The rate of growth of Q is obtained in the usual way. Using the law of large numbers, the variation of average quality can be computed by adding the expected technological jump of each industry: $\dot{Q} = \int_0^1 I_o [\delta(j_\omega + 1) - \delta(j_\omega)] d\omega$. By applying the definition of Q one obtains:

$$\frac{\dot{Q}}{Q} = I_o [\gamma^{\sigma-1} - 1]$$

In steady state, condition (4.27) must hold. Thus, the innovation rate in steady state has the usual form:

$$I_o = \frac{n}{[\gamma^{\sigma-1} - 1]} \quad (4.28)$$

The growth of the average quality Q implies an steady-state utility growth of $\frac{\dot{u}(t)}{u(t)} = \frac{n}{\sigma-1}$. This is the standard result obtained after putting demands (4.2) into the instantaneous utility (4.1) taking logs and differencing.

Back to our particular setup, the steady-state rate I_o and equation (4.23) imply the following innovative potential of outsiders in steady state

$$I_{oL} = \left[\frac{n}{[\gamma^{\sigma-1} - 1] \left[\frac{\psi f}{\xi} \right]^{\frac{\xi}{\psi}}} \right]^{\frac{\psi}{\psi-\xi}} \quad (4.29)$$

The steady-state bias in the Schumpeterian replacement case is obtained by putting (4.29) into (4.22):

$$\cos^\xi \theta = \left[\frac{[\gamma^{\sigma-1} - 1] \psi f}{\xi n} \right]^{\frac{\xi}{\psi-\xi}} \quad (4.30)$$

Again, here in steady state equilibrium, as $\psi \rightarrow \infty$ the bias decreases ($\cos^\xi \theta \rightarrow 1$). Thus regulation limits the possibilities of bias in steady state. As Figure 4.2 shows, upon a certain level of ψ the economy can jump from the Schumpeterian equilibrium to the permanent monopolist one. The following proposition expose this.

Proposition 4 *For $\psi > \xi$ there exists a unique level of regulation $\bar{\psi}$ defining the threshold between the Schumpeterian replacement and the permanent monopolistic cases involved in the value of the leader firm (4.20).*

Proof. The value $\bar{\psi}$ defined above is the one solving $\cos^\xi \theta = [1 - \gamma^{-(\sigma-1)}]$. Denote $\Omega(\psi) \equiv \cos^\xi \theta = \left[\frac{[\gamma^{\sigma-1} - 1] \psi f}{\xi n} \right]^{\frac{\xi}{\psi-\xi}}$ and $\Psi \equiv [1 - \gamma^{-(\sigma-1)}]$. To prove proposition 4, we need to show that $\Omega(\psi)$ intercepts Ψ once for $\cos \theta \in]0; 1]$. We show first that Ω is an increasing function of ψ . Taking partial derivates gives:

$$\frac{\partial \Omega(\psi)}{\partial \psi} = \frac{-\xi}{\psi[\xi-\psi]^2} \left[\frac{[\gamma^{\sigma-1} - 1] \psi f}{\xi n} \right]^{\frac{\xi}{\xi-\psi}} \left[\xi - \psi + \psi \ln \left[\frac{[\gamma^{\sigma-1} - 1] \psi f}{\xi n} \right] \right].$$

Since $\cos^\xi \theta = \left[\frac{[\gamma^{\sigma-1}-1]\psi f}{\xi n} \right]^{\frac{\xi}{\psi-\xi}} \in]0; 1[$ and $\psi > \xi$, the sign of the term in the brackets at the right-hand end is negative. Thus $\frac{\partial \Omega(\psi)}{\partial \psi} > 0$, which means that $\Omega(\psi)$ is a monotonically increasing function of ψ . On the other hand, the term Ψ does not vary along with ψ . Furthermore, for $\gamma > 0$ and $\sigma > 1$ (the standard parameter) we verify $\Psi < 1$. Hence, for relevant values of $\cos \theta$ there exists a unique intercept for Ω and Ψ . Figure 4.2 illustrate this proof. ■

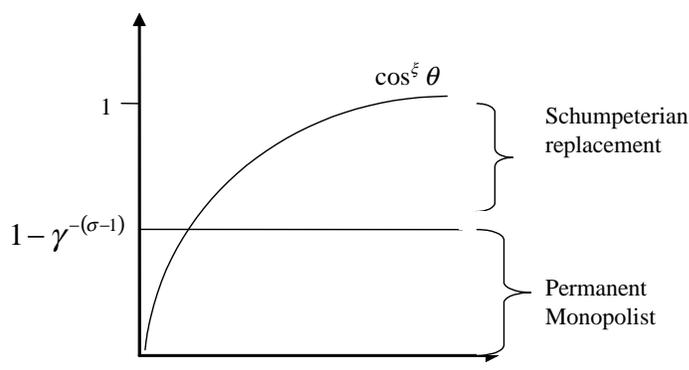


Figure 4.2. Threshold between continuous replacement and permanent monopolist equilibrium

We can analyse the role of regulation in steady-state by studying the share of labour allocated to research $s_r \equiv \frac{L_r}{L}$. This can be obtained from a system of two equations (the free entry condition (4.11) and (b) the labour market clearing (4.26)) with two unknowns: $x \equiv \frac{Q}{L}$ and E . For the free entry condition, the firm value is the one of the replacement case in (4.20). Both equations must be evaluated at the steady state values of I_{oL} and $\cos \theta$.

In addition, for a constant value of expenditure E , equation (4.6) must be verified and then $r = \rho$. Solving this system for x and using L_r as expressed by (4.25) one obtains:

$$s_r = \frac{1}{\Gamma_{rep} + \frac{\xi p}{\gamma^{\sigma-1}[p-1]\psi}} \quad (4.31)$$

Where $\Gamma_{rep} \equiv 1 + \frac{[1-\gamma^{-(\sigma-1)}]\rho}{[p-1]n} + \frac{1}{\gamma^{\sigma-1}[p-1]}$. The following proposition can now be stated.

Proposition 5 *In the Schumpeterian equilibrium, regulatory provisions ψ increase the labour share allocated to R&D s_r and their effect is all the more important that the size of innovation γ is bigger.*

Proof. By simple inspection of (4.31) one verifies that s_r is increasing in ψ . Analytically, using price setting $p = \gamma$ and (4.31) we evaluate the effect of ψ on s_r as $\frac{\partial s_r}{\partial \psi} = \frac{n^2[\gamma-1]\gamma^{2+\sigma}\xi}{[\gamma^\sigma\psi[n[\gamma-1]+\rho]+\gamma[n[\gamma\xi+\psi]-\rho\psi]]^2} > 0$. To understand the effect of the size of innovation note that the multiplicative factor of ψ in (4.31) is $\gamma^{\sigma-1} \left[1 - \frac{1}{\gamma}\right]$, which is increasing in γ . Although crossed derivates can be computed, for the sake of presentation we show numerical simulations. Figure 4.3 plots $\frac{\partial s_r}{\partial \psi}$ for different values of γ . The shape of the curve does not change for a large set of parameters values provided that $\gamma < \frac{\sigma}{\sigma-1}$ and $n < \rho$ (the standard intertemporal assumption). ■

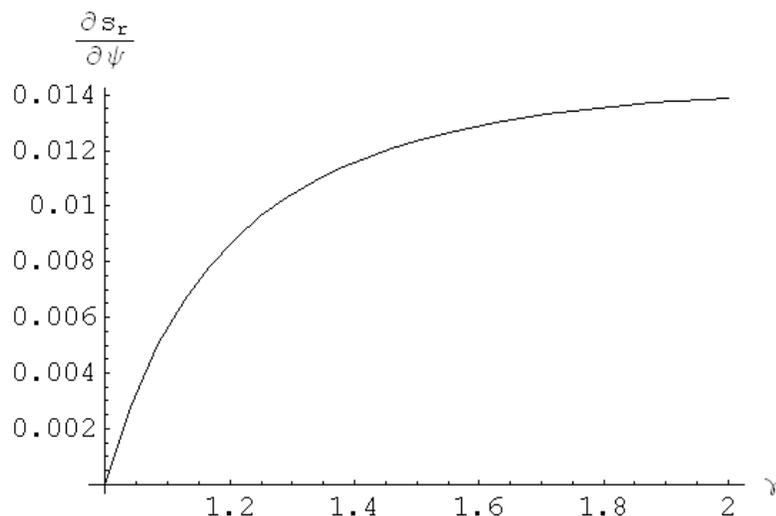


Figure 4.3. Size of innovation and the effect of regulation on R&D.(continuous replacement)

$$\xi = 0.5, n = 2\%, \sigma = 2, \rho = 5\%, \psi = 2$$

At the steady state Schumpeterian equilibrium, which namely verifies the free entry condition, the aggregate of R&D investment decisions is computed, of course, once costs have been taken into account. Thus the dissuasive effect of the technological bias appears. Since R&D becomes harder, at equilibrium, less firms will be willing to enter the R&D race. The aggregate labour allocated to R&D then decreases.

The size of innovation affects the monopolistic setting price and also influences the difficulty of R&D races because it affects the cumulative cost of climbing the quality-ladder. Concerning setting prices, the size of innovation acts as an increasing factor of the monopolist markup. This is a Schumpeterian incentive to R&D captured by the multiplicative term $\frac{p}{p-1} = 1 - \frac{1}{\gamma}$. This monopolistic incentive modulate the R&D incentives coming from the reduction of bias. As Figure 4.3 shows, the effect of regulation is (postively) conditioned by the size of innovation.

The permanent monopolist equilibrium

In this equilibrium some minor adaptations for labour market clearing must be considered. First, the monopolist allocate labour to research without being affected by the bias. Its probability of innovative success is then $I_L = \ell_L \Lambda_L$. Second, the optimal choice of bias is now given by $\cos^\xi \theta = [1 - \gamma^{-[\sigma-1]}]$. The condition $L = L_y + L_r + L_f$ is thus stated as:

$$1 = \frac{E}{p} + \frac{I_L \gamma^{\sigma-1} Q}{h L} + \frac{f}{h [1 - \gamma^{-[\sigma-1]}]^{\frac{\psi}{\xi}}} \frac{Q}{L} \quad (4.32)$$

As before, if expenditure and innovation rates are constant, we require $\frac{\dot{Q}}{Q} = \frac{\dot{L}}{L} = n$. Thus the steady-state rate of innovation remains the same: $I_L = \frac{n}{[\gamma^{\sigma-1}-1]}$. Moreover, since E is constant, consumption growth is still given by $\frac{\dot{u}(t)}{u(t)} = \frac{n}{\sigma-1}$.

To compute the steady-state expenditure, we can not use the free entry condition. In the case of permanent rent, none outside the market is willing to participate in the R&D race. Instead, what equilibrates the economy is the interest rate (4.18). Putting this expression in the optimal path of expenditure (4.6) implies:

$$E = \frac{\rho x}{[1 - \gamma^{-[\sigma-1]}] h p - 1} \frac{p}{p - 1} \quad (4.33)$$

The steady-state share of labour allocated to R&D $s_{rm} = \frac{L_r}{L}$ for the permanent monopolistic case can be obtained by substituting E , as defined by (4.33), into labour market clearing (4.32) for I_L at the steady state. This yields:

$$s_{rm} = \frac{1}{\left[\Gamma_{per} + \frac{f}{n [1 - \gamma^{-(\sigma-1)}]^{\frac{\psi}{\xi} - 1}} \right]} \quad (4.34)$$

Where $\Gamma_{per} \equiv 1 + \frac{\rho}{n[p-1]}$.

Proposition 6 *In the permanent monopolist equilibrium, the level of regulation ψ reduces the share of labour allocated to R&D.*

Proof. $\frac{\partial s_{rm}}{\partial \psi} = \frac{f[1-\gamma^{-(\sigma-1)}]^{1-\frac{\psi}{\xi}} \ln[1-\gamma^{-(\sigma-1)}]}{n\xi \left[1 + \frac{f}{n} [1-\gamma^{-(\sigma-1)}]^{1-\frac{\psi}{\xi}} + \frac{\rho}{n[\gamma-1]} \right]} < 0$ since $0 < 1 - \gamma^{-(\sigma-1)} < 1$. Thus, s_{rm} is decreasing in ψ . ■

Because of the discontinuity of the leader firm value, the optimal steady-state bias induced by the leader does not vary along with regulation. Indeed, the monopolist will not go beyond the level given by $\cos^{\xi} \theta = [1 - \gamma^{-(\sigma-1)}]$. If regulation increases, but not enough to ensure a continuous monopolistic replacement, its effect translates into more labour required for defensive strategies. Since in this region ($\psi < \bar{\psi}$) the decision of labour allocated to defensive purposes does not consider its cost, it merely implies less labour to R&D. In this equilibrium, the modulation made by the size of innovation on the effect of regulation is less clear. By simple inspection one notes that it depends on particular values of $\frac{\psi}{\xi}$. For the parameter values of Figure 4.3, the effect of γ on $\frac{\partial s_{rm}}{\partial \psi}$ depicts a relationship as illustrated in Figure 4.4.

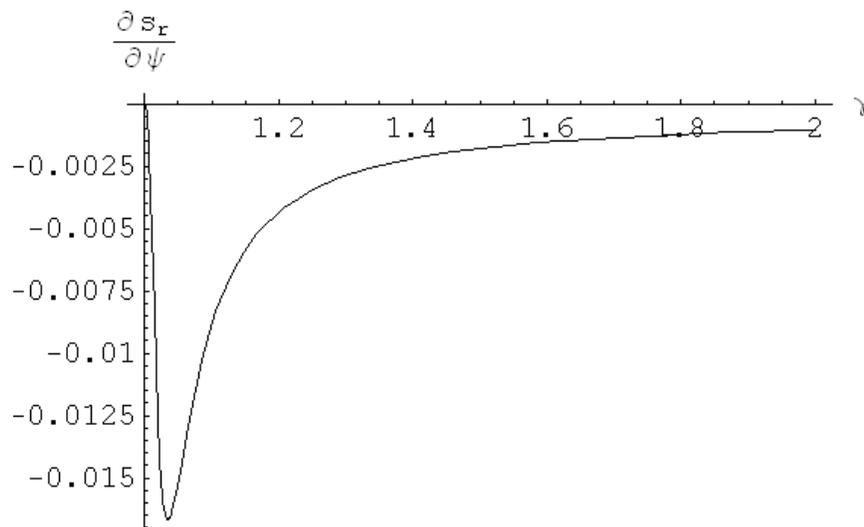


Figure 4.4. Size of innovation and the effect of regulation on R&D.(permanent monopolist)

$$\xi = 0.5, n = 2\%, \sigma = 2, \rho = 5\%, \psi = 2$$

4.3 Evidence

4.3.1 Empirical strategy

Our aim is to identify the effect of regulation on R&D effort at the industry level. Following the model, the role of regulation depends on its level. If regulation is high enough, the continuous Schumpeterian replacement equilibrium arises and regulatory provisions do have an incitative effect on R&D. On the contrary, if regulation is low enough to allow the credibility of the leader commitment, the permanent equilibrium arises and regulatory provisions have a negative effect on R&D effort.

Since data on outsiders R&D is not available we cannot empirically differentiate between both situations. Moreover, as explained above, the outcome of zero R&D effort comes from the choice of a linear technology in R&D, the standard assumption. In practice, monopolists are replaced, even if very later. Indeed, as we are dealing with quality improvements within manufacturing, we should expect a value of σ and γ leading to a low level of $[1 - \gamma^{-[\sigma-1]}]$ and, therefore, a high level of bias θ required to ensure leader credibility. Thus, one may assume the "truly" permanent monopolistic case as an extreme possibility and suppose that sooner or later monopolists are replaced.

Consequently, we should be mainly concerned with the Schumpeterian equilibrium. We then expect a positive effect of regulation on R&D effort, which is more likely to be observed for higher sizes of innovation. Data availability is also constraining in this respect. We suppose that high technology manufacturing (HT) industries make bigger innovative steps. In the sample, these industries are defined as 30-33 ISIC Rev-3 industries. This includes the information and communication technologies (ICT industries) and the manufacturing of medical precision and optical instruments. Results remain similar if one includes industries 29 (machinery and equipment) and motor vehicles (34), industries using intensively ICT technologies.

Therefore, one should expect that, for these industries, innovation especially allows for additional possibilities of monopolistic markups. If this is true, R&D incentives induced by regulation should be higher in HT industries relative to the rest. Let y_{it} be the measure of aggregate R&D effort (labour share in the model) of industry i at time t . We proxy R&D effort with the R&D intensity of the industry measured as the R&D expenditure over

value added. Denoting R_{it} the regulation proxy and HT the dummy variable identifying HT industries, our regressions have the following specification:

$$y_{it} = \alpha_1 R_{it} + \alpha_2 R_{it} \times HT + \alpha_3 HT + \alpha_5 x_{it} + \epsilon_{it} \quad (4.35)$$

Where $\epsilon_{it} = \eta_i + \mu_{it}$, x_{it} is a vector of controls. All variables are in natural logs (except HT). The marginal effect of regulation can be computed as

$$\frac{\partial E [y_{it}/HT]}{\partial R_{it}} = \alpha_1 + \alpha_2 HT$$

If $HT = 0$ then the marginal effect is α_1 and reflects the effect of regulation on non-HT industries. When $HT = 1$ the marginal effect is $\alpha_1 + \alpha_2$. This means that α_1 is also the effect of regulation which is common to HT and non-HT industries. Thus, α_2 is the effect of regulation on R&D intensity in HT industries *relative* to non-HT ones.

Our model predicts a positive effect of regulation on R&D intensity that increases with the size of innovation. Hence, we expect a positive and significant estimate $\hat{\alpha}_2$. In other words, if an R&D-boosting effect of regulation can be expected by our theoretical argumetns, it is more likely to be observed in the specificity of high technology industries. In *absolute* terms, the over all effect of regulation on R&D intensity in HT industries will be given by $\hat{\alpha}_1 + \hat{\alpha}_2$. While the significance of $\hat{\alpha}_2$ can be ridden directly from the regressions, for $\hat{\alpha}_1 + \hat{\alpha}_2$ we need to compute the joint significance (See Friedrich, 1982; Braumoeller, 2004; Mullahy, 1999): $\frac{\hat{\alpha}_1 + \hat{\alpha}_2}{\sqrt{\hat{\sigma}_{\hat{\alpha}_1 \hat{\alpha}_1} + \hat{\sigma}_{\hat{\alpha}_2 \hat{\alpha}_2} + 2\hat{\sigma}_{\hat{\alpha}_1 \hat{\alpha}_2}}}$, where $\hat{\sigma}_{ab}$ is the sample covariance between a and b .

Since individuals units are manufacturing industries in different countries we expect a fixed component in the error term. The bias produced by this unobserved time-invariant heterogeneity can be eliminated by the Within Group estimator, at the cost of losing the information provided by $\hat{\alpha}_3$. The Within Group estimator transforms the model by subtracting the sample period mean of each variable for each individual. This allows to eliminate η_i , but also all time-invariant variables such as HT . As our focus of interest is mainly $\hat{\alpha}_2$ and $\hat{\alpha}_1 + \hat{\alpha}_2$ we adopt this strategy.³⁰

Among controls x_{it} in (4.35) we consider (i) the lag of the closeness relative to the technological frontier (measured as the labour productivity of the country-industry couple relative to the highest one in the world in the same industry at the corresponding period); (ii) a capital intensity ratio; (iii) innovation spill-overs proxied by the innovative activity performed by the rest of the world in the same industry; (iv) financial deepness proxied by the ratio of total asset investment of institutional investors over GDP; and (v) the dependent variable in the previous period.

The control included in (v) implies a dynamic model since it includes the past realisation of the dependent variable on the left-hand-side of (4.35). Because of the presence of an unknown fixed effect in the error term, the lagged value of the dependent variable will be endogenous to the error term. Among different solutions proposed in the literature, a

³⁰ Further insights about HT can be learned by using the fixed effect vector decomposition (FEVD) developed by Plümer and Troeger (2007). It consists of three stages. First, a fixed model effect is estimated in order to measure η_i . The second stage correlates this measure with time-invariant variables, those that are eliminated in the usual fixed effect strategy. This step then decomposes η_i into a part explained by time-invariant variables and an unexplainable one. The third stage re-estimates the model by OLS and includes the unexplainable error term accounted in the second step. This final step also controls for collinearity between time-varying and time-invariant variables and it adjusts the degrees of freedom. Results (not reported) do not change when we use this methodology.

commonly suggested estimator is System-GMM (Arellano and Bover, 1995; Blundell and Bond, 1998). Intuitively, GMM-based methods exploit the exogeneity of lagged regressors (moment conditions) which is used as information in the search for identification. Basically, what System-GMM does is to include not only the moment conditions provided by the transformed equation (that purge the fixed effect) but also those implied by the equation in levels (not transformed), which is instrumented by lagged differences. This provides a better fit when series are persistent since in that case past differences tend to be better instruments than past values. However, GMM estimators are basically constructed for micro panel data containing a large number of individuals for a short sample period. In our industry panel (time-series cross-section data), we have a small number of individuals. In addition, the availability of data for the model including all controls reduces considerably the sample size. This might be very constraining for instrumenting strategies. Namely, the test of exogeneity of instruments are weakened when the number of instruments are large relative to the number of individuals.

On the other hand, a simple OLS estimation will neglect η_i and yield upward biased estimates of the autoregressive coefficient. The within-group estimator will partially address this problem since it purges the fixed effect by subtracting the mean. In this transformation y_{it-1} becomes $\bar{y}_{it-1} = y_{it-1} - \frac{1}{T} \sum_{t=2..T} y_{it-1}$. A similar transformation applies to the error term. A downward bias is expected because the y_{it-1} term present in \bar{y}_{it-1} will correlate negatively with the $-\frac{1}{T}\epsilon_{it-1}$ term of the transformed error term. However, as it has been noted by Bond (2002) and Benavente et al. (2005), this should be less problematic when the number of periods T increases (the correlation is reduced by T). As we

have potentially 15 years, we will keep within-group estimates and avoid the problems of instrumenting with a small number of individuals.

4.3.2 Data

We use the dataset constructed in Chapter 3. It contains information for 17 manufacturing industries across 17 OECD countries. Transversal deflation uses the industry-level PPA for 1997 of Timmer, Ympa and van Ark (2006). R&D series are provided by the OECD STAN dataset. The sample period is given by the R&D data availability (1987-2003). More details of the data are given in Chapter 3, Section 3.4.

We use the indicators of regulation of Chapter 3, which are provided by the OECD. We consider the economy-wide indicators of product market regulation PMR, a collection of inward- and outward-oriented market barriers. An important component of PMR that we shall consider in regressions is the size of the public enterprise sector (PMR-Public). This proxy can capture different ways to conduct R&D between public and private actors and also the regulatory environment in R&D activities. Indicators of regulation in times-series at the country level are also available for non-manufacturing sectors (telecoms, electricity, gas, post, rail, air passenger transport, and road freight). This information is summarised in the REGREF indicator provided by the OECD. The corresponding effect of these regulatory provisions on manufacturing activities is also computed by the OECD. These manufacturing "knock-on" effects of regulation (REGIMP) is a useful proxy of regulation at the industry level available in the form of panel data. The methodology in the construction of these regulation indicators are fully detailed in Conway and Nicoletti (2006) and Con-

way, Janod and Nicoletti (2005). The interpretation of these indicators is discussed in the analysis of results.

4.3.3 Results

Results of Within Group regressions are presented in Tables 4.1 to Table 4.4 for each regulation proxy. All regressions consider Huber-White corrected standard errors. Columns display a progressive inclusion of the explanatory variables. We start with the basic model considering regulation and R&D spillovers (column [1]). We then allow for a differentiated effect of regulation depending on the size of innovation, which is captured by the interaction between regulation and the dummy variable HT (column [2]). In line with recent works on innovation (Aghion et al. [2005]), the model in column [3] includes the proximity to the technological frontier. We use the lag of this variable in order to avoid (at least in part) reverse causality caveats. In column [4] we add the capital labour ratio and the financial deepness proxy. Finally, in column [5] we test a dynamic model including the lagged value of R&D intensity and the rest of controls. All models considers year dummies and individual fixed effects. Further, in the bottom part of each table we include the assessment of the overall effect of regulation on R&D intensity in HT industries. This is computed as the marginal effect $\hat{\alpha}_1 + \hat{\alpha}_2$ (equation 4.35) and its significance.

Table 4.1 shows the results corresponding to the regulation proxy REGREF related to regulatory provisions in non-manufacturing sectors (telecoms, electricity, gas, post, rail, air passenger transport, and road freight). Manufacturing industries are intermediate inputs of these seven services and also use it in their business process. In this sense, manufacturing

production can be seen as subject to their regulation. In a more indirect way, this indicator also allows to capture the regulatory environment of an economy. Following this indicator, in our sample average, Greece and Italy appear as the most regulated countries. UK and US on the contrary are in the opposite extreme.

In the basic model of column [1], regulation has a positive and significant impact on R&D intensity. As expected, international R&D spillovers (R&D intensity of the rest of the world in the same industry), have a positive and significant effect in column [1]. The same is true for the rest of regressions. The model in column [2] yields a positive and significant coefficient of the interaction between regulation and the dummy variable HT. Thus, relative to the rest of industries, the effect of regulation is higher in HT manufacturing. Confirming the model's prediction this interaction term is positive and significant in all specifications. On the other hand, regulation fails to account for a significant effect in non-HT industries (the estimated elasticity of REGREF alone).

The marginal effect, computed in the bottom part of Table 4.1, considers both (a) the effect of regulation that is common for HT and non-HT industries ($\hat{\alpha}_1$ in equation 4.35) and (b) the additional incentives of HT industries to carry out R&D when regulation is increased ($\hat{\alpha}_2$ in equation 4.35). This marginal effect of regulation on R&D intensity in HT industries is mostly positive and significant. Only in the model with full controls the minimum level of significance is not attained.

Capital labour ratio and financial assets over GDP have a positive and significant estimated elasticity in column [4]. When the lag of the dependent variable is included (column [5]), their effect is no longer significant. On the contrary, the closeness to frontier

is only significant in the latter model (at 10%) and its sign is negative. Theoretically it can not be discarded a negative sign since in advanced technological states R&D costs are higher. The change of sign and significance in this estimate, however, calls for further analysis since a correlation is expected with the lagged dependent variable. On the other hand, R&D spillovers and the interaction term are still significant in this autoregressive specification.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator					
Regulation proxy: Regulatory Provisions in Services (REGREF)					
	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.146*** (0.047)	0.205*** (0.042)	0.226*** (0.039)	0.364*** (0.066)	0.199*** (0.071)
REGREF	0.264*** (0.082)	0.047 (0.070)	0.011 (0.066)	-0.384*** (0.105)	-0.182** (0.085)
REGREF x HT		0.663*** (0.094)	0.705*** (0.089)	0.817*** (0.123)	0.286*** (0.107)
Closeness to Frontier (t-1)			0.087 (0.058)	0.030 (0.057)	-0.073* (0.042)
K/L				0.160** (0.079)	-0.015 (0.061)
Financial Assets				0.131* (0.077)	0.073 (0.070)
R&D/VA (t-1)					0.601*** (0.045)
_cons	-3.023*** (0.220)	-2.761*** (0.195)	-3.003*** (0.320)	-2.109*** (0.551)	-0.645 (0.524)
REGREF on HT industries (marginal effect)		0.709*** (0.119)	0.716*** (0.114)	0.433*** (0.147)	0.104 (0.127)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT (dummy)

Table 4.1.

The so called "knock-on" effect of non-manufacturing regulation on manufacturing activities are captured by the regulation proxy REGIMP. This policy indicator is constructed accordingly to the "use" of non-manufacturing sectors in manufacturing. It gives then a measure of the regulatory constraints on the input side of production. The advantage is that it is available in time-series cross-section data. Results are presented in Table

4.2. As before, the impact of R&D spillover on R&D intensity is significant in all specifications. Further, in non-HT industries regulation does not account for a significant effect on R&D intensity. This time this is observed in all columns. However, once the interaction is considered, one observes the positive effect of regulation on R&D intensity in HT industries. This is true in relative and absolute terms. For both the interaction term and the overall marginal effect of regulation on HT manufacturing, the estimated coefficients are positive and significant in all specification, even for the autoregressive model.

The sign of the rest of controls are similar than before, but their significance changes. Financial deepness fails to yield a significant effect. This time, neither does the closeness to frontier in column [5]. On the contrary, its positive sign in column [3] is significant.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator					
Regulation proxy: "Knock on" effect of non-manufacturing regulation (REGIMP)					
	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.159*** (0.048)	0.204*** (0.044)	0.225*** (0.041)	0.342*** (0.069)	0.184** (0.072)
REGIMP	-0.026 (0.129)	-0.175 (0.125)	-0.179 (0.125)	-0.300 (0.221)	-0.004 (0.195)
REGIMP x HT		1.533*** (0.260)	1.720*** (0.231)	1.558*** (0.288)	0.593** (0.238)
Closeness to Frontier (t-1)			0.105* (0.060)	0.043 (0.057)	-0.068 (0.042)
K/L				0.161** (0.082)	-0.013 (0.062)
Financial Assets/ GDP				0.115 (0.084)	0.079 (0.077)
R&D/VA (t-1)					0.610*** (0.045)
_cons	-2.618*** (0.287)	-1.892*** (0.323)	-2.166*** (0.361)	-2.868*** (0.566)	-0.692 (0.525)
REGIMP on HT industries (marginal effect)		1.358*** (0.291)	1.541*** (0.256)	1.258*** (0.337)	0.589** (0.292)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT (dummy)

Table 4.2

Results are slightly different for the product market regulation proxy (PMR). PMR is an aggregate of economy-wide indicators aiming at capture market barriers. It does not vary in every period. We dispose of two surveys (2 points in time) distributed in the sample. This is probably the main reason for some changes in the estimations. Table 4.3 presents the results. Now the effect of regulation in the simple model (column [1]) appear to be negative and significant. This is also true for the effect of regulation in non-HT technologies in column [2] and [3], but the significance is not attained when further controls are included (column [4] and [5]). Interestingly, a positive and significant interaction between regulation and HT industries still shows up in these regressions, at the exception of the full control model with autoregressive dependent variable. While the result of additional R&D incentives induced by regulation in HT industries still holds, the addition of the positive and the negative part of regulation consequences yields a non significant overall marginal effect of regulation on HT industries.

Again a change of sign and significance is observed for the closeness to frontier. In general, the level of significance of the controls in these PMR regressions does not allow further conclusions.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Economy-wide product market regulation (PMR)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.152*** (0.048)	0.192*** (0.046)	0.217*** (0.043)	0.331*** (0.070)	0.170** (0.073)
PMR	-0.782*** (0.240)	-0.933*** (0.244)	-0.908*** (0.235)	-0.262 (0.332)	-0.009 (0.257)
PMR x HT		0.675*** (0.171)	0.788*** (0.143)	0.641*** (0.188)	0.037 (0.161)
Closeness to Frontier (t-1)			0.067 (0.060)	0.036 (0.058)	-0.071* (0.042)
K/L				0.133 (0.086)	-0.030 (0.062)
Financial Assets/ GDP				0.079 (0.084)	0.062 (0.076)
R&D/VA (t-1)					0.621*** (0.045)
_cons	-2.117*** (0.223)	-1.998*** (0.217)	-2.221*** (0.313)	-2.475*** (0.640)	-0.797 (0.567)
PMR on HT industries (marginal effect)		-0.258 (0.255)	-0.120 (0.227)	0.379 (0.355)	0.029 (0.252)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT (dummy)

Table 4.3.

Among market barriers summarised in PMR, one important indicators is the size of public sector enterprise (PMR-Public). One should expect that a higher and active scope of the state in manufacturing impose higher regulation, namely in the production of new varieties. Table 4.4 shows the results considering PMR-Public. The effect of regulation in the simple model is again positive and significant (column [1]). Similarly, once the interaction is considered the effect of PMR Public alone (the impact of regulation on R&D inn non-HT industries) is non significant. Concerning our estimates of interest, we observe again that the interaction variable has a positive and significant coefficient in almost all specifications. In column [4] (full set of controls), however, the significance is ensured only at 10% and in column [5] (full set of control and autoregressive dependent variable) it is not attained. The overall marginal effect of regulation on HT industries is positive and

significant as before. The estimates related to the rest of controls are similar than in PMR regressions. Only the closeness to the frontier is significant in the autoregressive model.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Size of Public Sector Entprise (PMR Public)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.155*** (0.054)	0.190*** (0.052)	0.217*** (0.049)	0.318*** (0.071)	0.166** (0.073)
PMR Public	0.555** (0.250)	0.147 (0.250)	0.193 (0.245)	0.371 (0.321)	0.162 (0.215)
PMR Public x HT		1.566*** (0.551)	2.011*** (0.470)	0.818* (0.418)	-0.076 (0.332)
Closeness to Frontier (t-1)			0.086 (0.064)	0.044 (0.058)	-0.070* (0.041)
K/L				0.113 (0.085)	-0.037 (0.062)
Financial Assets/ GDP				0.107 (0.079)	0.066 (0.070)
R&D/VA (t-1)					0.622*** (0.045)
_cons	-3.751*** (0.327)	-3.657*** (0.310)	-4.093*** (0.427)	-3.395*** (0.662)	-1.002* (0.549)
PMR Public on HT industries (marginal effect)		1.713*** (0.531)	2.204*** (0.469)	1.189*** (0.396)	0.086 (0.313)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2548	2548	2535	1110	1012
Number of groups	176	176	176	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT (dummy)

Table 4.4.

Overall, these results confirm the main model prediction regarding the Schumpeterian equilibrium. As regulation increase, the dissuasive effect of defensive strategies of the leaders can be reduced. As a consequence, R&D incentives are higher, but the final effect regulation is always modulated by the size of innovation since it shapes monopolist incentives. This prediction implies that the positive effect of regulation should empirically be found when the size of innovation is higher. This is what the interaction term confirm for almost all regressions and indicators of regulation. Finally, it should be stressed that further work is needed concerning the dynamic regressions. The reduced size of the sample has compelled us to abandon a GMM strategy. A detailed examination of available instru-

ments should be carry out. The aim of this task should be to find a reduced and powerful set of instruments allowing to control for the (reduced) risk of downward bias in the autoregressive coefficient, without weakening the tests of exogeneity of instruments. However, note that for the time varying regulation proxies (REGREF and REGIMP), the interaction term still yields a positive and significant coefficient in the dynamic specification. This is important because these indicators are more pertinent to perform panel data regressions.

One may argue that our time-series cross-section data structure implies intra-group correlation. Thus, we run all regressions using clustered Huber-White correction of standard errors. Results are presented in Tables 4.5 to 4.8 (in appendix). Concerning the interaction term, most of the previous results are preserved. Namely, for the time varying indicators REGREF and REGIMP, the sign of the estimate is positive and significant in all regressions, even for the autoregressive model. The significance of the overall marginal effect of regulation on R&D in HT industries is reduced for the static model with the full set of controls and the autoregressive one. As before, the lack of significance of this estimate still appears in PMR regressions. However, the marginal effect still remain positive and significant in most of regressions.

Finally, as an additional robustness check we redefine the HT dummy variable to incorporate other activities using intensively ICT industries as suppliers. We namely include industries 29 (machinery and equipment) and motor vehicles (34). We show the results in Tables 4.9 to 4.12 (in the appendix). Here again, the main argument of the model is confirmed: the coefficient of the interaction term is still positive and significant for most of specifications and indicators.

4.4 Conclusion

We have shown in a simple quality-ladders model the consequences of defensive innovation strategies on R&D effort and market structure. Among available strategies, defensive reactions may render R&D more costly and reduce the incentives to innovate. Institutions constraining this set of strategies and reducing its deterring effects may increase the resources devoted to innovation and also the number of active R&D race participants.

The evolution of R&D expenditure in OECD industries confirms these results, specially for time-varying indicators of market regulation. In general, static regressions provide clear results. In most specifications, regulation positively influences R&D in high-technology industries and its effect is clearly higher relative to the rest of industries. Due to the reduced size of our times-series cross-section data, we tested the dynamic specifications using Within-group estimates. While a downward bias risk still exists, we argue that, at least partially, it should be reduced by the length of the sample. notwithstanding , for the time-varying indicators our main results still hold in dynamic specifications.

Despite data limitation on R&D and the simple framework of the model, the core message seems clear: Defensive reactions in manufacturing, hard to enforce and more or less limited by market regulation, raise the question about the role of market institutions steering rivalry externalities.

Notice that industry-level evidence is useful since it exploits the consequences of different competitive environments. In that sense, further efforts can be addressed to check the robustness of our results by using alternative measures of performance and more de-

tailed indicators of regulation, as well as by including firm demographic data at the industry level.

Overall, the results of this Chapter are in line with those presented in Chapter 3 in which we used patenting measures to identify the effect of competition and regulation on innovation at the leading edge. Using different specifications, data and robustness checks, the evidence presented in this part of the thesis suggest that the outcome of deregulation programs may not have the expected pro-innovative effect argued in recent policy agendas. The study of the impact of this kind of policy seems to need a deep analysis of firm strategic behaviour.

4.A Appendix to Chapter 4

4.A.1 Robustness check 1: clustered corrected standard errors

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Regulatory Provisions in Services (REGREF)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.146* (0.079)	0.205*** (0.071)	0.226*** (0.062)	0.364*** (0.104)	0.199*** (0.054)
REGREF	0.264 (0.198)	0.047 (0.147)	0.011 (0.139)	-0.384* (0.205)	-0.182 (0.118)
REGREF x HT		0.663*** (0.231)	0.705*** (0.226)	0.817*** (0.221)	0.286** (0.123)
Closeness to Frontier (t-1)			0.087 (0.130)	0.030 (0.106)	-0.073 (0.058)
K/L				0.160 (0.144)	-0.015 (0.078)
Financial Assets				0.131 (0.127)	0.073 (0.071)
R&D/VA (t-1)					0.601*** (0.044)
_cons	-3.023*** (0.425)	-2.761*** (0.359)	-3.003*** (0.645)	-2.109** (1.021)	-0.645 (0.613)
REGREF on HT industries (marginal effect)		0.709** (0.301)	0.716** (0.290)	0.433 (0.264)	0.104 (0.147)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Clustered Huber-White corrected standard errors in parentheses
 * p<0.10, ** p<0.05, *** p<0.01; All variables in natural logs, except HT (dummy)

Table 4.5.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: "Knock on" effect of non-manufacturing regulation (REGIMP)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.159* (0.081)	0.204*** (0.073)	0.225*** (0.064)	0.342*** (0.108)	0.184*** (0.056)
REGIMP	-0.026 (0.257)	-0.175 (0.255)	-0.179 (0.257)	-0.300 (0.369)	-0.004 (0.232)
REGIMP x HT		1.533*** (0.588)	1.720*** (0.560)	1.558*** (0.574)	0.593** (0.293)
Closeness to Frontier (t-1)			0.105 (0.138)	0.043 (0.102)	-0.068 (0.055)
K/L				0.161 (0.147)	-0.013 (0.076)
Financial Assets/ GDP				0.115 (0.135)	0.079 (0.075)
R&D/VA (t-1)					0.610*** (0.045)
_cons	-2.618*** (0.537)	-1.892*** (0.635)	-2.166*** (0.737)	-2.868** (1.109)	-0.692 (0.683)
REGIMP on HT industries (marginal effect)		1.358** (0.629)	1.541*** (0.589)	1.258* (0.643)	0.589* (0.327)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Clustered Huber-White corrected standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01; All variables in natural logs, except HT (dummy)

Table 4.6.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Economy-wide product market regulation (PMR)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.152* (0.081)	0.192** (0.075)	0.217*** (0.066)	0.331*** (0.107)	0.170*** (0.057)
PMR	-0.782* (0.415)	-0.933** (0.430)	-0.908** (0.408)	-0.262 (0.400)	-0.009 (0.289)
PMR x HT		0.675** (0.310)	0.788*** (0.266)	0.641*** (0.244)	0.037 (0.130)
Closeness to Frontier (t-1)			0.067 (0.139)	0.036 (0.101)	-0.071 (0.052)
K/L				0.133 (0.156)	-0.030 (0.080)
Financial Assets/ GDP				0.079 (0.135)	0.062 (0.077)
R&D/VA (t-1)					0.621*** (0.045)
_cons	-2.117*** (0.416)	-1.998*** (0.396)	-2.221*** (0.596)	-2.475** (1.004)	-0.797 (0.626)
PMR on HT industries (marginal effect)		-0.258 (0.423)	-0.120 (0.377)	0.379 (0.438)	0.029 (0.260)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Clustered Huber-White corrected standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01; All variables in natural logs, except HT (dummy)

Table 4.7.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Size of Public Sector Entrprise (PMR Public)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.155* (0.090)	0.190** (0.085)	0.217*** (0.076)	0.318*** (0.110)	0.166*** (0.057)
PMR Public	0.555 (0.381)	0.147 (0.400)	0.193 (0.395)	0.371 (0.450)	0.162 (0.231)
PMR Public x HT		1.566 (0.971)	2.011** (0.849)	0.818 (0.565)	-0.076 (0.283)
Closeness to Frontier (t-1)			0.086 (0.150)	0.044 (0.101)	-0.070 (0.052)
K/L				0.113 (0.155)	-0.037 (0.078)
Financial Assets/ GDP				0.107 (0.134)	0.066 (0.071)
R&D/VA (t-1)					0.622*** (0.045)
_cons	-3.751*** (0.531)	-3.657*** (0.496)	-4.093*** (0.814)	-3.395*** (1.046)	-1.002* (0.594)
PMR Public on HT industries (marginal effect)		1.713* (0.892)	2.204*** (0.823)	1.189** (0.513)	0.086 (0.227)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2548	2548	2535	1110	1012
Number of groups	176	176	176	98	98

Note: Clustered Huber-White corrected standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01; All variables in natural logs, except HT (dummy)

Table 4.8.

4.A.2 Robustness check 2: high technology definition

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Regulatory Provisions in Services (REGREF)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.146*** (0.047)	0.201*** (0.046)	0.233*** (0.043)	0.362*** (0.072)	0.184** (0.077)
REGREF	0.264*** (0.082)	0.046 (0.073)	-0.008 (0.068)	-0.355*** (0.107)	-0.164* (0.086)
REGREF x HT2		0.449*** (0.072)	0.505*** (0.076)	0.254** (0.107)	0.045 (0.077)
Closeness to Frontier (t-1)			0.125** (0.063)	0.071 (0.060)	-0.066 (0.043)
K/L				0.124 (0.084)	-0.031 (0.062)
Financial Assets				0.106 (0.079)	0.061 (0.070)
R&D/VA (t-1)					0.617*** (0.045)
_cons	-3.023*** (0.220)	-2.786*** (0.209)	-3.140*** (0.342)	-2.330*** (0.574)	-0.659 (0.527)
REGREF on HT2 industries (marginal effect)		0.495*** (0.101)	0.497*** (0.099)	-0.101 (0.152)	-0.119 (0.103)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT2 (dummy)

Table 4.9

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: "Knock on" effect of non-manufacturing regulation (REGIMP)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.159*** (0.048)	0.200*** (0.047)	0.231*** (0.044)	0.352*** (0.072)	0.183** (0.076)
REGIMP	-0.026 (0.129)	-0.203 (0.129)	-0.230* (0.130)	-0.215 (0.220)	0.032 (0.197)
REGIMP x HT2		0.969*** (0.184)	1.153*** (0.187)	0.681*** (0.231)	0.231 (0.176)
Closeness to Frontier (t-1)			0.133** (0.065)	0.076 (0.060)	-0.057 (0.043)
K/L				0.133 (0.085)	-0.025 (0.062)
Financial Assets/ GDP				0.107 (0.085)	0.074 (0.077)
R&D/VA (t-1)					0.619*** (0.045)
_cons	-2.618*** (0.287)	-1.990*** (0.322)	-2.332*** (0.361)	-2.807*** (0.563)	-0.633 (0.524)
REGIMP on HT2 industries (marginal effect)		0.766*** (0.210)	0.922*** (0.201)	0.466 (0.293)	0.262 (0.240)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT2 (dummy)

Table 4.10.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Economy-wide product market regulation (PMR)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.152*** (0.048)	0.182*** (0.047)	0.210*** (0.045)	0.325*** (0.071)	0.171** (0.075)
PMR	-0.782*** (0.240)	-0.958*** (0.252)	-0.945*** (0.244)	-0.284 (0.349)	-0.017 (0.264)
PMR x HT2		0.476*** (0.127)	0.577*** (0.122)	0.311** (0.144)	0.046 (0.112)
Closeness to Frontier (t-1)			0.089 (0.063)	0.062 (0.059)	-0.068 (0.041)
K/L				0.130 (0.087)	-0.029 (0.062)
Financial Assets/ GDP				0.079 (0.084)	0.062 (0.076)
R&D/VA (t-1)					0.621*** (0.045)
_cons	-2.117*** (0.223)	-2.028*** (0.223)	-2.331*** (0.324)	-2.613*** (0.643)	-0.803 (0.565)
PMR on HT2 industries (marginal effect)		-0.482** (0.236)	-0.368* (0.218)	0.026 (0.304)	0.029 (0.233)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2756	2756	2743	1110	1012
Number of groups	189	189	189	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT2 (dummy)

Table 4.11.

Dependent variable: R&D intensity (R&D/VA) - Within Group estimator
Regulation proxy: Size of Public Sector Entrprise (PMR Public)

	[1]	[2]	[3]	[4]	[5]
R&D Spillovers	0.155*** (0.054)	0.179*** (0.054)	0.210*** (0.051)	0.307*** (0.072)	0.164** (0.074)
PMR Public	0.555** (0.250)	0.142 (0.277)	0.158 (0.275)	0.481 (0.359)	0.196 (0.238)
PMR Public x HT2		1.005** (0.409)	1.335*** (0.382)	0.176 (0.383)	-0.134 (0.277)
Closeness to Frontier (t-1)			0.105 (0.068)	0.050 (0.059)	-0.073* (0.041)
K/L				0.102 (0.086)	-0.037 (0.063)
Financial Assets/ GDP				0.110 (0.079)	0.066 (0.070)
R&D/VA (t-1)					0.622*** (0.045)
_cons	-3.751*** (0.327)	-3.681*** (0.319)	-4.176*** (0.443)	-3.556*** (0.658)	-1.005* (0.552)
PMR Public on HT2 industries (marginal effect)		1.147*** (0.373)	1.493*** (0.352)	0.657** (0.324)	0.062 (0.240)
year dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	2548	2548	2535	1110	1012
Number of groups	176	176	176	98	98

Note: Huber-White corrected standard errors in parentheses
All variables in natural logs, except HT2 (dummy)

Table 4.12.

4.A.3 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.
R&D / Added Value	2852	0,104	0,527
PMR	5760	1,801	0,437
REGREF	6375	4,193	1,312
PMR Public	6375	3,015	1,280
REGIMP	6375	0,132	0,037
Closeness to Frontier	6043	56,946	23,458
K/L (hours)	2785	0,046	0,031
Financial Assets/GDP	4440	66,915	50,330

Table 4.13.

General Conclusion

In this thesis, we have studied the link between market structure and productivity. We have paid particular attention to manufacturing features related to firm heterogeneity, economies of scale and asymmetric knowledge. These features have been studied in different strategic contexts. In the first part, we focused on firm productivity gains and intra-industry trade, mainly motivated by the representation of a developing economy. In the second part, we considered R&D and innovation in a closed economy, mainly motivated by recent debates concerning European performances and the role of regulation on innovation. By the means of both theoretical and empirical tools, the thesis emphasises the role of market structure on firm's incentives to improve productivity. The specific outcome of market structure on productivity gains depends on the particular features of production, knowledge and the composition of the industry.

The results of this research can be summarised in two main contributions. First, the thesis sheds light on our understanding of heterogeneous productivity gains at the firm level in an open economy. In this sense, it contributes to the “new new” trade theory by addressing the evolution of firm productivity. As a consequence, the thesis puts forward the importance of within-firm channels to explain the effect of trade on aggregate productivity. Indeed, one important finding of the first part of the thesis is that the effect of these within-firm channels is not homogeneous across firms. Using plant-level data of Chile in the period (1980-1999), Chapter 1 empirically highlights how foreign competition and the access to larger markets determine firm's productivity improvements. While export-oriented firms

do obtains productivity gains, import-competing ones suffer from foreign competition. The fact that import-competing industries appear as producing with increasing returns to scale is a plausible explanation for this result. This is quite intuitive since the case of Chile is in fact one of a small highly open economy.

Chapter 1 also shows that exporters get more advantages from the access to foreign technology (as measured by trade barriers on machinery) and that within-firm productivity improvements do help to explain the aggregate evolution. Chapter 2 theoretically deals with these insights. By allowing technology adoption in a Melitz-type model, we explain that the evolution of productivity is heterogeneous across firms and that it will depend on the ex-ante gains from investment in technology. Monopolistic competition is crucial to reproduce an emphasised process of self-selection. Firms compete with the whole economy. The average productivity of the economy increases with individual investments. However firms do not take the external effect of their investment into account. This externality discourages the investment of those firms in which, ex-ante, labour productivity is less sensible to investment. In fact, they may reduce their initial level of productivity in comparison to a model with exogenous and fixed productivity gains. For similar reasons, most of gains from trade are concentrated on the intensive margin. Among exporters, only a reduced number will capture the increase in foreign demands.

The second contribution of the thesis is to address the effect of regulation on firm's incentives to innovate when there are strategic interactions among competitors. Allowing for the possibility of innovative leaders, the thesis provides new insights in Schumpeterian innovation theory. We emphasise a complementary explanation to the traditional "Schum-

peterian” and “trimming fats” mechanisms, which account for a negative and a positive effect of competition, respectively. This new mechanism highlights the consequences of rivalry among competitors when the set of strategies enable incumbents to deter their rivals in the R&D contest. Actually, if the innovation of a firm has consequences on the R&D process of its competitors, or if innovation is not the only strategy available to a firm in order to increase profits, the increase in competition may not be always an incentive to “escape from competition” or to “trim fats”. On the contrary, it can be an incentive to “reduce competition” itself. Implicitly, this raises the question about what does regulation mean. If we understand it as the rules of the game that define the set of available strategies (even if in an indirect manner), regulation can in fact boost innovation. In the second part, using times-series cross-section data for a sample of industries belonging to OECD countries, Chapter 3 shows that the effect of regulation at the technological leading edge can in fact foster innovation. Actually, allowing for an innovative leader whose new discoveries reduce the diffusion of knowledge, we apply this argument to the Aghion et al. (2005) model and show the possibility of multiple equilibriums. In Chapter 4, we go into more details on these mechanisms. Here, the theoretical contribution is to endogenously determine the conditions under which the Arrow-replacement effect no longer applies in the usual way. Indeed, when the new innovative firm uses its private knowledge to introduce a bias in the visible properties of the good, it can get a technological advantage that, in a Stackelberg-type game, allows the firm to drive its rivals out of the R&D race. Thus, if regulation can reduce the possibilities of bias, it can also foster R&D. The model predicts that, empirically, this effect is more likely to be observed when the size of innovation is high. In our

data of OECD industries, using R&D intensity, we observe the positive effect of regulation in high technology industries.

The research carried out in this thesis calls for further extensions. On the whole, for the sake of analytical parsimony, all theoretical tools used in the thesis have considered a reduced form of labour market with inelastic labour supply. The inclusion of more realistic representation of labour market such as efficiency-wages setting for instance, can give further insights on interactions between labour and product markets. On the empirical ground, dynamic specifications may need further strategies to solve the problem of weak instruments. The use of simulation to select appropriate estimators in each case may be an interesting empirical strategy.

Starting from results of Chapter 1, a natural extension is to continue on the search for identification of mechanisms linking trade and firm productivity. Namely, the case of exporters can be studied in more detail. In Chapter 1, we considered the trade orientation of the industry in order to use the full sample period and to include the years following the radical trade reform in Chile. Starting from 1990, data on exports is available at the firm level. Though the variability of import barriers is reduced, the decade of 1990s is the beginning of trade agreements oriented to boost exports. Thus, one can focus on industry-cases and test, by analysing cohorts, the importance of learning-by-exporting as a channel of productivity improvements. A second extension of this part of the thesis consist in improving our understanding of the stochastic aspects of the evolution of firm productivity. In Chapter 2, we have set a reduced version of what should be a stochastic dynamic model accounting for the modification of the distribution of firm productivity. The analysis of the

distribution density at equilibrium may require the use of stochastic simulation that can be completed with our micro data.

Regarding our work on the Schumpeterian innovative process, the open economy can be explicitly included. Empirically, one interesting line of research is to address the impact of regulation on revealed comparative advantages. The dataset contains information to compute this type of indicator. Thus, the finding of Chapter 3 can be extended to consider an alternative measure of external performance which can complete our finding using patenting series. The difficulty of this attempt lies in the selection of plausible indicators of domestic regulation. A solution may consist in using more disaggregated indicators of market regulation. In that case, one may face the time-invariant structure with a methodology of fixed effect decomposition (see footnote 30). Theoretically, the extension of the model presented in Chapter 4 to the open economy can be oriented to study how market structure in a country affects its trading partner. To avoid corner solutions, technologies of R&D can be adapted to consider decreasing returns. In a model of trade between two symmetric countries, that only differ in their domestic regulation, one should expect international externalities coming from domestic regulation. For instance, depending on costs, a firm selling to a high regulated economy may reduce its level of bias in its domestic market, which in turn modifies market structure in the foreign market.

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