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# Sustainable development investment in Brazil and socio-economic externalities: three empirical essays

Swaroop Rao

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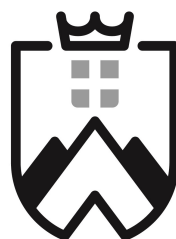
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**UNIVERSITÉ  
SAVOIE  
MONT BLANC**

## **THÈSE**

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préparée au sein du **Laboratoire IREGÉ**  
et de **l'École Doctorale CST**

## **Investissement dans le développement durable au Brésil et externalités socio-économiques : trois essais empiriques**

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## Résumé

À l'heure où les effets du changement climatique anthropique deviennent visibles et où l'on attend des pays qu'ils contribuent aux réductions des émissions de gaz à effet de serre, les débats se concentrent souvent avec les pays en développement, considérés comme les moteurs de la croissance économique – une croissance qui entraîne une amélioration des conditions socio-économiques, notamment en ce qui concerne la création d'emplois et la réduction des inégalités sociales et de la pauvreté. Ces pays sont depuis longtemps confrontés à un dilemme politique qui oppose les préoccupations environnementales, d'une part, et les besoins de développement, d'autre part. Le concept de développement durable vise donc à donner une orientation au monde en développement qui tienne compte des facteurs environnementaux et sociaux (entre autres). En utilisant des méthodes d'évaluation économétriques, cette thèse examine de manière critique les impacts que les investissements dans le développement (durable) ont eu sur les indicateurs socio-économiques au Brésil, en particulier sur l'inégalité des revenus et la création d'emplois.

**Mots clés :** développement durable, méthodes économétriques, Brésil

## Abstract

In the present era where the effects of anthropogenic climate change are becoming visible, and where countries are expected to contribute to emissions mitigation, the spotlight is often on developing countries, which are often considered to be engines of economic growth – growth that leads to improved socioeconomic conditions, including employment creation and reductions in inequalities and poverty. These countries have long faced a policy dilemma that pits environmental concerns on the one hand with development needs on the other. The concept of Sustainable Development therefore aims to give a direction to the developing world that takes into account environmental and social factors (among others). Using econometric evaluation methods, this thesis critically examines the impacts that (sustainable) development investment has had on socio-economic indicators in Brazil, especially on income inequality and on employment creation.

**Keywords :** sustainable development, econometric methods, Brazil



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*À la SNCF et à la région Auvergne-Rhône-Alpes :  
j'ai vécu mes meilleurs moments de créativité  
dans le TER d'Annecy à Grenoble.*

*Que d'autres jeunes chercheurs et chercheuses  
trouvent l'inspiration dans notre région si belle  
et que les pouvoirs publics investissent davantage  
pour faire perdurer notre riche histoire ferroviaire*

---



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## Résumé

Dans les années 2020 dans les pays développés, le changement climatique occupe une position centrale dans le discours public, avec un large éventail d'acteurs prenant activement part aux débats sur l'atténuation et l'adaptation au changement climatique. Ce qui était (et reste) un débat de politique publique a depuis débordé sur le domaine privé, les chercheurs s'intéressant même aux impacts sur la santé mentale des adultes et des enfants d'un avenir climatique incertain (Ballew et al., 2019, Léger-Goodes et al., 2022). Cependant, les causes et les répercussions du changement climatique anthropique sont de nature globale et ne sont pas uniformes selon les zones géographiques ou les groupes de population, ou entre les pays développés et les pays en développement (Masson-Delmotte et al., 2021, Parry et al., 2007). Il a été démontré que le changement climatique aura des effets économiques durables, en plus des effets sur la santé et le bien-être, avec des effets potentiellement plus durs pour les pays en développement (Ahluwalia and Patel, 2022). En conséquence, le discours public sur le changement climatique est également différent entre les pays développés et les pays en développement. L'un des principaux points de friction dans les négociations internationales sur le climat a été le rôle des pays en développement, en particulier de la Chine, de l'Inde et du Brésil, dans la contribution à l'effort climatique coordonné au niveau international (Chemnick, 2021, Parsons and Taylor, 2021). Le thème de la justice climatique, dans toute sa complexité, a donc gagné en importance dans les discussions des universitaires, des politiques et de la société civile, et même les tribunaux ont souvent renforcé les arguments en faveur de la justice climatique (Jenkins, 2018, Strack, 2021).

En raison de cette nature non uniforme des causes et des répercussions du changement climatique, les discussions tournent souvent autour du thème du partage des responsabilités, les pays impliqués lors des négociations internationales sur le climat ayant souvent des points de vue différents sur ce que la justice distributive implique pour leurs pays respectifs (même si leurs citoyens ne partagent pas nécessairement les mêmes points de vue) (Schleich et al., 2016). Un exemple

important de cette discussion a eu lieu lors du Sommet de la Terre de 1992 à Rio de Janeiro, où le concept de "responsabilités communes mais différenciées" a été adopté comme stratégie pour atténuer le changement climatique, en tenant compte des "conditions sociales et économiques" respectives des pays et de leurs "priorités, objectifs et circonstances spécifiques de développement national et régional" ([Rajamani, 2000](#), [United Nations, 1992](#)).

Au cours du même sommet, la Déclaration de Rio sur l'environnement et le développement a également été signée par au moins 166 pays ([United Nations, 2022](#)) qui prend sérieusement note des liens entre les prérogatives du développement et de la protection de l'environnement. Le principe 3 de la déclaration ([United Nations General Assembly, 1992](#)) l'indique clairement :

Le droit au développement doit être réalisé de manière à répondre équitablement aux besoins des générations présentes et futures en matière de développement et d'environnement.

En outre, cette déclaration, dans son principe 4, donne une impulsion au concept (alors) naissant de développement durable :

Pour parvenir à un développement durable, la protection de l'environnement doit faire partie intégrante du processus de développement et ne peut être considérée isolément de celui-ci.

Et enfin, sur le thème de la pauvreté et de l'inégalité, le principe 5 stipule :

Tous les États et tous les peuples doivent coopérer à la tâche essentielle de l'élimination de la pauvreté, condition indispensable du développement durable, afin de réduire les disparités de niveau de vie et de mieux répondre aux besoins de la majorité des habitants de la planète.

Dans le but de rendre opérationnels ces objectifs de développement durable, huit "objectifs du millénaire pour le développement" (OMD) ont été élaborés lors du sommet du millénaire en 2000, parmi lesquels figurent les suivants : ([United Nations, 2015](#))<sup>1</sup> :

- OMD 1 : Réduire l'extrême pauvreté et la faim
- OMD 7 : Assurer un environnement durable, et
- OMD 8 : Partenariat mondial pour le développement)

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1. Seuls les OMD et les ODD qui présentent un intérêt immédiat pour le sujet de cette thèse ont été mentionnés ici.

. En 2016, les OMD ont été remplacés par les dix-sept objectifs de développement durable (ODD) qui établissent un programme de développement pour l'après-2015 ([United Nations General Assembly, 2015](#)). Les objectifs pertinents parmi eux sont :

- SDG 1 : Mettre fin à la pauvreté sous toutes ses formes et en tout lieu.
- SDG 7 : Assurer l'accès de tous à une énergie abordable, fiable, durable et moderne
- SDG 8 : Promouvoir une croissance économique soutenue, inclusive et durable, le plein emploi productif et un travail décent pour tous
- SDG 9 : Construire des infrastructures résilientes, promouvoir une industrialisation inclusive et durable et encourager l'innovation
- SDG 10 : Réduire les inégalités au sein des pays et entre eux
- SDG 12 : Assurer des modes de consommation et de production durables
- SDG 13 : Prendre des mesures urgentes pour lutter contre le changement climatique et ses impacts
- SDG 17 : Renforcer les moyens de mise en œuvre et revitaliser le partenariat mondial pour le développement durable

Si ces objectifs servent le "développement durable" en général, le terme englobe une grande variété de notions, de normes et d'aspirations qui peuvent être synergiques ou en conflit les unes avec les autres, et ce à des degrés divers. La littérature scientifique a relevé les sources potentielles de synergie et de tension entre ces objectifs, et les chercheurs ont élaboré des cadres pour évaluer les interactions entre les objectifs : ([Lou et al., 2022](#), [Nilsson et al., 2016](#)). [Pradhan et al. \(2017\)](#), par exemple, entreprennent une telle évaluation, et trouvent des preuves de synergies substantielles (par exemple, l'ODD 1 étant synergique avec la plupart des autres ODD), mais aussi des compromis potentiels entre les ODD (comme avec l'ODD 12 et la plupart des autres ODD). Une évaluation et une quantification minutieuses de ces compromis sont nécessaires pour une réalisation efficace et effective de tous les objectifs de développement durable. Ceci est d'autant plus pertinent que les investissements dans l'atténuation des émissions ne peuvent qu'avoir une trajectoire ascendante, avec au moins 600 à 800 milliards de dollars US par an d'investissements supplémentaires dans le seul secteur de l'énergie considérés comme nécessaires pour atteindre un objectif de température de +1,5°C pour 2100 ([Ahluwalia and Patel, 2022](#)). L'examen critique des compromis potentiels entre les objectifs socio-économiques et environnementaux du dévelop-



pement durable dans les pays en développement constitue donc la motivation première de cette thèse.

A travers les trois chapitres de cette thèse, différents aspects de ces tensions ou compromis potentiels entre divers objectifs de développement durable sont étudiés. En utilisant le cadre des externalités des investissements, les externalités socio-économiques dans ce cas, ces compromis potentiels sont quantifiés. Peu d'études dans la littérature traitent de l'évaluation des investissements de développement au Brésil à différents niveaux et en utilisant des données à différents niveaux. Grâce aux récentes avancées en matière de méthodes économétriques, cette thèse examine les impacts socio-économiques des investissements de développement aux niveaux macro, méso et micro. Le chapitre 1 traite d'une analyse des projets du mécanisme de développement propre (MDP) et de son impact sur l'inégalité des revenus, le chômage et la pauvreté au Brésil. Le chapitre 2 examine les investissements de la banque nationale de développement du Brésil (BNDES) dans la production d'électricité et leur impact sur la production économique, l'emploi et les salaires au niveau municipal. Le chapitre 3 examine à nouveau les investissements de la BNDES et leur contribution potentielle à la polarisation et à l'inégalité des salaires dans l'État de São Paulo au Brésil, en utilisant des données au niveau des travailleurs.

Le Brésil, ses divisions régionales à différents niveaux et ses travailleurs constituent la base empirique de cette thèse. Pour le chercheur, le Brésil constitue un objet de recherche très intéressant, en raison de son importance dans l'économie mondiale (encore plus parmi les autres pays en développement tels que le groupement BRICS), de la diversité de son économie et du grand nombre d'investissements de développement qui ont été réalisés dans le pays au cours des deux dernières décennies (91 milliards de reais brésiliens (37,6 milliards de dollars US) entre 2003 et 2017 par la seule BNDES). Dans le même temps, le Brésil est toujours confronté à des problèmes de disparités sociales ainsi qu'à des problèmes environnementaux tels que la déforestation de la forêt amazonienne. Les engagements internationaux du Brésil en matière de climat, tels que ceux pris lors de la COP26 concernant la neutralité carbone d'ici 2050, ne font que renforcer le besoin d'analyses détaillées des synergies et des compromis potentiels entre l'atténuation des émissions et les objectifs de développement. Si les résultats présentés dans cette thèse sont formellement valables dans le contexte brésilien, en raison de la portée et de la profondeur des données et des analyses, les leçons tirées sont pertinentes et instructives pour d'autres pays en développement également. En outre, la disponibilité de sources de données riches et fiables a également été un facteur important dans le choix du Brésil pour les analyses de cette thèse.

Les implications politiques des résultats présentés dans les chapitres suivants ont pour but d'aider les décideurs politiques du Brésil et d'autres pays en développement, notamment dans la définition des priorités de leurs banques nationales de développement (ou équivalentes), ainsi que dans les négociations internationales sur le climat, à prendre en compte de manière plus précise les externalités des investissements de développement. Dans l'esprit du principe 4 de la Déclaration de Rio sur l'environnement et le développement (cité plus haut), si la protection de l'environnement doit être considérée comme faisant partie intégrante du développement, il est essentiel que toutes les externalités (qu'elles soient environnementales, sociales ou économiques) de l'investissement dans le développement soient prises en compte, afin de parvenir au développement durable de la manière la plus efficace possible.

Le reste de cette résumé sert à fournir des informations de base qui mettent en contexte chacun des chapitres de la thèse, ainsi qu'à relier les trois chapitres au niveau conceptuel. Tout d'abord, l'inégalité des revenus au Brésil est présentée, car elle fait partie intégrante du reste de la thèse, suivie d'une discussion sur le financement international de l'atténuation, puis d'une discussion sur l'investissement dans la production d'électricité propre. Un plan de la thèse est ensuite présenté, qui résume les bases théoriques des trois chapitres individuels de la thèse. Une conclusion générale de la thèse est ensuite présentée pour résumer les principaux résultats et les recommandations politiques résultant des chapitres de la thèse et pour offrir des directions pour les recherches futures que je voudrais entreprendre dans la suite de cette thèse.

## **Inégalité des revenus dans le monde et au Brésil**

Au milieu du 20<sup>e</sup> siècle, alors que l'inégalité des revenus au niveau mondial semble être restée stable, une réduction de l'inégalité des revenus à l'intérieur des pays a été constatée par [Chancel and Piketty \(2021\)](#), alors que la même étude constate que l'inégalité des revenus à l'intérieur des pays a augmenté depuis 1980. Avec l'augmentation des revenus des ménages et l'élévation des niveaux de développement induite par l'essor de l'économie chinoise, la prospérité mondiale est peut-être en hausse, mais cette prospérité est distribuée de manière inéquitable [Jaumotte, Lall and Papageorgiou \(2013\)](#). La littérature établit également un lien crucial entre la mondialisation et l'inégalité des revenus, un lien sur lequel se baseront les études de cette thèse. L'inégalité des revenus, par définition, est considérée comme un aspect intrinsèquement négatif d'une société ou, du moins, comme un objectif indésirable auquel une société doit aspirer, simplement parce qu'il va à l'encontre du principe d'une société égalitaire. Bien que l'inégalité des revenus ne soit pas

nécessairement associée à une augmentation de la pauvreté, elle conduit à ce que les sections les plus pauvres de l'économie soient plus exposées aux caprices des cycles économiques (Jaumotte et al., 2013). Les inégalités de revenus peuvent affecter la croissance économique en créant des inefficacités dans la distribution des compétences et de la main-d'œuvre dans l'économie (Deininger and Squire, 1997), en plus de provoquer des troubles sociaux (Keeley, 2015, Scheidel, 2017). Le Brésil et l'Amérique latine en général ont été considérés comme particulièrement touchés par les fortes inégalités de revenus (Suanes, 2016). Sur le plan théorique, les chapitres de cette thèse sont motivés par les théories de la différenciation sectorielle de l'économie, un concept proposé pour la première fois par (Fisher, 1939), et de la polarisation des salaires induite par le changement technologique favorisant les compétences (Skill-Biased Technological Change, SBTC) (Katz and Murphy, 1992), qui s'est ensuite transformé en concepts de changement technologique basé sur la routine (Routine-Biased Technological Change, RBTC). L'un des chapitres en particulier explore certains des liens entre le changement technologique basé sur les compétences et l'inégalité des revenus, inspiré par Acemoglu (2002) dont la thèse est qu'une augmentation du " ...biais des compétences au cours des dernières décennies semble être la cause principale de l'augmentation de l'inégalité [salariale] ". La thèse examine la question plus large des impacts socio-économiques des investissements de développement dans les pays en voie de développement en utilisant ces théories comme base, tout en se concentrant sur différents niveaux d'analyse (en utilisant des données de niveau micro, méso et macro), en utilisant le cas empirique du Brésil.

Les origines de l'inégalité des revenus au Brésil ont fait l'objet de nombreuses discussions dans le discours public et universitaire. L'inégalité des revenus semble avoir atteint son apogée durant l'ère industrielle, aux alentours de 1870, pendant le boom des matières premières. Si les études empiriques ont clairement montré que l'inégalité des revenus est restée élevée par rapport au "monde développé", les raisons sous-jacentes de l'inégalité "endémique" des revenus dans la région n'ont pas fait l'unanimité parmi les chercheurs.

Sokoloff and Engerman (2000) placent les dotations en facteurs et les institutions de l'époque coloniale à l'origine de l'inégalité des revenus dans la région. Ils affirment que, par rapport aux (actuels) États-Unis et au Canada, certaines parties de l'Amérique du Sud et des Caraïbes étaient mieux dotées en ressources qui encourageaient la spécialisation du travail. Cela a permis le développement d'institutions qui ont préservé ces inégalités en raison des possibilités de recherche de rente qui étaient présentes et qui ont ensuite favorisé les élites. La population (relativement) importante d'indigènes et la prédominance de l'esclavage en tant que pratique n'ont fait que favoriser

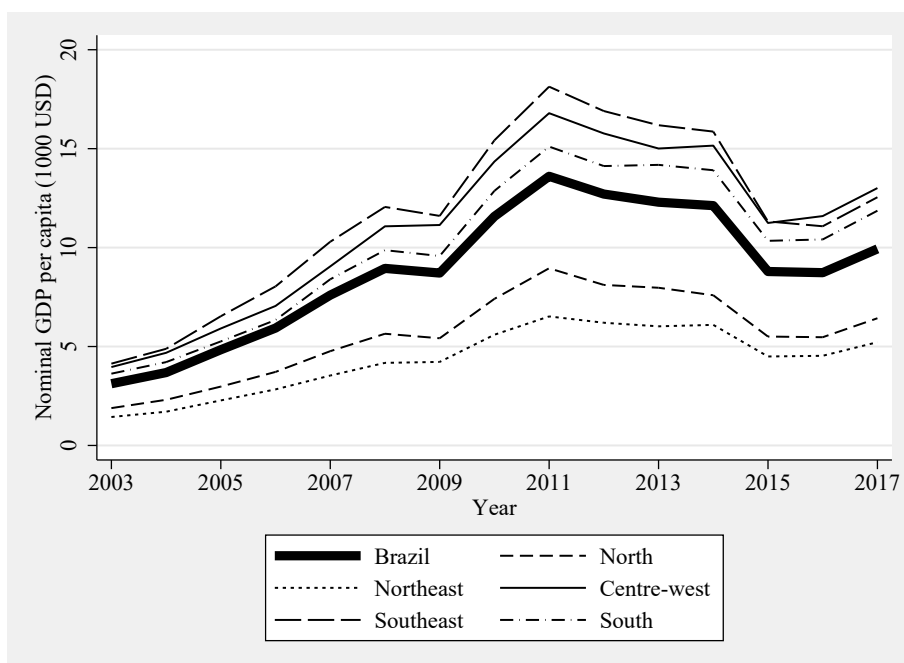
le développement de ces institutions. Selon les auteurs, cette situation contraste avec les régions d'Amérique du Nord qui étaient moins dotées en ressources à l'avènement du colonialisme et qui ont donc connu des schémas d'immigration plus égalitaires (parmi les profils économiques des immigrants).

Un point de vue opposé est proposé par [Williamson \(2015\)](#), qui souligne qu'il est important de replacer les statistiques historiques sur l'inégalité des revenus dans leur contexte et de les comparer à des statistiques similaires dans le monde entier. Selon lui, l'inégalité des revenus en Amérique latine n'était pas différente de celle de l'Europe du Nord-Ouest d'avant 1800 ou des États-Unis dans les années 1860. Là où l'inégalité des revenus a augmenté, c'est pendant le boom des matières premières des années 1870 jusqu'à la veille de la Première Guerre mondiale, mais ce faisant, la région a rejoint le "club des pays riches en matière d'inégalité"; là où l'Amérique latine se distingue du reste du monde industrialisé, c'est qu'elle n'a pas connu le "grand nivellement égalitaire" de l'après-guerre que les autres pays industrialisés ont connu et qui a réduit l'inégalité des revenus. [Williamson \(2015\)](#) estime que les origines de l'inégalité des revenus en Amérique latine à l'heure actuelle résident moins dans son histoire coloniale que dans son expérience unique en matière de développement au cours des dernières années du 20<sup>e</sup> siècle.

Dans le dernier quart du XX<sup>e</sup> siècle, le discours académique sur l'inégalité des revenus s'est de plus en plus concentré sur le rôle des rendements de l'éducation sur les salaires et l'inégalité des salaires. Au début des années 2000, lorsque les inégalités de revenus ont commencé à diminuer, les réductions ont été largement attribuées aux améliorations du système éducatif du pays. D'autres causes qui ont également été créditées comme contribuant au phénomène sont les augmentations successives du salaire minimum (une augmentation chaque année), la réduction de la discrimination (basée sur le sexe ou l'ethnicité) sur le marché du travail, et une création accrue d'emplois dans le secteur formel ([de Souza, 2017](#)). Le programme de transfert de prestations sociales conditionnelles *Bolsa Familia*, lancé officiellement en 2003, a été crédité d'une contribution substantielle à la réduction des inégalités de revenus, des analyses postérieures à sa mise en œuvre affirmant que *Bolsa Familia* a davantage contribué à la réduction des inégalités que les augmentations du salaire minimum ([Barros, 2007](#)).

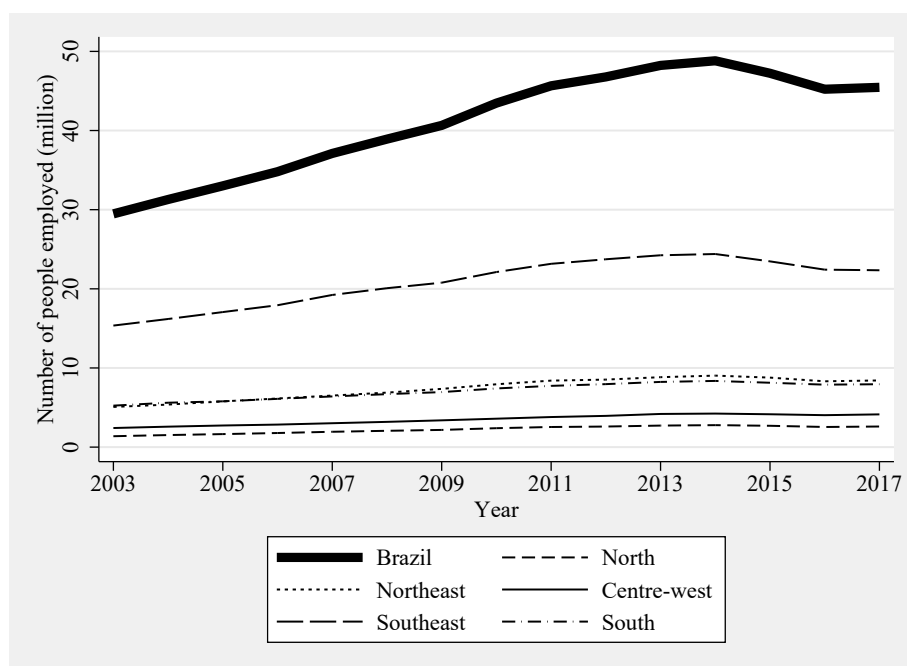
Dans les trois chapitres de cette thèse, l'évolution de divers indicateurs socio-économiques du Brésil et de ses régions au début du 21<sup>ème</sup> siècle a été étudiée, ainsi que l'impact de certains investissements de développement au cours de cette période. La figure 1 montre l'évolution du PIB nominal par habitant (en dollars américains) entre 2003 et 2017, et la figure 2 décrit l'évolution

du nombre de personnes employées au cours de la même période. Cette évolution est à considérer conjointement avec l'évolution de la population, vue dans la figure 3. Une tendance générale à la baisse peut être observée dans les niveaux de salaire moyen en termes de salaire minimum (salaire moyen au niveau de la municipalité, agrégé au niveau de la macrorégion pour la présentation) dans la figure 4. Les mesures de l'inégalité des revenus occupent une place importante dans les chapitres suivants de la thèse, et par conséquent, l'évolution de l'indice d'inégalité des salaires de Gini dans les régions du Brésil est visible dans la Figure 5. Il convient de noter que l'indice d'inégalité salariale présenté ici correspond à l'inégalité salariale au sein de chaque municipalité, agrégée au niveau de la macro-région (et du pays) (les inégalités salariales entre municipalités ne sont pas représentées dans cette figure).



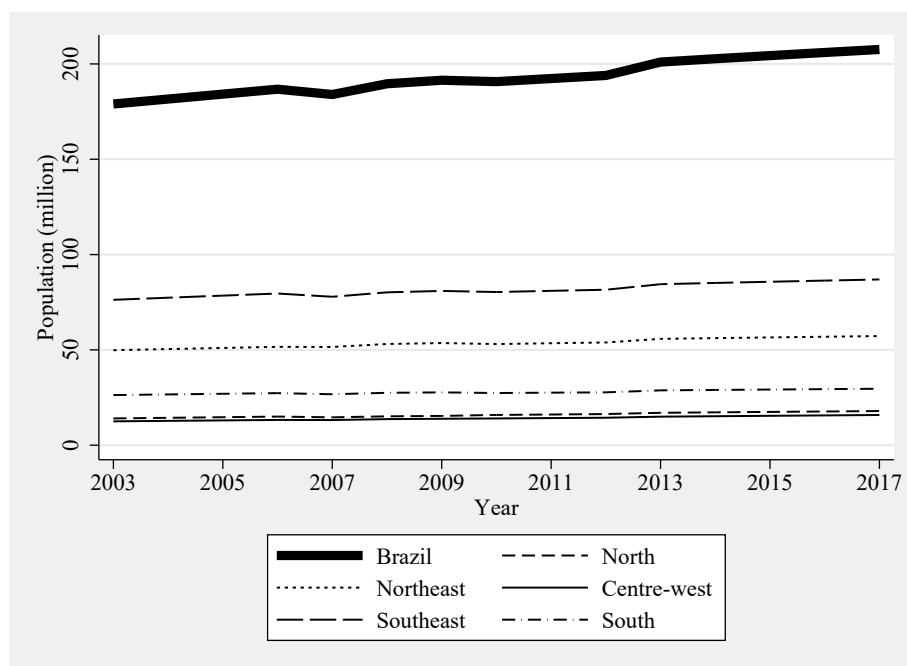
Source : IBGE, représentation de l'auteur

FIGURE 1 – Évolution du PIB nominal par habitant (en dollars américains) de 2003 à 2017 au Brésil et dans ses macrorégions



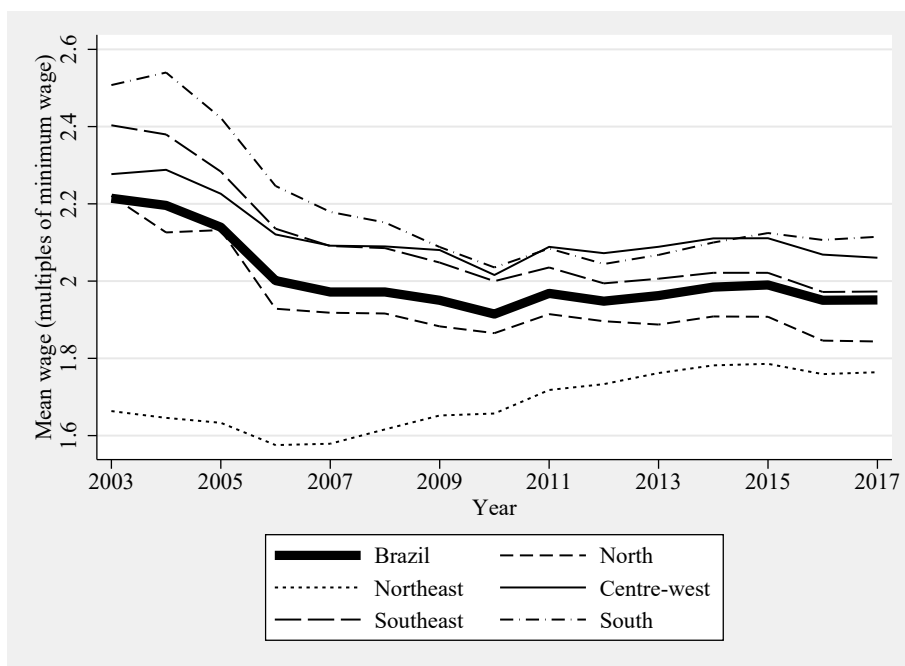
Source : Enquête sur l'emploi RAIS, représentation de l'auteur

FIGURE 2 – Évolution du nombre total de personnes ayant un emploi formel de 2003 à 2017 au Brésil et dans ses macrorégions



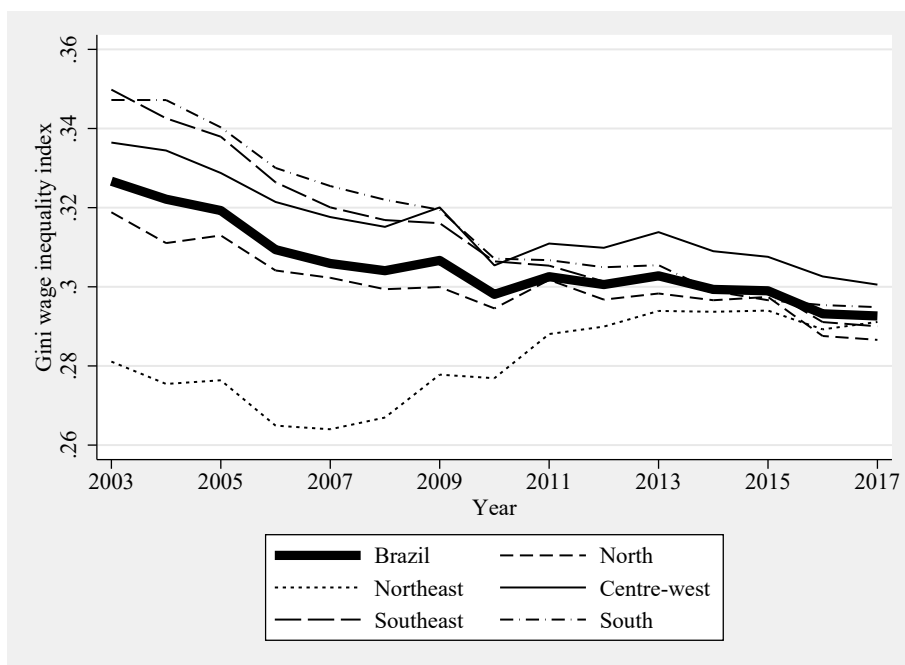
Source : IBGE, représentation de l'auteur

FIGURE 3 – Évolution de la population de 2003 à 2017 au Brésil et dans ses macrorégions



Source : Enquête sur le travail RAIS, représentation de l'auteur

FIGURE 4 – Évolution des niveaux de salaire moyen (en multiples du salaire minimum) de 2003 à 2017 au Brésil et dans ses macrorégions



Source : Enquête sur l'emploi RAIS, représentation de l'auteur

FIGURE 5 – Évolution de l'indice de Gini moyen intra-municipal des inégalités salariales de 2003 à 2017 au Brésil et dans ses macrorégions

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## Financement international de l'atténuation des émissions GES

La Convention-cadre des Nations unies sur les changements climatiques (CCNUCC) a cherché à mobiliser des fonds pour un financement international "vert" sous la forme de projets "durables". L'un des premiers efforts importants a été le protocole de Kyoto ; l'accord de Paris, considéré à bien des égards comme son successeur, cherche à approfondir ce concept, ainsi que d'autres initiatives telles que le Fonds vert pour le climat. Avec l'introduction du protocole de Kyoto en 1997, le concept de "croissance verte" dans les pays en développement est né, les pays devant et tentant d'équilibrer les objectifs économiques, environnementaux et sociaux par le biais d'investissements dans les infrastructures. Cela a conduit un large éventail d'acteurs à réaliser de tels investissements, parmi lesquels des acteurs publics (gouvernementaux), privés et étrangers (gouvernementaux et privés) (Keane and Potts, 2009, OECD, 2012). Dans le même temps, en conséquence directe du protocole de Kyoto, les pays développés (dits pays de l'annexe I) avaient l'obligation contraignante de réduire leurs émissions de gaz à effet de serre (GES) à certains objectifs. Les pays en développement (dits pays non-annexe I), quant à eux, pouvaient recevoir des investissements des pays de l'annexe I destinés à des projets spécifiques qui étaient manifestement "propres" ou, en d'autres termes, qui contribuaient à une réduction nette des émissions de GES. Ce mécanisme, appelé "mécanisme de développement propre" (MDP), trouve son origine dans les articles 6 et 12 du protocole de Kyoto, l'article 12.2 définissant l'objectif du MDP : L'article 12.2 définit l'objet du MDP : "le but du mécanisme pour un développement propre est d'aider les Parties non visées à l'annexe I à parvenir à un développement durable et à contribuer à l'objectif ultime de la Convention, et d'aider les Parties visées à l'annexe I à se conformer à leurs engagements chiffrés de limitation et de réduction des émissions prévus à l'article 3". (United Nations, 1998).

Parallèlement au développement de projets tels que les projets MDP sur le terrain, la littérature académique sur les investissements "verts" similaires a également commencé à se développer, notamment les études qui remettent en question la durabilité des projets. La question porte principalement sur la définition même de la durabilité, à savoir si le développement durable est nécessairement unidimensionnel en ce sens qu'il se concentre uniquement sur la réduction des émissions de GES, ou s'il inclut d'autres aspects du développement socio-économique, tels que la création d'emplois et l'inégalité des revenus. Deux chapitres (chapitre 1 et chapitre 3) de cette thèse tourneront autour d'un de ces aspects socio-économiques, à savoir l'inégalité des revenus (ou inégalité des salaires), tandis qu'un chapitre traite de la création d'emplois. La motivation de cette



thèse découle du fait que l'inégalité et d'autres facteurs socio-économiques n'ont pas fait l'objet d'une grande attention de la part des politiques en matière de développement "vert". D'un côté, cela est concevable, étant donné que l'intérêt premier est l'objectif environnemental de réduction des émissions, mais d'un autre côté, cela ignore les effets d'entraînement de ces projets sous la forme d'externalités et remet en question la notion même de durabilité (Sutter and Parreño, 2007). Cette thèse et ses recommandations politiques seront particulièrement intéressantes et pertinentes pour les négociations climatiques actuelles et futures, ainsi que pour les autorités nationales et les banques de développement nationales qui ont un intérêt direct à s'assurer non seulement que les réductions d'émissions sont réalisées, mais aussi qu'elles n'affectent pas négativement d'autres conditions socio-économiques cruciales. D'un point de vue politique, une façon de redistribuer certains des avantages socio-économiques des projets de financement vert pourrait être de renforcer les arguments en faveur d'une distribution équitable au niveau supranational (c'est-à-dire dans les négociations internationales sur le climat). Une étape importante pour y parvenir serait de mieux internaliser les externalités de l'investissement dans le développement, ce qui inclut une mesure complète des impacts socio-économiques de l'investissement. Dans le cas du mécanisme de développement propre, ou du projet international de développement durable qui le remplacera (suite à l'accord de Paris), le défi des prochaines années sera de promouvoir l'équité et de forcer les investisseurs à diriger leurs ressources vers les zones et les types de projets où elles sont nécessaires pour promouvoir le développement, et pas seulement là où elles peuvent être rentables (en l'absence d'interventions politiques). L'apport à ce débat contemporain constitue la motivation politique de cette thèse.

### **Investissement dans la production d'électricité "propre"**

Les projets de production d'électricité ont en commun le fait qu'ils utilisent des sources d'énergie primaire comme intrants et produisent de l'électricité qui est ensuite injectée dans le réseau. En dehors de cela, entre les différents types de projets de production d'électricité (solaire PV/éolien/charbon/gaz, etc.), les mécanismes techniques précis réellement impliqués dans la conversion, ainsi que l'ingénierie et la logistique nécessaires pour y parvenir, sont très souvent assez différents, chaque type de projet de production d'énergie nécessitant des compétences d'ingénierie différentes pour être construit, entretenu et exploité. La production d'énergie à partir de combustibles fossiles, par exemple, nécessite la présence constante de personnel dans la centrale

pour en assurer la maintenance et la sécurité. Ce mode de fonctionnement est clairement différent de celui des projets de panneaux solaires photovoltaïques, par exemple, qui comprennent une phase de construction nécessitant une main-d'œuvre humaine, et qui ne requièrent ensuite qu'une maintenance minimale. Les projets d'énergie de la biomasse, en revanche, nécessiteraient davantage d'intervention humaine, et ressemblent en un sens aux projets d'énergie fossile. Pendant la construction et l'exploitation de ces différents types de projets, il n'est pas surprenant de constater une hétérogénéité dans les types d'impact économique et d'emploi créés au niveau local (ainsi qu'à des niveaux beaucoup plus importants, comme le niveau régional ou national), simplement en raison des différents types de compétences et d'intensités de travail que ces différents types de projets de production d'électricité requièrent.

Il existe un courant de littérature en macroéconomie qui utilise des données au niveau des pays pour examiner le lien entre la consommation d'énergie et les résultats économiques (PIB). S'il est prouvé qu'il existe une corrélation entre la consommation d'énergie (quel que soit le type) et la croissance économique ([Apergis and Payne, 2012](#)), il est également prouvé que différents types de sources d'énergie pourraient avoir des impacts différents ([Ohler and Fetters, 2014](#)). Il y a une pénurie d'études économétriques qui utilisent des données micro-économiques pour analyser le développement économique, l'emploi et les impacts salariaux des projets de production d'électricité propre ([Blyth et al., 2014](#)), et encore moins qui comparent explicitement la production d'énergie propre avec la production d'énergie fossile. Cette thèse, en particulier dans les chapitres 1 et 2 entend répondre à cette lacune de la littérature en utilisant des données pour mesurer les impacts locaux de différents types de projets de production d'électricité.

Il existe une vaste littérature qui modélise les avantages pour l'emploi des installations de production d'électricité propre. Cette littérature est indécise quant aux avantages nets pour l'emploi des politiques favorisant le développement des énergies renouvelables ([Bulavskaya and Reynès, 2018](#), [Cai et al., 2017](#), [Caldés et al., 2009](#)). La plupart de ces études utilisent une analyse input-output (IO), dont les données sont généralement disponibles au niveau national, tandis que d'autres études, comme celles de [Bohmann et al. \(2019\)](#), [Bulavskaya and Reynès \(2018\)](#), utilisent un modèle d'équilibre général calculable (EGC) (voir l'analyse de [Jenniches \(2018\)](#)).

À titre d'exemple de la littérature utilisant des modèles d'entrées-sorties, [Tourkolias and Mirasgedis \(2011\)](#) utilisent une méthodologie d'entrées-sorties dans une évaluation économique des avantages pour l'emploi des technologies d'énergie renouvelable en Grèce. Ils estiment que les bénéfices pour l'emploi se situent entre 0,7 EUR/MWh et 4,8 EUR/MWh, avec des variations

entre les types de technologies (éolienne, solaire PV, hydroélectrique, géothermique, biomasse), et également une certaine hétérogénéité en ce qui concerne l'emploi généré pendant les phases de construction et d'exploitation. Bien que dans la présente thèse les bénéfices pour l'emploi ne soient pas estimés en utilisant une méthodologie similaire, ces études sont utiles à mentionner, car elles permettent de comparer les bénéfices pour l'emploi de la production d'électricité propre à la production d'énergie fossile (lignite et gaz naturel). Alors que le gaz naturel crée des avantages pour l'emploi évalués entre 0,4 EUR/MWh et 0,6 EUR/MWh, les centrales au lignite créent des avantages pour l'emploi entre 2,9 EUR/MWh et 3,5 EUR/MWh. Toutefois, il convient de noter qu'une part importante des avantages pour l'emploi liés à la production d'électricité propre intervient lors de la phase de construction, la part des avantages dus à la construction atteignant 75,6% pour le solaire photovoltaïque et 22,2% pour la biomasse. La part correspondante des avantages en termes d'emploi pour les centrales au lignite et au gaz naturel est respectivement de 6,9% et 4,5% (Tourkolias et al., 2009).

Cette hétérogénéité des résultats entre la production d'électricité propre et la production d'électricité fossile pourrait s'expliquer par les différences de compétences et d'intensité de travail des emplois créés par chaque type d'investissement. Bulavskaya and Reynès (2018), par exemple, utilisent un modèle EGC pour montrer un impact économique positif net de l'expansion de l'électricité propre dans leur étude sur les Pays-Bas, et expliquent leurs résultats en soulignant une intensité de capital et de travail plus élevée des investissements dans la production d'électricité propre. Cependant, dans une conclusion légèrement différente, Consoli et al. (2016) montrent que les emplois "verts" sont plus intensifs en compétences que les emplois "non verts" (bien qu'ils ne traitent pas directement le sujet de l'intensité du travail).

Cette hétérogénéité observée dans la création d'emplois est particulièrement importante car la création d'emplois est considérée comme réduisant la pauvreté absolue, un facteur crucial dans les pays en développement. Il est admis qu'en général, la croissance économique réduit la pauvreté absolue (Dollar and Kraay, 2002, Ravallion, 2001), mais toutes les croissances ne sont pas égales - la croissance dans certains secteurs a plus d'effets de réduction de la pauvreté que la croissance dans d'autres (Loayza and Raddatz, 2010). Il existe également des preuves à l'appui du lien entre la création d'emplois et la réduction de la pauvreté, étant donné que les revenus du travail constituent une grande partie du revenu des pauvres. Ce lien bénéficie d'un soutien théorique et empirique (Loayza and Raddatz, 2010, Ravallion and Datt, 1996). La croissance du secteur agricole, par exemple, créerait plus d'opportunités d'emploi que les autres secteurs, étant donné qu'il est à plus

forte intensité de main-d'œuvre, et contribuerait donc davantage à la réduction de la pauvreté. Un effet similaire pourrait être à l'œuvre lorsqu'il s'agit des impacts des projets de production d'énergie propre et de production d'énergie fossile.

Par conséquent, dans les chapitres 1 et 2 de la présente thèse, l'objectif est d'informer la littérature en étudiant les impacts économiques différenciés des investissements dans la production d'électricité propre (en les opposant aux investissements dans la production d'énergie non électrique) en utilisant des méthodes économétriques de données de panel. En outre, le chapitre 2 étudie également les effets dynamiques de l'investissement dans ces types de projets afin de voir dans quelle mesure l'impact économique (s'il existe) est persistant dans le temps.

[Tourkolias and Mirasgedis \(2011\)](#) et [Cai et al. \(2017\)](#) montrent également que les avantages nets pour l'emploi (ou du moins leur évaluation) varient en fonction de facteurs tels que l'origine des équipements (fabriqués dans le pays ou importés de l'étranger), et l'évolution du prix de ces technologies sur le marché mondial. D'autres études ont également relevé les effets potentiellement négatifs des stratégies d'expansion de la production d'énergie propre qui reposent davantage sur les importations que sur la fabrication nationale (voir [Frondelet al. \(2010\)](#)). [Lehr et al. \(2012\)](#) montrent que pour l'Allemagne, si la création nette d'emplois peut avoir une perspective positive lorsque les exportations du secteur des énergies renouvelables sont optimistes, les effets sont plus modestes, voire négatifs dans le cas extrême où les exportations sont lentes.

Alors que les études input-output saisissent les avantages en termes d'emploi en amont de l'investissement (par exemple, la fabrication de panneaux solaires PV ou de pales d'éoliennes), cette méthodologie ne mesure pas les effets keynésiens plus larges des investissements sur l'économie, c'est-à-dire l'emploi créé en aval de l'investissement (par exemple, les nouvelles entreprises créées pour répondre à la prospérité croissante de la population). Les modèles EGC, quant à eux, modélisent les effets sur l'ensemble de l'économie, et tirent donc leur utilité de ce fait. Cependant, si ces modèles rendent compte des impacts plus larges d'une part accrue d'énergie propre dans le mix énergétique, les effets immédiats d'un investissement au niveau local ne sont pas pris en compte.

Il y a donc lieu de supposer que les impacts économiques et de création d'emplois de la production d'électricité propre et de la production d'électricité fossile pourraient être différents. Nous pouvons nous attendre à cette différence parce que les emplois créés par ces deux types d'investissement peuvent exiger des intensités de travail et de compétences différentes qui, à leur tour, affectent différemment les marchés du travail locaux. En complément de cette discussion de la littérature macroéconomique plus large, la thèse propose une analyse qui utilise des données

micro-économiques du Brésil pour répondre à des questions similaires.

### **La polarisation du marché du travail dans les pays en développement**

Il existe une vaste littérature qui montre la polarisation des marchés du travail dans divers pays. On a largement considéré que le changement technologique basé sur les compétences a joué un rôle central dans cette polarisation de l'emploi et des salaires en faveur des travailleurs hautement qualifiés (Katz and Murphy, 1992). Cette hypothèse a depuis été nuancée afin de mettre davantage l'accent sur les tâches routinières par rapport aux tâches non routinières impliquées dans les emplois, et donc sur un changement technologique biaisé par la routine qui favorise les emplois impliquant des tâches non routinières qui sont moins sujets à l'automatisation (ou en général, à l'innovation technologique qui pourrait les rendre obsolètes) et à la perte d'emplois impliquant des tâches routinières (Autor, Katz and Kearney, 2008, Autor, Levy and Murnane, 2003), entraînant ainsi une polarisation en forme de U. Des données récentes suggèrent même que la polarisation pourrait remonter aux années 1950 (Bárány and Siegel, 2018).

La polarisation du marché du travail a été diversement caractérisée, principalement par la polarisation des salaires et la polarisation des emplois (Acemoglu and Autor, 2011), mais aussi parfois par la polarisation des heures de travail (da Silva, Laws and Petroulakis, 2019). La polarisation des salaires, en particulier, a été mise en évidence dans de nombreuses études portant sur de nombreux pays et marchés (cf. Autor and Dorn (2013), Autor, Katz and Kearney (2008)), mais des études ont également noté que les niveaux de salaire (aux États-Unis) ne sont pas polarisés de la même manière d'une période à l'autre, même lorsqu'il existe une polarisation de l'emploi au cours de la même période (Acemoglu and Autor, 2011, Longmuir, Schröder and Targa, 2020). On suppose que la relation entre la polarisation des emplois et la polarisation des salaires est due au fait que les changements dans la demande de travail ne sont pas uniformes dans la distribution - plus précisément, que les emplois routiniers subissent une perte de demande par rapport aux emplois non routiniers (Autor et al., 2008), ce qui entraîne une augmentation des inégalités. Certains auteurs ont fait valoir que la relation pourrait plutôt être déterminée par l'offre, lorsque les travailleurs moyennement qualifiés qui sont déplacés se déplacent vers le bas de la distribution des salaires, tirant ainsi les salaires vers le bas (Beaudry, Green and Sand, 2014).

Cette polarisation du marché du travail a été démontrée pour divers pays, notamment dans le monde développé – pour les États-Unis (Autor, Katz and Kearney, 2006), en Europe et au Royaume-Uni (Goos, Manning and Salomons, 2009, Goos and Manning, 2007), et au Canada

(Green and Sand, 2015). On s'attend généralement à ce que la polarisation du marché du travail soit plus lente dans les pays en développement ; Il existe des preuves limitées de cette polarisation dans le monde en développement. Azam (2012) démontrent une légère polarisation des salaires en Inde entre 1993 et 2004 (de manière similaire à Sarkar (2017) en Inde dans les années 1990 et 2000), et Borat, Lilenstein, Oosthuizen and Thornton (2020) le montrent pour l'Afrique du Sud entre 2000 et 2015, en attribuant la tendance, au moins partiellement, à la SBTC. Un rythme plus lent d'adoption des technologies et la délocalisation des tâches de routine des pays développés vers les pays en développement sont probablement responsables de cette absence de polarisation observée dans ces pays.

Dans le contexte brésilien ou latino-américain, il existe peu d'études traitant en profondeur de la polarisation du marché du travail, mais le sujet a récemment commencé à attirer l'attention. Firpo, Portella, Riva and Ubida (2021) utilisent les données de l'enquête PNAD au Brésil pour montrer une image contradictoire de la polarisation des salaires qui était favorable aux pauvres entre 2003 et 2012 mais favorable aux riches entre 2012 et 2019. Ils trouvent également peu de preuves de la polarisation des emplois au cours des mêmes périodes. Maloney and Molina (2019) trouvent des signes 'initiaux' de polarisation de l'emploi au Brésil et au Mexique, tout en constatant que la polarisation est rare dans les pays en développement en général (contrairement aux pays développés). Gasparini et al. (2021) ont montré que l'automatisation croissante affecte les travailleurs dans les professions à forte intensité de routine, mais ils n'ont trouvé aucune preuve de polarisation du marché du travail, similaire à celle trouvée par Beylis et al. (2020). Il existe également peu d'études (comme celle de Reinhold (2016)) qui tentent explicitement de se concentrer sur des unités plus petites que le niveau national, ce qui s'avère nécessaire, compte tenu de la grande taille de certains pays et marchés du travail comme le Brésil.

### **Les grandes lignes de la thèse**

Cette thèse s'intéresse donc à la question du développement durable et plus particulièrement aux conséquences des politiques d'investissement. Les chapitres s'intéressent spécifiquement aux impacts de ces investissements de développement sur les inégalités de revenus, l'emploi et les salaires. Cette thèse étend la littérature existante en suggérant les mécanismes par lesquels cet effet se produit. D'un point de vue conceptuel, ceci est fait en considérant les impacts de ces projets comme des externalités, permettant ainsi une évaluation d'impact significative sans essayer d'imposer une définition ex ante du développement durable. D'un point de vue empirique, l'analyse est

réalisée en utilisant des données de recensement spatialement organisées de haute qualité, combinées à des données administratives fiables pour les projets de développement. Chaque chapitre de la thèse utilise un niveau d'analyse différent, évaluant des questions de recherche similaires à un niveau macro, méso et micro. En particulier, deux de ces chapitres utilisent des données au niveau micro pour analyser une problématique (l'évaluation des investissements de développement) qui est très souvent traitée au niveau macro. Sur le plan méthodologique, les questions de recherche sont abordées à l'aide de méthodes quasi-expérimentales, qui sont à la pointe de la recherche actuelle en économétrie. Une vue d'ensemble des chapitres, de leurs principales contributions théoriques et des méthodes économétriques utilisées est présentée ci-dessous, et de manière plus concise dans le tableau 1.

- Le chapitre 1 de cette thèse porte sur les projets MDP au Brésil, et évalue les impacts du déploiement des projets sur l'inégalité des revenus à un niveau micro-régional, en séparant les projets par type de technologie impliquée (solaire, éolien, production de gaz de décharge, etc.). Les données utilisées proviennent principalement de la base de données des projets MDP, et de l'IBGE. Une méthode de différence dans les différences est employée pour estimer les impacts causaux de la mise en œuvre des projets MDP sur l'inégalité des revenus, sur le chômage et sur les niveaux de pauvreté entre 2000 et 2010. Cette étude se positionne dans les discussions politiques concernant l'avenir du Mécanisme de Développement Propre (MDP), plus spécifiquement l'article 6 de l'Accord de Paris, autour duquel la discussion a été particulièrement active après la COP25 à Madrid, où un consensus n'a pas été atteint concernant la conception du 'nouveau' mécanisme MDP qui devait remplacer le MDP dans le cadre du Protocole de Kyoto. Les projets MDP ont également souvent fait l'objet de critiques pour leur manque d'"additionnalité" démontrable, le terme faisant référence à l'additionnalité environnementale ou financière. Ce chapitre prolonge ce débat en étudiant l'impact du déploiement des projets MDP sur d'autres paramètres du développement durable, à savoir l'inégalité, le chômage et la réduction de la pauvreté.

Dans des revues de la littérature sur les effets des projets MDP sur la réduction de la pauvreté, [Dirix, Peeters and Sterckx \(2016\)](#) et [Olsen \(2007\)](#) ont conclu qu'il y a peu de preuves que les projets MDP aient contribué de manière substantielle à réduire la pauvreté. [Sirohi \(2007\)](#), dans une étude à méthodes mixtes portant sur 65 projets, ont constaté que les projets MDP en Inde qui bénéficient aux groupes à faibles revenus ont tendance à être situés dans des zones rurales. [Crowe \(2013\)](#), dans une étude plus qualitative et plus tardive de 114 pro-

jets MDP dans le monde, y compris des projets avec des normes supplémentaires (avec des dates d'enregistrement en 2010 et 2011), a constaté que les projets MDP réguliers ne réussissent que "modérément" à fournir des avantages en faveur des pauvres et que les projets qui y parviennent sont caractérisés par l'utilisation de normes de projet supplémentaires, un degré élevé de participation des parties prenantes, et l'implication d'entités gouvernementales et à but non lucratif en tant que développeurs de projets. [Du and Takeuchi \(2019\)](#) ont étudié l'effet des projets MDP sur le revenu et l'emploi dans les communautés rurales en Chine, en utilisant une méthode des doubles différences. Ils ont constaté que les projets de biomasse contribuaient à la création de revenus et d'emplois. Dans le contexte brésilien en particulier, [Mori-Clement \(2019\)](#) a constaté que l'effet des projets MDP sur l'emploi local au Brésil était mitigé, et lorsqu'il était présent, faible et transitoire. [Mori-Clement \(2019\)](#) a testé l'impact des projets MDP sur les inégalités, l'emploi et la pauvreté au Brésil entre 2000 et 2010, de manière similaire à cette présente étude. [Mori-Clement \(2019\)](#) a également utilisé une approche de différence dans La différence principale réside sur l'amélioration de la comparabilité des municipalités qui ont reçu ou non un projet MDP par le biais de l'appariement des scores de propension. L'unité spatiale utilisée était la municipalité (alors que, dans la présente étude, il s'agit de la micro-région, qui est plus grande). [Mori-Clement \(2019\)](#) ont constaté que l'inégalité a diminué de 2% dans les municipalités qui avaient un projet hydroélectrique MDP par rapport aux municipalités qui n'en avaient pas.

Sur le plan théorique, le chapitre se base sur des théories concernant la manière dont les investissements directs étrangers (IDE) entrants affectent l'inégalité des revenus dans le pays d'accueil, en particulier lorsque l'investissement entrant concerne un secteur spécifique de l'économie (c'est-à-dire l'extraction, l'industrie ou les services). En particulier, on constate que l'inégalité des revenus tend à augmenter lorsque l'IDE entrant est dans les secteurs de la fabrication ou des services (qui emploient des travailleurs plus qualifiés), contrairement aux travailleurs non qualifiés qui pourraient être employés dans le secteur extractif. L'investissement MDP, qui présente des caractéristiques communes, est considéré comme une forme indirecte d'IDE, et est donc analysé sous cet angle.

Empiriquement, l'approche d'évaluation utilisée est un modèle économétrique qui teste l'hypothèse selon laquelle l'activité des projets MDP (mesurée par le nombre de crédits de réduction d'émissions émis) dans une micro-région brésilienne a eu un effet sur l'inégalité des revenus, le chômage et la pauvreté, entre 2000 et 2010. Comme toutes les micro-régions



n'ont pas reçu de projet MDP, les effets observés pourraient être attribués à la présence et à la taille du projet. Des variables de contrôle, ainsi qu'une approche des doubles différences, sont utilisées pour tenir compte de l'hétérogénéité. Les projets ont également été séparés selon le type de technologie utilisée pour réaliser les réductions d'émissions : l'hypothèse étant que les effets de la présence de différents types de projets seraient hétérogènes, en raison du type et du niveau de compétences que chaque type de projet requiert. On a constaté une réduction des inégalités de revenus, du chômage et de la pauvreté dans les micro-régions qui ont bénéficié de projets MDP par rapport aux micro-régions qui n'en ont pas bénéficié. Certains types de projets (éviter le méthane, production d'hydroélectricité) ont eu des effets plus importants que d'autres types de projets. La recommandation pour les décideurs politiques est que les facteurs socio-économiques tels que l'inégalité, le chômage et la pauvreté soient considérés comme des objectifs de développement durable, et donc mesurés de manière plus fiable et plus précise afin de permettre le suivi et la vérification. Ceci est particulièrement pertinent à la lumière des discussions autour d'un règlement actualisé pour le MDP lors de la COP25 à Madrid. Depuis lors, des progrès ont été réalisés lors de la COP26 à Glasgow pour mieux inclure les résultats du développement durable, y compris les questions d'équité, parmi les objectifs du MDP (UNFCCC, 2021).

- Le chapitre 2 évalue les investissements de la Banque nationale de développement du Brésil (BNDES) et leur contribution à la production économique, à la création d'emplois et à l'évolution des niveaux de salaire moyen au niveau des municipalités du Brésil entre 2003 et 2017. Comme dans le chapitre 1, les investissements sont séparés par type – dans ce cas, séparés en investissements hors production d'électricité, production d'électricité et production d'électricité propre. À l'aide de données de panel compilées à partir des données de la BNDES, de l'IBGE et de l'enquête annuelle sur le travail du RAIS, un modèle économétrique à effets fixes à deux voies (TWFE) est utilisé pour tester l'hypothèse selon laquelle la présence d'investissements de la BNDES a un effet sur les variables de résultat d'intérêt. Une telle analyse est pertinente pour une banque de développement telle que la BNDES, afin d'étudier les priorités que le développement durable impliquent pour la Banque en matière environnementales, sociales ou économiques.

Empiriquement, nous considérons le cas du Brésil, où sa banque nationale de développement (Banco Nacional de Desenvolvimento Econômico e Social, BNDES) a joué un rôle important en stimulant les projets de développement des infrastructures en l'absence d'in-

investissements de capitaux privés (Hanley et al., 2016). Dans cet article, nous relient les activités de la Banque de 2003 à 2017 à l'agenda du développement durable, en examinant ses investissements dans la production d'électricité (propre et fossile) et leurs impacts sur les niveaux de PIB par habitant, les niveaux d'emploi et les niveaux de salaire. La littérature actuelle qui a traité des impacts des projets de la banque sur la création d'emplois s'est concentrée sur son impact global sans distinguer les types de projets (Pereira, 2007, Reiff et al., 2007, Torres Filho and Puga, 2006), ou a traité des impacts sur la productivité (Coelho and de Negri, 2011). Une autre littérature s'est également concentrée sur les impacts sur l'investissement (Barboza and Vasconcelos, 2019). Cependant, les projets de production d'électricité représentant près de 20% de l'ensemble des investissements de la BNDES sur la période 2003-2017 (pour un montant de 91 milliards Reais ou 37,6 milliards USD<sup>2</sup>), l'impact de ces projets sur les résultats économiques mérite notre attention.

D'un point de vue théorique, le chapitre suit un courant de la littérature en matière d'évaluation des politiques qui s'intéresse aux impacts socio-économiques des investissements de développement, en particulier ceux des énergies propres. La littérature atteste du fait que les investissements dans les énergies propres ont des besoins en main-d'œuvre et en compétences différents de ceux des investissements dans d'autres projets, y compris les projets d'énergie fossile. Il y a donc lieu d'émettre l'hypothèse que ces différents investissements pourraient également avoir des résultats socio-économiques différents.

Pour tester ces différences de manière empirique, les données ont été organisées dans une structure de panel, avec une structure "échelonnée", ce qui implique que les traitements (c'est-à-dire l'afflux d'investissements dans une municipalité) ont eu lieu à différents moments du panel. Des avancées récentes dans la littérature économétrique ont permis de prendre en compte les traitements échelonnés tout en utilisant des modèles TWFE (Callaway and Sant'Anna, 2021, Goodman-Bacon, 2018), qui ont été appliqués dans l'économétrie présentée dans ce chapitre. En outre, une approche basée sur la pondération des probabilités inverses (IPW) ainsi que l'inclusion d'effets fixes (estimateur doublement robuste) ont été utilisées dans le modèle pour tenir compte des problèmes d'endogénéité et pour mettre en évidence les effets causaux. Des effets de traitement dynamiques ont également été présentés pour analyser la persistance des effets de ces investissements.

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2. Le réal brésilien ayant été très volatil par rapport au dollar américain entre 2003 et 2017, un taux de change moyen de 1 USD = 2,42 BRL a été utilisé tout au long de cet article chaque fois qu'une conversion est présentée.

Les résultats indiquent que si les investissements de développement de la BNDES ont eu en général des effets positifs sur la production économique, l'emploi et les niveaux de salaire moyens dans les municipalités brésiliennes, ils indiquent également que l'ampleur des effets est différente pour les investissements dans la production d'électricité (principalement les investissements dans la production d'électricité propre) et les autres investissements de développement, les investissements dans la production d'électricité étant moins bons que les autres investissements de développement. Des différences peuvent également être notées entre la production d'électricité en général et la production d'électricité propre en particulier. Ces différences doivent toutefois être analysées dans le contexte des externalités positives qu'apportent les investissements dans la production d'électricité propre, qui ne sont pas internalisées dans les données de comptabilité nationale utilisées dans ce chapitre. Ces résultats visent à fournir des orientations au BNDES et aux autres banques de développement pour qu'ils adoptent une vision plus large du développement durable, multidimensionnelle et prenant en compte les facteurs socio-économiques en plus des facteurs environnementaux.

- Chapitre 3 étudie la polarisation des salaires dans l'État de São Paulo au Brésil, en utilisant des données au niveau des travailleurs pour construire une expérience naturelle entre les travailleurs exposés aux investissements de la BNDES entre 2003 et 2013 et les travailleurs non exposés, utilisant ainsi un facteur d'identification alternatif pour discerner la polarisation des salaires. Complémentaire aux deux premiers chapitres, le chapitre ajoute une nouvelle perspective aux impacts distributifs de l'investissement dans le développement, et constate que la polarisation des salaires observée est cohérente avec le changement technologique basé sur les compétences (SBTC) et le changement technologique basé sur la routine (RBTC).

La polarisation du marché du travail a été observée dans de nombreux pays développés, un phénomène qui tend à favoriser l'augmentation des emplois et des salaires aux deux extrêmes du spectre des compétences des emplois, favorisant les emplois hautement et faiblement qualifiés au détriment des emplois moyennement qualifiés (SBTC). Les concepts de RBTC nuancent encore cette lecture des changements du marché du travail pour différencier les emplois par leur "contenu routinier", où les emplois qui peuvent être accomplis par l'automatisation sont les plus désavantagés. Le phénomène a été peu étudié dans les pays en développement, mais quelques études suggèrent une polarisation "naissante" des marchés du travail, même dans les pays en développement. La principale question de recherche traitée dans ce chapitre consiste donc à rechercher des signes de polarisation du marché du

travail dans l'État de São Paulo au Brésil, en réponse aux investissements de développement de la BNDES.

Dans le contexte brésilien ou latino-américain, il existe peu d'études qui traitent de la polarisation du marché du travail en profondeur, mais le sujet a récemment commencé à attirer l'attention. [Firpo, Portella, Riva and Ubida \(2021\)](#) utilisent les données de l'enquête PNAD au Brésil pour montrer une image contradictoire de la polarisation des salaires qui était favorable aux pauvres entre 2003 et 2012 et favorable aux riches entre 2012 et 2019. Ils trouvent également peu de preuve de la polarisation des emplois au cours des mêmes périodes. [Maloney and Molina \(2019\)](#) trouvent des signes 'initiaux' de polarisation de l'emploi au Brésil et au Mexique, tout en constatant que la polarisation est rare dans les pays en développement en général (contrairement aux pays développés). [Gasparini et al. \(2021\)](#) ont montré que l'automatisation croissante affecte les travailleurs dans les professions à forte intensité de routine, mais ils n'ont trouvé aucune preuve de polarisation du marché du travail, similaire à celle trouvée par [Beylis et al. \(2020\)](#). Il existe également peu d'études (comme celle de [Reinhold \(2016\)](#)) qui tentent explicitement de se concentrer sur des unités plus petites que le niveau national, pourtant nécessaire sur des pays ayant la taille du Brésil.

Afin de mesurer la présence de la polarisation du marché du travail (ou son absence), la plupart des études disponibles dans la littérature citée ci-dessus comparent les niveaux de salaire réel à travers les périodes, pour mesurer la polarisation de l'emploi et la polarisation des salaires, respectivement, tout en mesurant simultanément l'augmentation de l'innovation technologique. Dans le présent article, une autre méthode est proposée pour mettre en évidence la présence ou l'absence de polarisation du marché du travail dans l'État de São Paulo. L'exposition de la population aux investissements de la BNDES sur une période de 10 ans est utilisée comme identification. Il s'agit d'une approche inspirée de la littérature sur l'évaluation des politiques, qui cherche à se rapprocher le plus possible d'une expérience naturelle en utilisant un facteur d'identification approprié.

L'investissement de la BNDES constitue la base empirique de l'analyse, et est utilisé comme facteur d'identification pour tester la polarisation du marché du travail – ceci est possible puisque tous les travailleurs de l'état n'ont pas été exposés à l'investissement de la BNDES. Les différences entre ceux qui ont été exposés et ceux qui n'ont pas été exposés à l'investissement de la BNDES peuvent être attribuées à l'effet de l'exposition à l'investissement. Les données au niveau des travailleurs ont été obtenues à partir de l'enquête annuelle sur le

travail RAIS, et les données des comptes nationaux à partir de l'IBGE. La principale contribution de ce chapitre à la littérature est l'estimation des effets de traitement (ou, dans ce cas, des effets d'exposition) à travers la distribution des salaires, en utilisant des méthodes de régression quantile, spécifiquement l'estimateur des effets de traitement quantile inconditionnel (Unconditional Quantile Treatment Effects estimator, UQTE) introduit par [Firpo et al. \(2009\)](#).

Le chapitre conclut que des signes naissants de polarisation des salaires ont été observés dans l'État de São Paulo entre 2003 et 2013, et que la conclusion est cohérente avec la RBTC. Même s'il a été observé que les professions susceptibles d'avoir des emplois à fort contenu routinier sont susceptibles d'être désavantagées par rapport aux emplois à faible contenu routinier, des recherches supplémentaires sont nécessaires pour tester clairement le lien avec la RBTC. Ces résultats éclairent le phénomène de la polarisation du marché du travail dans les pays en développement. Ils ont également une incidence sur l'inégalité des salaires, et donc sur les priorités de développement (durable) des banques de développement telles que la BNDES, qui peuvent potentiellement tirer des leçons de ces résultats.

## Conclusion

Les trois chapitres de cette thèse examinent différents aspects du développement durable au Brésil en utilisant différentes perspectives (niveau macro-meso-micro) en utilisant de riches ensembles de données organisées spatialement à chaque niveau d'analyse (macro-meso-micro) et des données détaillées des projets de développement. À l'aide de méthodes économétriques récemment développées, l'impact des investissements dans le développement a été étudié, et leurs externalités socio-économiques quantifiées. Si les aspects environnementaux jouent un rôle central dans le développement durable, beaucoup, y compris les Nations unies, ont accepté la vision du développement durable qui inclut également des aspects socio-économiques plus larges du développement, comme en témoignent notamment les objectifs de développement durable des Nations unies. Au Brésil, l'investissement dans le développement est passé par différents canaux : certains sont plus directs, sous la forme d'une participation de l'État à des projets de développement, comme par l'intermédiaire de la banque nationale de développement BNDES, tandis que d'autres sont plus indirects, comme les investissements réalisés grâce à des mécanismes tels que le mécanisme de développement propre. Dans cette thèse, ces deux canaux d'investissement dans le développement sont examinés afin d'obtenir et de quantifier leurs impacts socio-économiques,

notamment sur l'emploi, les niveaux de salaire et l'inégalité.

Le MDP, qui trouve son origine dans le protocole de Kyoto, est une tentative d'équilibrer la réalisation des objectifs d'atténuation des émissions de carbone des pays signataires avec les besoins de développement des pays ne figurant pas à l'annexe I. Le MDP est un mécanisme d'investissement dans le développement. Dans le premier chapitre de la thèse, il a été constaté, à l'aide d'un modèle des doubles différences, que les projets MDP au Brésil ont permis de réduire les inégalités de revenus, la pauvreté et le chômage entre 2000 et 2010. Notamment, ces réductions dépendent du type de projet. Les projets d'évitement du méthane, les projets hydroélectriques et les projets de biomasse sont les types de projets qui ont entraîné ces réductions. À l'aide de théories sur les flux d'IDE et leurs effets sur le marché du travail, il a été théorisé que les impacts différentiels des différents types de projets pourraient être dus au secteur dans lequel l'emploi a été créé grâce à ces investissements. Plus précisément, il a été proposé que l'augmentation de l'emploi dans les secteurs primaire et secondaire entraîne des réductions plus importantes de l'inégalité des revenus, de la pauvreté et du chômage, par rapport au secteur tertiaire. Malgré les préoccupations légitimes exprimées dans la littérature sur l'additionnalité de ces projets, l'étude propose une évaluation politique qui vise à guider les négociations internationales sur le climat en cours et à venir en appelant à un suivi plus étroit des projets ainsi qu'à une meilleure prise en compte des impacts socio-économiques en plus des impacts environnementaux dans la conception des futurs mécanismes de type MDP.

Un examen plus approfondi des impacts socio-économiques différenciés des investissements dans la production d'énergie a été proposé par rapport aux investissements dans la production non énergétique dans le deuxième chapitre. Les investissements de la banque nationale de développement brésilienne, la BNDES, ont été analysés à cet effet. La conclusion générale est que les effets sur la production économique, les niveaux d'emploi et les niveaux de salaire des investissements dans la production d'énergie sont plus faibles que ceux des investissements dans la production non énergétique, et qu'au sein des investissements dans la production d'énergie, les investissements dans la production d'énergie propre semblent avoir un impact plus faible sur ces trois indicateurs socio-économiques. La littérature souligne la possibilité que les différentes intensités de travail entre les types de projets puissent contribuer à ces différents impacts. Cette recherche ouvre la question de savoir ce que le développement durable implique réellement, en particulier pour une banque de développement telle que la BNDES, et dans quelle mesure les impacts socio-économiques des investissements doivent être pris en compte en plus des impacts

environnementaux.

Dans la lignée du thème de l'analyse des impacts macroéconomiques des investissements des banques de développement, le troisième chapitre se penche sur la question de la polarisation des salaires dans l'État de São Paulo au Brésil sur une période de dix ans, entre 2003 et 2013. La question de la polarisation des salaires en réponse à l'investissement dans les nouvelles technologies - une question bien étudiée dans la littérature d'économie du travail relative au monde développé - a été analysée dans le contexte d'un État brésilien, jusqu'à présent non étudié en détail. En utilisant des méthodes récentes d'économétrie, on trouve des preuves de la polarisation des salaires qui sont cohérentes avec le changement technologique basé sur les compétences (SBTC). Cela a des implications pour la politique du marché du travail, notamment en ce qui concerne les questions d'inégalités salariales.

Alors qu'il y a actuellement un élan accru à travers le monde pour atteindre les objectifs de réduction des émissions à la lumière de l'Accord de Paris et des COP successives, il reste nécessaire de considérer le développement durable dans toutes ses dimensions. Cette thèse représente donc un pas de plus dans l'intégration des facteurs socio-économiques dans l'ambition du développement durable, et ceci est réalisé en utilisant le concept des externalités de l'investissement de développement. La quantification et l'évaluation de ces externalités, tant socio-économiques qu'environnementales, permettraient une évaluation plus précise et plus complète, ou une internalisation, de tous les effets - positifs et négatifs - qu'implique l'investissement dans le développement durable. Cela faciliterait à son tour une allocation plus efficace des ressources et établirait des signaux de marché plus appropriés qui accéléreraient la progression vers les objectifs du développement durable, au sens du terme développé par la déclaration de Rio de 1992 sur l'environnement et le développement. Les recommandations politiques qui suivent les trois articles de la thèse vont donc dans ce sens.

Tout d'abord, la tâche du chercheur ou de l'évaluateur serait facilitée (voire possible) si les résultats socio-économiques ainsi que les caractéristiques des investissements étaient mieux suivis et mesurés. Concrètement, pour les décideurs et les administrateurs au Brésil et dans d'autres pays, cela implique la collecte fiable et systématique de données socio-économiques relatives aux bénéficiaires ainsi que de données sur l'emploi généré (ou perdu, selon le cas) directement en raison de ces investissements.

Deuxièmement, une allocation efficiente et efficace des ressources et des capitaux par les organes administratifs nationaux et par les banques de développement devrait tenir compte des

exigences, idéalement, de tous les aspects du développement durable conformément aux ODD, mais en particulier des aspects environnementaux et socio-économiques. L'extrême pauvreté et les inégalités sont encore présentes dans de nombreux pays, notamment parmi les pays en développement, et les décideurs politiques sont confrontés à la nécessité de répondre à une multitude d'objectifs de développement durable. Une meilleure quantification des externalités, comme c'est le cas dans cette thèse, vise à guider les décideurs politiques et les administrateurs vers une allocation plus efficiente des investissements de développement et une mise en œuvre plus efficace des projets de développement. Le phénomène de polarisation du marché du travail, en particulier, pourrait être une préoccupation croissante pour les populations, même dans les pays en développement ou leurs régions. Les prémices d'une prise de conscience des facteurs socio-économiques du développement durable sont visibles à la BNDES. Le 7 juin 2002, la Banque a approuvé une "politique sociale, environnementale et climatique du système BNDES", qui reconnaît les aspects socio-économiques en plus des aspects environnementaux dans les notions de développement durable (BNDES, 2022).

Troisièmement, les négociations internationales en cours et à venir sur le climat constituent une plateforme importante pour renforcer l'importance des prérogatives du développement durable dans le financement international de l'atténuation destiné aux pays en développement. Une allocation efficace des ressources d'atténuation ne peut être qu'au service de la réalisation des objectifs climatiques convenus dans l'Accord de Paris. Des progrès ont été réalisés dans la prise en compte des objectifs de développement durable dans le successeur du MDP de l'ère de Kyoto, mais il faut s'efforcer de prendre en compte de manière plus complète les facteurs socio-économiques en plus des objectifs environnementaux.

Les trois chapitres offrent des perspectives à différentes échelles : d'une analyse à l'échelle macro plus pertinente pour la politique climatique internationale à une analyse à l'échelle méso pertinente à l'échelle nationale (brésilienne), en passant par une analyse à l'échelle micro concernant les travailleurs d'un État fédéral brésilien. En résumé, les trois chapitres analysent chacun un aspect du développement durable qui est actuellement remis en question dans les politiques publiques contemporaines. Les résultats, fondés sur la littérature économique, visent non seulement à fournir aux décideurs politiques un aperçu des externalités socio-économiques des investissements de développement, mais aussi à renforcer le rôle des facteurs socio-économiques dans les notions plus larges de développement durable.

Dans la continuité du travail présenté dans cette thèse, je souhaite capitaliser sur les avancées



récentes des méthodes d'évaluation économétrique pour analyser les mesures et les politiques dans les domaines de l'économie de l'environnement et du développement. Les analyses des pays en voie de développement présentent un cas particulièrement intéressant car les données fiables sont souvent rares, et les évaluations des implications politiques de ces études pourraient potentiellement être très précieuses pour les décideurs politiques concernés, sans parler des populations elles-mêmes. Au niveau micro, l'exploration des questions relatives à l'acceptation des politiques et des mesures de réduction des émissions, en particulier dans les pays en développement, est également une trajectoire qui mérite d'être explorée.

TABLE 1 – Vue d'ensemble des chapitres de la thèse

Chapitre	Contributions à la connaissance	Méthode	Unité d'analyse	Étape de publication
1	Évaluation de l'impact du Mécanisme de Développement Propre (MDP) sur l'inégalité des revenus au Brésil, en séparant les projets par type	Différence dans la Différence, panel avec deux périodes de temps	Micro-région (niveau macro)	Publié dans la revue <i>Climate Policy</i> (rang A, liste HCERES), mai 2020
2	Évaluer les impacts socio-économiques des projets de production d'électricité propre par rapport aux autres projets de la BNDES en utilisant un estimateur à effets fixes à deux voies sur un panel "échelonné" de municipalités au Brésil	Effets fixes à deux voies, panel avec 15 périodes de temps et un traitement échelonné	Municipalité (niveau méso)	— En cours de soumission à la revue <i>Ecological Economics</i> (rang A, liste HCERES). — Publié dans la série de documents de travail FAERE, 2022.
3	Utilisation d'un facteur d'identification alternatif (exposition aux investissements de développement de la BNDES) pour analyser la polarisation des salaires dans l'État de São Paulo au Brésil	Régression quantile inconditionnelle	Travailleur (niveau micro)	Projet d'article de revue présenté au séminaire du laboratoire IREGÉ de l'Université Savoie Mont Blanc en mars 2022



## General Introduction

*I*n the 2020s in the developed world, climate change arguably occupies a central position in public discourse, with a wide range of actors taking active part in debates on climate change mitigation and adaptation. What was (and remains) a public policy debate has since spilled over into the private domain, with researchers even delving into mental health impacts on adults and children of an uncertain climate future (Ballew et al., 2019, Léger-Goodes et al., 2022). However, the causes and repercussions of anthropogenic climate change are global in nature and not uniform across geographies or people groups, or between developed and developing countries (Masson-Delmotte et al., 2021, Parry et al., 2007). It has been shown that climate change will have long lasting economic effects, in addition to health and welfare effects, with potentially harsher effects for developing countries (Ahluwalia and Patel, 2022). Accordingly, public discourse around climate change is also different between developed and developing countries. One of the key sticking points in international climate negotiations has been the role of developing countries, particularly of China, India, and Brazil, in contributing to the internationally-coordinated climate effort (Chemnick, 2021, Parsons and Taylor, 2021). The topic of climate justice, in all its complexity, has hence gained prominence in scholarly, policy, and civil society discussions alike, with even courts often strengthening the case for climate justice (Jenkins, 2018, Strack, 2021).

Due to this non-uniform nature of the causes and repercussions of climate change, discussions often centre around the topic of burden-sharing, with negotiators in international climate negotiations often having different perspectives on what distributive justice entails for their respective countries (even if their citizens do not necessarily share the same perspectives) (Schleich et al., 2016). An important instance of this discussion was at the 1992 Earth Summit in Rio de Janeiro, where the concept of ‘common but differentiated responsibilities’ was agreed upon as a strategy to mitigate climate change, taking into account countries’ respective ‘social and economic conditions’ and their ‘specific national and regional development priorities, objectives, and

circumstances' (Rajamani, 2000, United Nations, 1992).

During the same summit, the Rio Declaration on Environment and Development was also signed by at least 166 countries (United Nations, 2022) which takes serious note of the interlinkages between prerogatives of development and protection of the environment. Principle 3 of the declaration (United Nations General Assembly, 1992) makes this clear :

The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

In addition, this declaration, in its Principle 4 gives impetus to the (then) fledgling concept of sustainable development :

In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

And finally, on the topic of poverty and inequality, Principle 5 states :

All States and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world.

In a step towards operationalising these sustainable development goals, eight 'Millennium Development Goals' (MDGs) were drafted during the Millennium Summit in 2000, among which were (United Nations, 2015)<sup>3</sup> :

- MDG 1 : Eradicate Extreme Poverty and Hunger
- MDG 7 : Ensure Environmental Sustainability, and
- MDG 8 : Global Partnership for Development)

. In 2016, the MDGs were succeeded by the seventeen Sustainable Development Goals (SDGs) that set an agenda for development post-2015 (United Nations General Assembly, 2015). The relevant goals among them are :

- SDG 1 : End poverty in all its forms everywhere
- SDG 7 : Ensure access to affordable, reliable, sustainable and modern energy for all

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3. Only the MDGs and SDGs immediately relevant to the topic of this thesis have been mentioned here.

- SDG 8 : Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- SDG 9 : Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- SDG 10 : Reduce inequality within and among countries
- SDG 12 : Ensure sustainable consumption and production patterns
- SDG 13 : Take urgent action to combat climate change and its impacts
- SDG 17 : Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

While these goals serve ‘sustainable development’ in general, the term encompasses a wide variety of notions, norms, and aspirations that might be synergetic, or might be in conflict with each other, and in varying degrees. Scholarly literature has noted the potential sources of synergy and tension between these goals, and scholars have developed frameworks to assess interactions between goals (Lou et al., 2022, Nilsson et al., 2016). Pradhan et al. (2017) for instance, undertake one such assessment, and find evidence for substantial synergies (for instance, with SDG 1 being synergetic with most other SDGs), but also potential trade-offs between SDGs (such as with SDG 12 and most other SDGs). Careful evaluation and quantification of these tradeoffs are necessary for an efficient and effective realisation of all the sustainable development goals. This is all the more relevant given that investment in emissions mitigation can only have an upward trajectory, with at least 600 billion USD to 800 billion USD per year of additional investments in the energy sector alone being seen as necessary to reach a +1.5°C temperature target for 2100 (Ahluwalia and Patel, 2022). Critically examining the potential tradeoffs between the socioeconomic and environmental goals of sustainable development in developing countries hence forms the primary motivation for this thesis.

Through the three chapters of this thesis, different aspects of these potential tensions or trade-offs between various sustainable development goals are studied. Using the framework of externalities of investments, socio-economic externalities in this case, these potential trade-offs are quantified. Few studies in the literature deal with assessing development investment in Brazil at different levels and using data at different levels. Using recent advances in econometric methods, this thesis looks at the socio-economic impacts of development investment at the macro, meso, and micro- levels. Chapter 1 deals with an analysis of the projects of the Clean Development

Mechanism (CDM) and its impact on income inequality, unemployment, and poverty in Brazil. Chapter 2 looks at the Brazilian national development bank's (BNDES) investments in electricity generation and their impacts on economic output, on employment, and on wage levels at the municipality level. Chapter 3 again looks at the BNDES' investments and their potential contribution to wage polarisation and wage inequality in São Paulo state in Brazil, using worker level data.

Brazil, its regional divisions at various levels, and its workers form the empirical base for this thesis. For the researcher, Brazil constitutes a very interesting object of research, because of its importance in the world economy (even more so among other developing countries such as the BRICS grouping), its diverse economy, and because of the large amount of development investment that has been undertaken in the country over the past two decades (91 billion Brazilian Reais (37.6 billion US Dollars<sup>4</sup>) between 2003 and 2017 by the BNDES alone). At the same time, Brazil still faces issues of social disparities as well as environmental issues such as the deforestation of the Amazon rainforest. International climate commitments by Brazil, such as at the COP26 concerning carbon neutrality by 2050 (Ahluwalia and Patel, 2022) only sharpen the need for detailed analyses of potential synergies and tradeoffs between emissions mitigation and development objectives. While the results presented in this thesis are formally valid in the Brazilian context, due to the scope and the depth of the data and analyses, the lessons drawn are pertinent and instructive for other developing countries as well. In addition, the availability of rich and reliable data sources were also important factors in the choice of Brazil for the analyses in this thesis.

The policy implications of the results presented in the following chapters are intended to serve policymakers in Brazil and in other developing countries, particularly in setting the priorities of their national development banks (or equivalent), as well as in international climate negotiations, to more accurately take into account the externalities of development investment. In the spirit of Principle 4 of the Rio Declaration on Environment and Development (quoted above), if environmental protection is to be considered an integral part of development, it is essential that all the externalities (be it environmental or social or economic) of development investment be taken into account, in order to achieve sustainable development in the most efficient manner possible.

The rest of the general introduction serves to provide background information that puts each of the chapters of the thesis in context, as well as connect the three chapters at a conceptual level.

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4. A rate of 1 USD = 2.42 BRL applied.

First, income inequality in Brazil is presented, since it forms an integral part of the rest of the thesis, followed by a discussion on international mitigation finance, followed by a discussion on investment in clean electricity generation. An outline of the thesis is then presented, which leads to the three individual chapters of the thesis. A general conclusion to the thesis is presented after Chapter 3 to summarise the main findings and policy recommendations resulting from the chapters in the thesis and to offer directions for future research that I would like to undertake in extension of this thesis.

### **Income inequality in the world and in Brazil**

In the middle of the 20th century, while global income inequality seems to have remained stable, a reduction in within-country income inequality has been noted by [Chancel and Piketty \(2021\)](#), whereas the same study finds that within-country income inequality increased since 1980. With increased household incomes and higher levels of development led by the rise of the Chinese economy, global prosperity might be rising, but this prosperity is being distributed inequitably, argue [Jaumotte, Lall and Papageorgiou \(2013\)](#). They also make a crucial link between globalisation and income inequality, a link upon which the studies in this thesis will be based. Income inequality, by definition, has been seen as an inherently negative aspect of a society, or at the very least, increased income inequality has been seen as an unwelcome goal for a society to aspire to merely because it goes against the principle of having an egalitarian society. While income inequality need not necessarily be associated with increased poverty, it does lead to poorer sections of the economy being more exposed to the whims of economic cycles ([Jaumotte et al., 2013](#)). Income inequality can affect economic growth by creating inefficiencies in the distribution of skills and labour in the economy ([Deininger and Squire, 1997](#)), in addition to causing social unrest ([Keeley, 2015](#), [Scheidel, 2017](#)). Brazil and Latin America in general have been seen as being particularly affected by high income inequality ([Suanes, 2016](#)). Theoretically, the chapters in this thesis are motivated by theories of sector differentiation of the economy, a concept first proposed by [Fisher \(1939\)](#), and wage polarisation induced by Skill-Biased Technological Change (SBTC) ([Katz and Murphy, 1992](#)), later developing into concepts of Routine-Biased Technological Change (RBTC). One of the chapters in particular explores some of the links between skill-biased technological change and income inequality, inspired by [Acemoglu \(2002\)](#) whose thesis is that an increase in ‘...skill bias during the past few decades appears to be the main cause of the increase in [wage] inequality’. The thesis looks at the broader question of socioeconomic impacts of development



investments in developing countries using these theories as a basis, while focussing on different levels of analysis (using micro-, meso-, and macro-level data), using the empirical case of Brazil.

The origins of income inequality in Brazil have been the focus of much discussion in public and academic discourse. In the industrial era, income inequality seems to have peaked during the industrial era around the year 1870 during the commodities boom. While empirical studies have been clear in showing that income inequality has remained high compared to the ‘developed world’, the underlying reasons behind the ‘endemic’ income inequality in the region has not found unanimous agreement among researchers ([de Souza, 2017](#)).

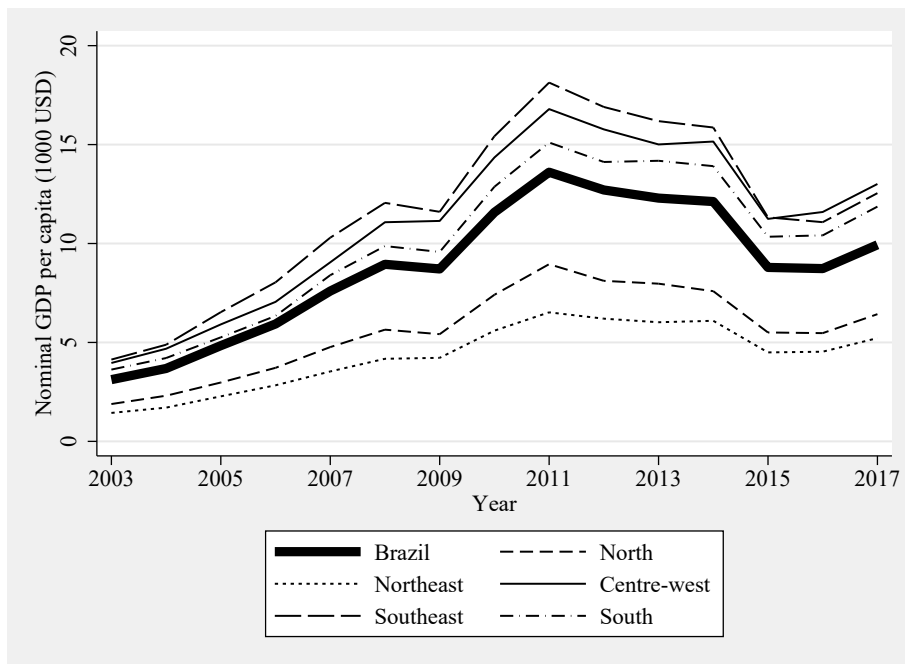
[Sokoloff and Engerman \(2000\)](#) put factor endowments and colonial-era institutions at the origin of income inequality in the region. They argue that in comparison to (what is today) the United States and Canada, parts of South America and the Carribean were better endowed with resources that encouraged specialisation of labour. This allowed institutions to develop that preserved these inequalities due to the opportunities of rent-seeking that were present that went on to favour the elites. The (relatively) large population of natives and the prevalence of slavery as a practice only aided these institutions to develop. This, according to the authors, is in contrast to parts of North America that were less endowed in resources at the advent of colonialism, and hence had immigration patterns that were more equal (among the economic profiles of the immigrants).

A contrasting view is offered by [Williamson \(2015\)](#), who stresses that it is important for historical income inequality statistics to be seen in context, and in comparison with similar statistics from around the world. According to him, income inequality in Latin America was not any different from pre-1800 northwest Europe or the United States in the 1860s. Where income inequality did rise was during the commodity boom from the 1870s until the eve of the First World War, but in doing so the region joined the ‘rich country inequality club’; where Latin America differs from the rest of the industrialised world, is in its failure to undergo the so-called ‘Great Egalitarian Leveling’ in the post-war era that other industrialised countries underwent, where income inequality reduced. [Williamson \(2015\)](#) opines that the origins of Latin American income inequality in the present lie less in its colonial history, but its unique experience in development in the later years of the 20th century.

The academic discourse around income inequality in the last quarter of the 20th century increasingly focused on the role of returns to education on wages and wage inequality. In the early 2000s, when income inequality started dropping, the reductions were largely credited to improvements in the educational system in the country. Other causes that were also credited as contributing to the

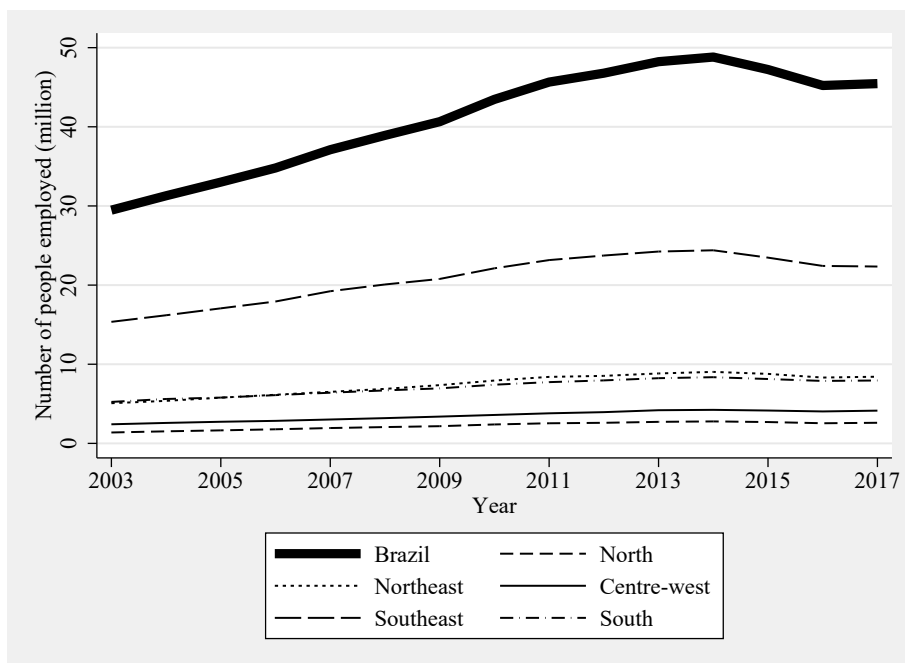
phenomenon are the successive increases in the minimum wage (an increase every year), reduction in discrimination (based on gender or ethnicity) in the labour market, and an increased creation of employment in the formal sector (de Souza, 2017). The *Bolsa Familia* conditional social benefits transfer programme, formally started in 2003, has been credited with substantial contributions to reductions in income inequality, with post-implementation analyses claiming that *Bolsa Familia* contributed to inequality reductions more than the increases in minimum salary (Barros, 2007).

In the three chapters of this thesis, the evolution of various socio-economic indicators of Brazil and its regions in the early 21st century has been studied, with the impact of certain development investments within this period being studied. Figure 6 shows the evolution of the nominal GDP per capita (in US Dollar terms) between 2003 and 2017, and Figure 7 depicts the evolution of the number of people employed during the same period. This evolution is to be considered in conjunction with the evolution of the population, seen in Figure 8. A generally downward trend can be seen in the mean wage levels in terms of the minimum wage (mean wage at the municipality level, aggregated at the macroregion level for presentation) in Figure 9. Measures of income inequality figure prominently in the following chapters of the thesis, and accordingly the evolution of the Gini wage inequality index in the regions of Brazil can be seen in Figure 10. It is to be noted that the wage inequality index presented here is the wage inequality within each municipality, aggregated at the macroregion (and national) level (and between-municipality wage inequalities are not represented in this figure).



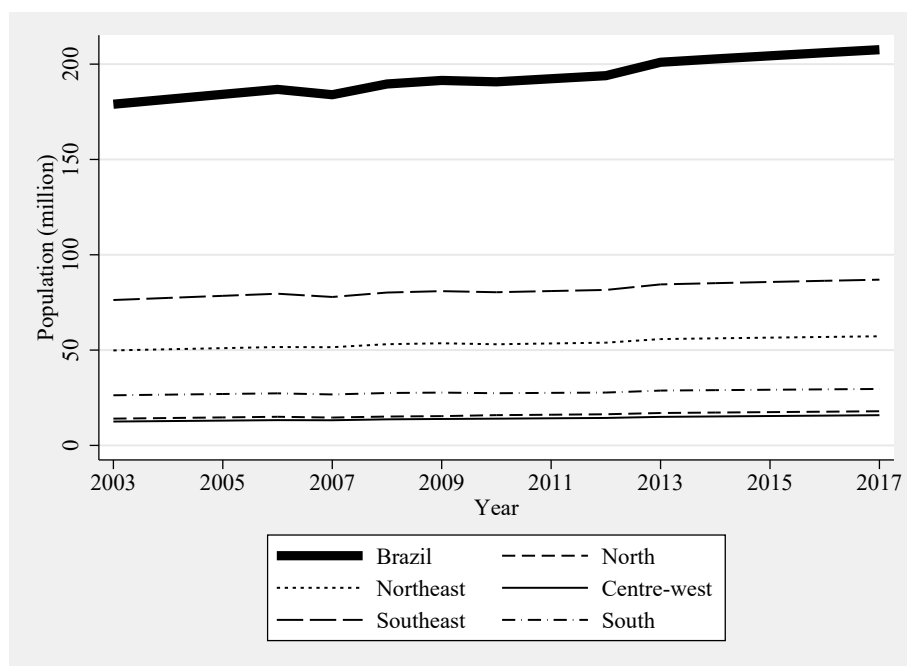
Source : IBGE, author's depiction

FIGURE 6 – Evolution of nominal GDP per capita (in US Dollars) from 2003 to 2017 in Brazil and its macroregions



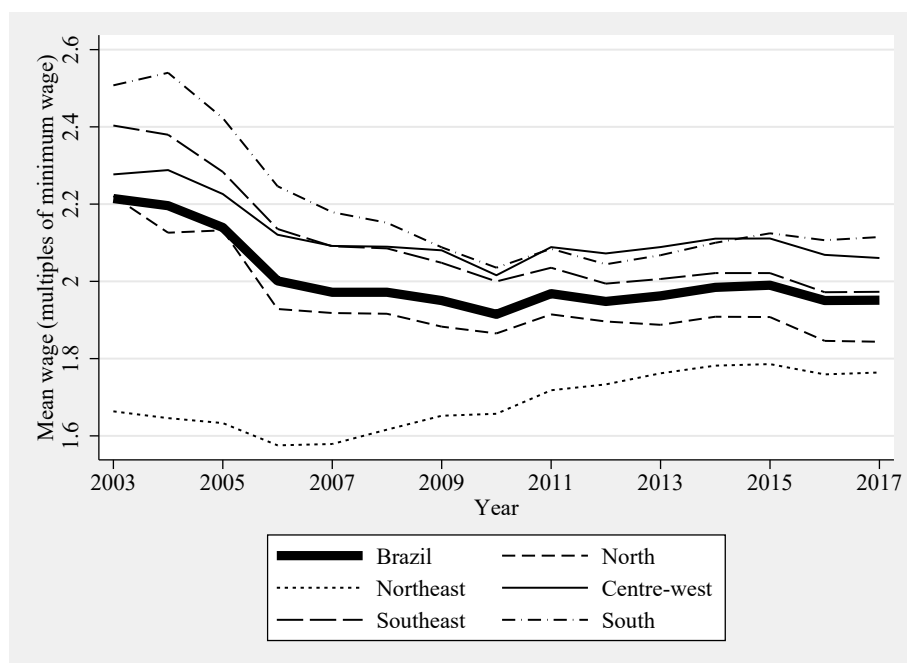
Source : RAIS labour survey, author's depiction

FIGURE 7 – Evolution of total number of people in formal employment from 2003 to 2017 in Brazil and its macroregions



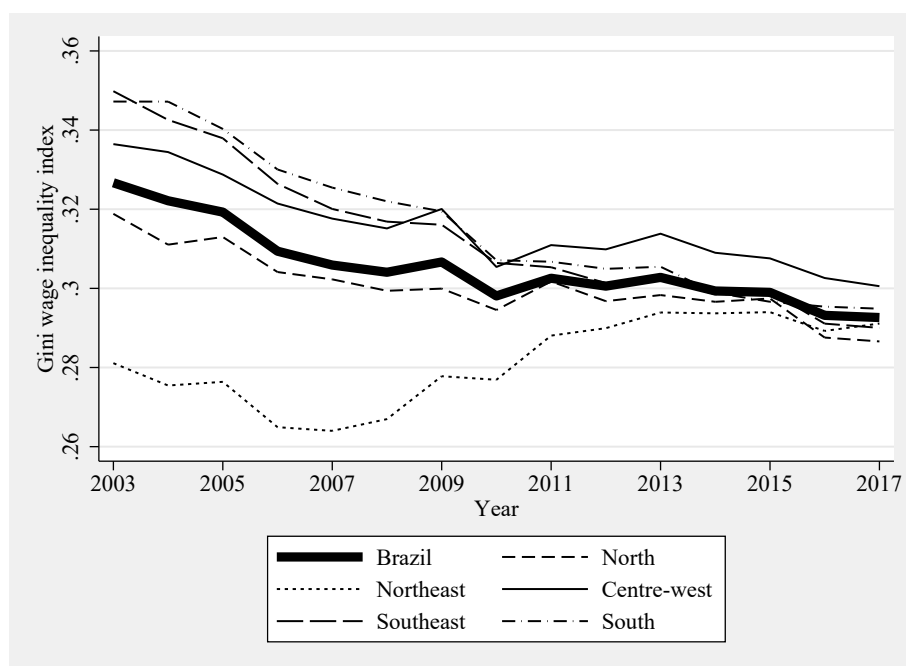
Source : IBGE, author's depiction

FIGURE 8 – Evolution of the population from 2003 to 2017 in Brazil and its macroregions



Source : RAIS labour survey, author's depiction

FIGURE 9 – Evolution of the mean wage levels (in multiples of the minimum wage) from 2003 to 2017 in Brazil and its macroregions



Source : RAIS labour survey, author's depiction

FIGURE 10 – Evolution of the mean intra-municipal Gini wage inequality index from 2003 to 2017 in Brazil and its macroregions

### International mitigation finance

The United Nations Framework Convention on Climate Change (UNFCCC) has been looking to mobilise funding for international ‘green’ finance in the form of ‘sustainable’ projects. One of the large initial efforts was with the Kyoto Protocol; the Paris Agreement, in many ways seen as its successor, seeks to take this concept further, as well as other initiatives such as the Green Climate Fund. With the introduction of the Kyoto Protocol in 1997, the concept of ‘green growth’ in developing countries took birth, with countries needing to, and attempting to balance economic, environmental, and social objectives by way of investment in infrastructure. This led to a wide range of actors making such investments, among which were public (governmental), private, and foreign (governmental and private) actors (Keane and Potts, 2009, OECD, 2012). At the same time, as a direct result of the Kyoto protocol, developed countries (so-called annex-I countries) had a binding obligation to reduce their greenhouse gas (GHG) emissions to certain targets. Developing countries (so-called non-annex-I countries) on the other hand, were eligible to receive investment from Annex I countries targeted at specific projects that were demonstrably ‘clean’, or in other words, contributed to a net reduction of GHG emissions. This mechanism, named the Clean Development Mechanism (CDM) takes its root in Articles 6 and 12 of the Kyoto Protocol,

with Article 12.2 defining the purpose of the CDM : ‘the purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.’ ([United Nations, 1998](#)).

In parallel with the development of projects such as CDM projects on the ground, the academic literature on similar ‘green’ investments also began to grow, among which were studies that raised the sustainability of projects into question. The question centres chiefly around the definition of sustainability itself, namely whether sustainable development is necessarily one-dimensional in that it focuses only on GHG emissions reductions, or if it includes other aspects of socio-economic development, such as employment creation and income inequality. Two chapters (Chapter 1 and Chapter 3) in this thesis will revolve around one of those socio-economic aspects, namely income inequality (or wage inequality), whereas one chapter deals with employment creation. The motivation for this thesis derives from the fact that inequality and other socioeconomic factors have not been paid much attention to by policy when it comes to ‘green’ development. On one hand this is conceivable, given that the primary interest is the environmental goal of emissions reductions, but on the other hand this ignores the knock-on effects of these projects in the form of externalities and calls into question the notion of sustainability itself ([Sutter and Parreño, 2007](#)). This thesis and its policy recommendations will be of particular interest and relevance to currently ongoing and future climate negotiations, as well as to national authorities and national development banks who have a direct interest in ensuring not only that emissions reductions are achieved, but also in that they do not negatively affect other crucial socioeconomic conditions. From a policy perspective, one way of redistributing some of the socioeconomic benefits of green finance projects could be to strengthen the case for equitable distribution at the supranational level (i.e. in international climate negotiations). An important step in accomplishing this would be to better internalise the externalities of development investment, which includes a comprehensive measurement of the socioeconomic impacts of the investment. In the case of the Clean Development Mechanism, or the international sustainable development project that will replace it (following the Paris Agreement), the challenge in the next few years will be to promote equity and force investors to direct their resources to the areas and project types where they are needed to promote development, and not only where they can be profitable (in absence of policy interventions). Adding to this contemporary debate forms the policy motivation for this thesis.

## Investment in ‘clean’ electricity generation

Electricity generation projects share the commonality that they all take in primary energy sources as inputs and output electricity that is then fed to the grid. Apart from that, between different types of electricity generation projects (solar PV/wind/coal/gas, etc.), the precise technical mechanisms actually involved in the conversion, as well as the engineering and logistics required to accomplish this are very often quite different, with each type of energy generation project requiring different engineering skillsets to construct, maintain, and operate. Generating fossil fuel power, for instance, requires that personnel be present in the power plant constantly to ensure maintenance and safety. This mode of functioning is clearly different from, for instance, solar PV projects that include a construction phase that requires human labour, and later require minimal maintenance. Biomass energy projects, on the other hand, would require more human intervention, and in a sense resemble fossil energy projects. During the construction and operation of these different types of projects, it should not be surprising to see heterogeneity in the types of economic impact and employment created at the local level (as well as at much bigger levels, like the regional or national level) simply due to the different types of skill and labour intensities that these different types of electricity generation projects require.

There is a stream of literature in macroeconomics that uses data at the country level to examine the link between energy consumption and economic outcomes (GDP). While there is evidence to suggest that there is a correlation between energy consumption (regardless of type) and economic growth ([Apergis and Payne, 2012](#)), there is also evidence to suggest that different types of energy sources might have different impacts ([Ohler and Fetters, 2014](#)). There is a dearth of econometric studies that use microeconomic data to analyse the economic development and employment and wage impacts of clean electricity generation projects ([Blyth et al., 2014](#)), and even fewer that explicitly compare clean energy generation with fossil energy generation. This thesis, particularly in [Chapter 1](#) and [Chapter 2](#) intends to respond to this gap in the literature by using microeconomic data to measure local impacts of different types of electricity generation projects.

A broad literature exists that models the employment benefits of clean electricity generation installations. This literature is undecided on the net employment benefits of policies that favour renewable energy development ([Bulavskaya and Reynès, 2018](#), [Cai et al., 2017](#), [Caldés et al., 2009](#)). Most of these studies use an input-output (IO) analysis, data for which is typically available

at the national level, whereas some other studies like those by [Bohlmann et al. \(2019\)](#), [Bulavskaya and Reynès \(2018\)](#) use a computable general equilibrium (CGE) model (see review by [Jenniches \(2018\)](#)).

As an illustrative example of the strand of literature using IO models, in an economic valuation of the employment benefits of renewable energy technologies in Greece, [Tourkolias and Mirasgedis \(2011\)](#) use an input-output methodology. They estimate employment benefits between 0.7 EUR/MWh and 4.8 EUR/MWh<sup>5</sup>, with variations between types of technology (wind, solar PV, hydroelectric, geothermal, biomass), and also some heterogeneity when it comes to employment generated during the construction and operation phases. While in the present thesis the employment benefits are not estimated using a similar methodology, these studies are useful to mention, since they allow a comparison of the employment benefits of clean electricity generation to fossil energy generation (lignite and natural gas). While natural gas creates employment benefits valued between 0.4 EUR/MWh and 0.6 EUR/MWh, lignite plants create employment benefits between 2.9 EUR/MWh and 3.5 EUR/MWh. However, it must be noted that a significant share of the employment benefits for clean electricity generation comes at the construction phase, the share of benefits due to construction being up to 75.6 percent for solar PV, and 22.2 percent for biomass. The corresponding share of employment benefits for lignite and natural gas plants are 6.9 percent and 4.5 percent respectively ([Tourkolias et al., 2009](#)).

An explanation for this heterogeneity in outcomes between clean electricity generation and fossil electricity generation could be the differing skill and labour intensities of the jobs created by each type of investment. [Bulavskaya and Reynès \(2018\)](#), for instance, use a CGE model to show a net positive economic impact of clean electricity expansion in their study of the Netherlands, and explain their results by pointing to a higher capital and labour intensity of clean electricity generation investments. However, in a slightly different finding, [Consoli et al. \(2016\)](#) show that ‘green’ jobs are more skill intensive than ‘non-green’ jobs (although they do not directly treat the subject of labour intensity).

This observed heterogeneity in employment creation is particularly important because employment creation is seen as reducing absolute poverty, a crucial factor in developing countries. It is accepted that in general, economic growth reduces absolute poverty ([Dollar and Kraay, 2002](#), [Ravallion, 2001](#)), but not all growth is equal—growth in certain sectors have more poverty-reducing

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5. 1 EUR = 0.99 USD as of September 2022.



effects than growth in others (Loayza and Raddatz, 2010). There is also evidence to support the link between employment generation and poverty reduction, given that work-based income makes up a large part of the income of the poor. There is theoretical and empirical support for this linkage (Loayza and Raddatz, 2010, Ravallion and Datt, 1996). Growth in the agricultural sector, for instance, would create more employment opportunities than other sectors, given that it is more labour-intensive, and therefore would contribute more to poverty reduction. A similar effect might be at work when it comes to the impacts of clean energy generation and fossil energy generation projects.

Therefore, in Chapter 1 and Chapter 2 of the present thesis, the aim is to inform the literature by studying the differentiated economic impacts of clean electricity generation investments (contrasting them with non-electricity-generation investments) using panel data econometric methods. In addition, Chapter 2 also studies the dynamic effects of investment in these project types to see the extent to which the economic impact (if present) is persistent with time.

Tourkolias and Mirasgedis (2011) and Cai et al. (2017) also show that the net employment benefits (or at least the valuation thereof) varies depending on factors such as the origin of the equipment (domestically manufactured or imported from abroad), and the evolution of the global market price of these technologies. Other studies have also noted the potentially negative impacts of clean energy generation expansion strategies that rely more on imports rather than domestic manufacturing (see Frondel et al. (2010)). Lehr et al. (2012) show that for Germany, while net employment creation might have a positive outlook when the renewable energy sector exports are optimistic, the effects are more modest or even negative in the extreme case when exports are slow.

While input-output studies capture the employment benefits upstream of the investment (for instance, manufacturing of solar PV panels, or wind turbine blades), this methodology does not measure the broader Keynesian effects of investments on the economy, i.e., the employment that is created downstream of the investment (for instance, new businesses that are created to cater to the population's increasing prosperity). CGE models on the other hand do model economy-wide effects, and therefore derive their utility from this fact. However, while these models capture the broader impacts of an increased share of clean energy in the energy mix, the immediate effects of an investment at the local level are not captured.

There is therefore reason to hypothesise that the economic and employment creation impacts of clean electricity generation and fossil electricity generation might be different. We can expect this difference because the jobs created by these two types of investment might require different

labour intensities and skill intensities that in turn affect the local labour markets differently. Complementary to this discussion of the broader macroeconomic literature, the thesis offers an analysis that uses microeconomic data from Brazil to respond to similar questions.

### **Outline of the thesis**

This thesis circles around the question of what sustainable development entails when it comes to development investment, with the chapters specifically looking at the impacts of development investments on income inequality, employment, and wages. This thesis extends the existing literature by suggesting the mechanisms through which this effect takes place. From a conceptual standpoint, this is done by considering the impacts of these projects as externalities, therefore allowing a meaningful impact assessment without trying to impose an ex-ante definition of sustainable development. Empirically, the analysis is executed by utilising high-quality spatially organised census data, combined with reliable administrative data for development projects. Each chapter in the thesis uses a different level of analysis, assessing similar research questions at a macro, meso, and at a micro-level. In particular, two of these chapters use micro-level data to analyse a *problematique* (evaluation of development investments) that is very often treated at a macro-level. Methodologically, the research questions are approached with quasi-experimental, research methods that are at the forefront of current scholarship in econometrics. An overview of the chapters, their main theoretical contributions and the econometric methods used is presented below, and in a more concise manner in [Table 2](#).

- Chapter 1 of this thesis looks at CDM projects in Brazil, and assesses the impacts of project deployment on income inequality at a micro-region level, separating the projects by the type of technology involved (solar, wind, landfill gas production, etc.). The data used is primarily from the CDM project database, and from the IBGE. A difference-in-differences method is employed to estimate the causal impacts of CDM project implementation on income inequality, on unemployment, and on poverty levels between 2000 and 2010. This study positions itself in the policy discussions concerning the future of the Clean Development Mechanism (CDM), more specifically Article 6 of the Paris Agreement, around which the discussion was particularly active after the COP25 in Madrid, where a consensus was not reached concerning the design of the ‘new’ CDM mechanism that was to replace the CDM under the ambit of the Kyoto Protocol. CDM projects have also often been subject to criticism for their lack of demonstrable ‘additionality’, the term referring to environmental or financial

additionality. This chapter extends this debate by studying the impact of CDM project deployment on other sustainable development parameters, namely inequality, unemployment, and poverty reduction.

Theoretically, the chapter bases itself on theories about how incoming Foreign Direct Investment (FDI) affects income inequality in the host country, particularly when the incoming investment is in a specific sector of the economy (i.e. extractive, industry, or services). In particular, it is seen that income inequality tends to rise when incoming FDI is in the manufacturing or the service sectors (that employ more skilled workers), in contrast to unskilled workers that might be employed in the extractive sector. CDM investment, sharing characteristics in common, is considered to be an indirect form of FDI, and is hence analysed from this perspective.

Empirically, the evaluation approach used is an econometric model that tests the hypothesis that CDM project activity (measured through the number of Emissions Reductions Credits issued) in a Brazilian microregion has had an effect on income inequality, unemployment, and poverty, between 2000 and 2010. Since not all microregions received a CDM project, the effects observed could be attributed to the presence and size of the project. Control variables as well as a difference-in-difference approach are used to account for heterogeneity. The projects were also separated by the type of technology used to achieve the emissions reductions, with the hypothesis being that the effects of the presence of different types of projects would be different, due to the different type and level of skill that each project type requires.

Evidence was found for reductions in income inequality, unemployment, and poverty in those microregions that received CDM projects relative to those microregions that did not receive a project. Certain types of projects (methane avoidance, hydroelectricity generation) were seen to have larger effects than other project types. The recommendation for policymakers is that socio-economic factors such as inequality, unemployment, and poverty be considered among sustainable development objectives, and hence be measured more reliably and accurately so as to enable monitoring and verification. This is particularly relevant in light of discussions around an updated rulebook for the CDM in the COP25 in Madrid. Since then, progress has been made during the COP26 in Glasgow to better include sustainable development outcomes including equity issues among the objectives of the CDM ([UNFCCC, 2021](#)).

- Chapter 2 assesses investments of the Brazilian National Development Bank (BNDES) and their contribution to economic output, employment creation, and changes in mean wage levels in at the municipality level in Brazil between 2003 and 2017. Similarly to Chapter 1, investments are separated by type – in this case separated into non-electricity-generation, electricity generation, and clean electricity generation investments. Using panel data compiled using data from BNDES, from IBGE, and from the RAIS annual labour survey, a Two-Way Fixed-Effects (TWFE) econometric model is used to test the hypothesis of whether the presence of BNDES investment has an effect on the outcome variables of interest. Such an analysis is pertinent for a development bank such as the BNDES to introspect on what priorities sustainable development entail for the Bank—environmental, social, economic, or a combination of them.

Theoretically, the chapter follows a strand of literature in policy evaluation that looks at the socioeconomic impacts of development investment, particularly those of clean energy investment. Literature attests to the fact that clean energy investment has different labour and skill needs compared to investment in other projects, including fossil energy projects. There is therefore reason to hypothesise that these different investments might have different socioeconomic outcomes as well.

To test these differences empirically, the data were organised into a panel structure, with a ‘staggered’ structure, implying that treatments (i.e. inflow of investment into a municipality) occurred at different points of time in the panel. Recent advances in the econometrics literature have allowed for staggered treatments to be taken into account while using TWFE models (Callaway and Sant’Anna, 2021, Goodman-Bacon, 2018), which have been applied in the econometrics presented in this chapter. In addition, an Inverse Probability Weighting (IPW) -based approach along with inclusion of fixed effects (doubly-robust estimator) has been used in the model to account for endogeneity concerns, and to elicit causal effects. Dynamic treatment effects were also presented to analyse the persistence of the effects of these investments.

The results indicate that while development investment by the BNDES in general has had positive impacts on economic output, employment, and on mean wage levels in Brazilian municipalities, they also indicate that the effect sizes are different for electricity generation investments (mainly clean electricity generation investments) and other development investment, with investment in electricity generation faring worse than other development invest-

ment. Differences can also be noted between electricity generation in general and clean electricity generation in particular. These differences, however, need to be analysed in the context of the positive externalities that clean electricity generation investment bring, which are not internalised in the national accounts data used in this chapter. These findings aim to provide guidance to the BNDES and other development banks to take a broader view of sustainable development, one that is multidimensional and considers socioeconomic factors in addition to environmental factors.

- Chapter 3 studies wage polarisation in São Paulo state of Brazil, using worker-level data to construct a natural experiment between those workers exposed to BNDES investment between 2003 and 2013 and those workers who were unexposed, hence using an alternative identifying factor to discern polarisation in the labour market, specifically wage polarisation. Complementary to the first two chapters, the chapter adds a new perspective to the distributional impacts of development investment, and finding that the wage polarisation observed is consistent with Skill-Biased Technological Change (SBTC) and Routine-Biased Technological Change (RBTC).

The polarisation of the labour market has been observed in many developed countries, a phenomenon that tends to favour increased jobs and wages on either extreme of the skill spectrum of jobs, favouring high-skilled and low-skilled jobs to the detriment of medium-skilled jobs (SBTC). Concepts of RBTC further nuanced this reading of the changes in the labour market to differentiate jobs by their ‘routine content’, where jobs that can be accomplished by automation are the most disadvantaged. The phenomenon has been poorly studied in developing countries, but a few studies do suggest an ‘incipient’ polarisation of the labour markets, even in developing countries. The principal research question dealt with in this chapter is therefore to look for signs of polarisation of the labour market in São Paulo state in Brazil, in response to development investments by the BNDES.

BNDES investment forms the empirical base of the analysis, and is used as an identifying factor in testing for labour market polarisation – this can be achieved since not all workers in the state were exposed to BNDES investment. The differences between those exposed and those unexposed to BNDES investment can be ascribed to the effect of exposure to the investment. Worker-level data was obtained from the RAIS annual labour survey, and national accounts data from the IBGE. The main contribution of this chapter to the literature is the estimation of treatment effects (or in this case, exposure effects) across the wage distribu-

tion, using quantile regression methods, specifically the Unconditional Quantile Treatment Effects (UQTE) estimator introduced by [Firpo et al. \(2009\)](#).

The chapter concludes by finding that there are incipient signs of wage polarisation observed in São Paulo state between 2003 and 2013, and that this finding is consistent with SBTC. Even though it was observed that those occupations that are likely to have jobs with higher routine content are likely to be disadvantaged relative to jobs with lower routine content, further research is needed to clearly test the link to RBTC. These findings throw light on the phenomenon of labour market polarisation in developing countries. They also to have an incidence on wage inequality, and therefore on the (sustainable) development priorities of development banks such as the BNDES, which can potentially draw lessons from these findings.

### **A note on form and style**

Since the thesis is a paper-based thesis, each of the chapters is (or is intended to be) a standalone article in an academic journal. Hence, within each chapter, the chapter might be referred to as an ‘article’. Each chapter is in a different stage of the publication process in a different journal, and therefore might follow slightly different styles and conventions. Notably, in those chapters that are intended for publication as co-authored journal articles, the first person plural ‘we’ might be used in certain sentences. Within each chapter, the form and style are consistent.

Chapter 1 has been published as an article in the journal *Climate Policy* in its May 2020 issue. The accepted manuscript has been reproduced here, with some minor cosmetic corrections.

TABLE 2 – Overview of chapters in the thesis

Chapter	Contributions to knowledge	Method	Unit of analysis	Stage of publication
1	Evaluating the impact of the Clean Development Mechanism (CDM) on income inequality in Brazil, separating projects by type	Difference-in-Difference, panel with two time periods	Microregion (macro-level)	Published in <i>Climate Policy</i> (Ranked A in the HCERES list), May 2020
2	Assessing the socio-economic impacts of clean electricity generation projects in comparison with other projects of the BNDES using a two-way fixed effects estimator on a ‘staggered’ panel of municipalities in Brazil	Two-way fixed-effects, panel with 15 time periods and a staggered treatment	Municipality (meso-level)	— Under submission to the journal <i>Ecological Economics</i> (Ranked A in the HCERES list). — Published in the FAERE Working Paper Series, 2022.
3	Using an alternate identifying factor (exposure to BNDES development investment) to analyse wage polarisation in São Paulo state in Brazil	Unconditional quantile regression	Worker (micro-level)	Draft journal article presented at the seminar of the IREG laboratory at the Université Savoie Mont Blanc in March 2022

## Authorship statement

Authorship statements follow the Contributor Roles Taxonomy (CRediT) (Brand et al., 2015).

1. Chapter 1 : Inequality, unemployment, and poverty impacts of mitigation investment : Evidence from the CDM in Brazil and implications for a post-2020 mechanism
  - David Grover : Conceptualisation, Methodology, Validation, Formal analysis, Writing-Original Draft, Writing-Review and Editing, Visualisation, Supervision, Project administration
  - Swaroop Rao : Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing-Original Draft, Writing- Review and Editing
2. Chapter 2 : Local economic development through clean electricity generation—an analysis for Brazil and a staggered difference-in-difference approach
  - Swaroop Rao : Conceptualisation, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing-Original Draft, Writing-Review and Editing, Visualisation, Project administration
  - David Grover : Writing- Review and Editing, Supervision
  - Dorothée Charlier : Writing-Review and Editing, Supervision
3. Chapter 3 : Wage polarisation in Brazil examined using policy evaluation methods : A study from São Paulo state using an unconditional quantile treatment effects estimator
  - Swaroop Rao : Conceptualisation, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing-Original Draft, Writing-Review and Editing, Visualisation, Project administration
  - David Grover : Supervision
  - Dorothée Charlier : Supervision





# 1

## Inequality, unemployment, and poverty impacts of mitigation investment

*Evidence from the CDM in Brazil and implications for a post-2020  
mechanism*

Note : this chapter is the Accepted Manuscript of an article published by Taylor & Francis in *Climate Policy* in its  
May 2020 issue. The version of record is accessible at

<http://www.tandfonline.com/10.1080/14693062.2020.1760773>.

## **Abstract**

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*Article 6 of the Paris Agreement provides for the creation of a successor to the Clean Development Mechanism (CDM), the parameters of which are currently being operationalised. This paper uses the broad literature on the relationship between general foreign direct investment (FDI) and inequality in FDI host countries to develop expectations about the likely impact of past and future international mitigation investment on inequality, unemployment and poverty outcomes. Using 2000 and 2010 census data for small geographic areas in Brazil, we compare the change in those outcomes in areas that experienced CDM project activity to the same in areas that did not, using a difference-in-difference approach. We find that areas with CDM project activity experienced improvements in those outcomes, which appear to be driven by project types that are associated with 'primary' sector activity. Including measurement and reporting procedures for these broader sustainable development outcomes in the rulebook of a post-2020 agreement could be favourable to the interests of both developed and developing countries.*

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## 1.1 Introduction

In Article 6 of the 2015 Paris Agreement, governments agreed to create a ‘mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development’, and to adopt ‘rules, modalities and procedures’ to implement the mechanism. Legal, accounting, and technical challenges exist to operationalising such a mechanism for the post-2020 period (von Unger, Greiner and Krämer, 2019). Developing country parties will be particularly concerned with the operationalisation of the ‘sustainable development’ objective in those commitments. However, the predecessor mechanism under the 1997 Kyoto Protocol, the Clean Development Mechanism (CDM or ‘Mechanism’ below), although it aimed to assist developing countries ‘in achieving sustainable development’, contained virtually no binding legal or economic provisions that would compel project developers and other actors to directly promote the aspects of sustainable development related to inequality, unemployment and poverty reduction in the design and operation of projects (Imran, Alam and Beaumont, 2014).

This paper takes as a starting point the numerous studies that have examined the impact of CDM projects on these aspects of sustainable development in developing countries (Boyd et al., 2009, Crowe, 2013, Olsen, 2007, Olsen and Fenhann, 2008, Subbarao and Lloyd, 2011, Sutter and Parreño, 2007, Wittman et al., 2015). Inequality, unemployment and poverty reduction are aspects of sustainable development, in addition to environmental protection (United Nations General Assembly, 1987). Some of these studies find that certain types of CDM projects associate with poverty reduction, in certain specific institutional and country contexts (Crowe, 2013, Du and Takeuchi, 2019, Mori-Clement, 2019), but when they do, they tend to be ‘only moderately successful’ (Crowe, 2013) and short-lived (Mori-Clement and Bednar-Friedl, 2019). Taken as a whole, this body of research provides little evidence that CDM projects deliver strong, consistent and measurable reductions in inequality, unemployment or poverty.

This may not be surprising, given the lack of incentives actors involved in the process have to promote these outcomes. The closest would be the rules governing the CDM project approval process that require project developers to demonstrate ‘environmental additionality’ or ‘financial additionality’ (Paulsson, 2009, UNFCCC, 2012). To the knowledge of the authors, no method of demonstrating additionality accommodates the specific sustainable development outcomes of interest here. Article 6 of the Paris Agreement does appear to make stronger commitments to sustainable development as compared to the Kyoto Protocol, and commentators have seen this as

a positive sign (Braden et al., 2019, Carbon Market Watch, 2017). However, the exact definition of sustainable development and any specific implementation measures have not been finalised, since at the close of the COP25 in Madrid, negotiators had not managed to agree on a common rulebook on a potential successor mechanism, although some developing countries have underscored that sustainable development should be a ‘national prerogative’ (Allan et al., 2019).

In any case, the scale of investment associated with CDM projects during the period 2004 to 2016 certainly had the potential to promote sustainable development outcomes. As an exploratory exercise, we calculated the total volume of reported capital investment associated with CDM projects in the approximately 79 countries that received one, during that period, as published by the UN Climate Change Secretariat in its Project Activities and Programme of Activities (PA and PoA) database<sup>1</sup>. The figure was USD 152 billion.

We then compared this to the total volume of foreign direct investment (FDI) received by those same countries during the same period, as published in the World Bank’s World Development Indicators<sup>2</sup>. This figure was USD 7,125 billion. This means that the ratio of CDM investment to FDI across all affected low- and middle-income countries together was approximately 1 to 47. Not all of the capital investment reported for CDM projects is newly-arrived foreign capital, of course, and there are also questions about the reliability of the reported CDM investment figures (discussed below). But this comparison underlines the point that the scale of CDM investment is not inconsiderable, and that the Mechanism has set a precedent for mobilising large volumes of private and mixed investment into low-cost mitigation in a way that lessens the risk and investment burden on the public sector (Zhang, 2001). However, despite these considerable reported capital investment volumes, their impact on the sustainable development outcomes of interest are poorly understood. This paper addresses this gap by quantitatively testing the impact of CDM project activity on inequality, unemployment and poverty in Brazil. It extends prior research in several ways. First, it frames the question of the impact of CDM activity within the broader, arguably more influential, literature on the effect that general FDI has on these outcomes. In doing so it considers how the specific skill content required for various CDM project types may differently affect those outcomes. Second, it rigorously defines the presence and extent of CDM project activity using

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1. Available at <https://cdm.unfccc.int/Projects/projsearch.html>. As discussed in section 1.3, all projects that had not been awarded certified emission reduction (CER) credits were discarded. It is also important to note that the capital investment figures reported in the PA and PoA may be planned rather than actual investments. This is why those figures have been stated as ‘reported’ investment volumes ‘associated’ with CDM projects.

2. The database defines FDI as the sum of equity capital, reinvestment of earnings, and other capital, and where ownership of ordinary shares of voting stock is 10 percent or greater.

careful project selection criteria, measured as the number of certified emission reduction (CER) credits issued to actual, verified projects. Section 1.2 situates the CDM within the literature on how and why FDI may affect inequality. Section 1.3 describes the data and methods used in the tests. Section 1.4 presents the findings. Section 1.5 discusses the findings and draws study conclusions. Section 1.6 gives policy implications.

## 1.2 Literature review

This section is organized as follows. It defines FDI and describes the channels through which FDI is thought to influence between-country and within-country inequality. It then elaborates recent research on how the impact of FDI seems to vary according to the sector it flows into, and the nature of the skills for which it creates demand. Within this debate it positions the literature evaluating the impact of CDM projects on inequality, unemployment and poverty. Testable research questions are posed.

### 1.2.1 FDI and inequality

FDI can be defined as the flow across international borders of firm-specific capital, including financial capital, proprietary production technologies, brands and trademarks, and organizational and/or managerial practices (Pandya, 2014). Many of the mitigation activities that have occurred under the CDM fit this definition (Niederberger and Saner, 2005), some albeit imperfectly. FDI in general is widely held to facilitate economic development and growth in the countries and sub-national territories that receive it (Almfraji and Almsafir, 2014, Herzer, 2008, Makki and Somwaru, 2004). Theory and evidence shows that these effects occur through various channels, including : the transfer to the host country of modern production technologies and managerial practices that raise the productivity of workers and firms (Alfaro, Kalemli-Ozcan and Sayek, 2009), the production of goods and services for consumption in the host country that were not previously available or available only at low quality or high cost (UNCTAD, 2010); and the additional tax revenues that governments raise from FDI-related production activities that then get invested in social and economic development programmes (Pan-Long, 1995).

However, while there is a degree of consensus that FDI facilitates economic growth and deve-

lopment, there is active scientific debate around whether FDI raises or lowers the level of income inequality among nationals in recipient countries (Basu and Guariglia, 2007, Bermejo Carbonell and Werner, 2018, Iamsiraroj, 2016). Concern over the inequality effects of FDI flowing to developing countries began to gather in the mid-1990s around the time that free trade agreements such as NAFTA were being implemented (Suanes, 2016). To the knowledge of the authors, few insights from this literature are currently reflected in the CDM policy evaluation literature or in the post-2020 mechanism design process.

### 1.2.2 Between- and within-country inequality

One strand of this literature examines the impact of FDI on between-country inequality. Standard models of international production, such as the Heckscher-Ohlin framework, predict that countries produce goods and services that use the factors of production in which they are abundant. This framework predicts that FDI flows to countries where the necessary production factors are abundant, and inexpensive, and once it arrives there, benefits the abundant production factor (Willem Te Velde, 2003). For example, if FDI flows from a high-income country where labour is expensive to a low-income country where labour is inexpensive, labour in the low-income country should benefit, and the level of wage inequality between the countries should fall (Herzer, Hühne and Nunnenkamp, 2014). In the same way, the return to capital that already existed in the FDI-receiving country should fall relative to that in the FDI-sending country, as the new inflow of capital into the receiving country should dilute the returns previously achieved by capital holders (Pandya, 2014).

Unfortunately the standard model does not account well for the impact that FDI has on within-country inequality, which has been the focus of the recent FDI literature and of the few quantitative CDM impact studies (Mori-Clement, 2019, Mori-Clement and Bednar-Friedl, 2019). When the focus is on the within-country impacts of FDI, the literature tends to focus on which types of workers benefit from the employment FDI creates. For example, Im and McLaren (2015) propose that FDI raises demand for skilled labour in the host country and hence the wages of skilled workers, which in turn drives a wedge between the wages of skilled and unskilled workers. In the account of Feenstra and Hanson (1996), FDI increases inequality because even the most basic production activities of multi-national companies raise demand for relatively skilled workers, given that a minimum skill quality threshold is needed to produce goods that are part of a global production chain. In an empirical study, Chen, Ge and Lai (2011) found that FDI in China increases inter-enterprise wage

inequality because foreign companies pay a wage premium to the local workers they employ.

Numerous empirical studies have found that FDI leads to greater within-country inequality, even if the relationship is not directly attributed to the nature of the employment created. [Jau-motte, Lall and Papageorgiou \(2013\)](#) studied a panel of countries during the period 1981-2003 and found that FDI was a leading explanation for rising income inequality in certain Asian and Latin American countries. [Basu and Guariglia \(2007\)](#) examined a panel of 119 developing countries during the period 1970-1999 and found that FDI increased both economic growth and inequality. In another panel study of country-years, [Pan-Long \(1995\)](#) found that FDI increased inequality particularly in Southeast Asian countries. In a study of 88 developing countries between 1980 and 1997, [Kentor \(2001\)](#) found that 'foreign capital dependence' raises income inequality.

### 1.2.3 FDI and skill demand

The most recent work on the FDI-inequality relationship has tried to move beyond treating FDI as uniform, towards examining how specific types of FDI affect inequality. The emerging hypothesis in this literature is that when FDI flows into the services/tertiary sector in a host-country, inequality rises because skilled workers tend to work in this sector and so benefit from greater demand for their skills in the form of higher wages. Unskilled workers do not benefit. However, when FDI flows into the primary sector and perhaps also the manufacturing sector, inequality falls, because these sectors employ a greater proportion of unskilled workers ([Jensen and Rosas, 2007](#), [Raveh and Reshef, 2016](#), [Suanes, 2016](#)).

Recent empirical studies tend generally to support this hypothesis. In a panel study of middle-income countries (1989-2010), [Bogliaccini and Egan \(2017\)](#) found that FDI into the services/tertiary sector associates more strongly with inequality than FDI into the manufacturing or primary sector. [Raveh and Reshef \(2016\)](#) found that 'general' capital imports to developing countries do not increase wage inequality between skilled and unskilled workers, but that imports of capital for performing R&D and other tasks related to innovation, do. [Jensen and Rosas \(2007\)](#) found that the Mexican states that attracted more FDI (which was heavily concentrated in manufacturing) during the 1990-2000 period experienced lower inequality relative to those that attracted less FDI. Other research on the Mexican case finds that the relative demand for skilled labour has increased in the context of rising FDI under NAFTA ([Hanson, 2003](#), [Herzer et al., 2014](#)).

The prior literature evaluating the impact of the CDM on inequality, unemployment and poverty can now be positioned within this skills- and employment-related perspective on why FDI



might increase inequality in some instances and decrease it in others. Little of the CDM evaluation literature has been guided by this perspective to date.

#### 1.2.4 Inequality and CDM activity

In reviews of the literature on the effects of CDM projects on poverty alleviation, [Dirix, Peeters and Sterckx \(2016\)](#) and [Olsen \(2007\)](#) concluded that there is little evidence that CDM projects have substantially helped reduce poverty. [Sirohi \(2007\)](#), in a mixed methods study involving 65 projects found that the CDM projects in India that benefit low-income groups tend to be located in rural areas. [Crowe \(2013\)](#), in a more qualitative and later study of 114 CDM projects worldwide, including projects with add-on standards (with registration dates in 2010 and 2011), found that regular CDM projects are only ‘moderately’ successful at delivering pro-poor benefits and that projects that do are characterized by the use of add-on project standards, a high degree of stakeholder participation, and the involvement of not-for-profit and government entities as project developers. [Du and Takeuchi \(2019\)](#) studied the effect of CDM projects on income and employment in rural communities in China, using a difference-in-difference method. They found that biomass projects contributed to income and employment generation. In the Brazilian context specifically, [Mori-Clement \(2019\)](#) found that the effect of CDM projects on local employment in Brazil was mixed, and when present, small and transitory. [Mori-Clement \(2019\)](#) tested the impact of CDM projects on inequality, employment, and poverty outcomes in Brazil between 2000 and 2010, much like the present study does. [Mori-Clement \(2019\)](#) also used a difference-in-difference approach and tried to improve the comparability of places that did and not did receive a CDM project through propensity score matching. The spatial unit used was the municipality (whereas, in the present study, it is the micro-region, which is larger). [Mori-Clement \(2019\)](#) found that inequality fell by 2 percent in the municipalities that had a CDM hydroelectric project relative to the municipalities that did not.

Our research builds on all this prior literature in several ways. First, it frames CDM investment activity within the broader literature on the inequality impacts of FDI, and proposes an explicit channel by which FDI may be inequality-reducing. Second, it operationalises the presence and extent of regional CDM project activity in an empirical model more rigorously than prior quantitative studies to our knowledge. Third, it derives from the findings recommendations for concretely including sustainable development outcomes in the design of a post-2020 investment mechanism.

Within this FDI-and-inequality framework, we now turn to the empirical analysis of CDM

project activity in Brazil. The first research question asks how CDM projects have influenced inequality, unemployment and poverty in the places that hosted them. The second question asks how these impacts vary across CDM project types.

## 1.3 Data and methods

### 1.3.1 Empirical context

Brazil has been a major recipient of FDI in the last decades and the largest recipient in South America (Suanes, 2016). World Development Indicators data from the World Bank show that Brazil received approximately USD 278 billion in net FDI during the period 2003 to 2010 in total. During the same period, UNFCCC figures show that the reported total investment volume associated with registered CDM projects in Brazil was approximately USD 7.5 billion. This makes a ratio of 1 to 17.

Brazilian society is also characterised by a high level of income inequality and there are many explanations for this (da Silveira Neto and Azzoni, 2011, Medeiros, 2016). In the context of the current research, it is relevant to point out that much of the FDI to Brazil in the last decade has flowed to the services/tertiary sector. The Central Bank of Brazil reports that in 2005, about 63 percent of all FDI to Brazil by volume went to the services/tertiary sector, while only 3.6 percent went to the primary sector, and the rest to manufacturing (Banco Central do Brasil, 2006). The large proportion of FDI that has gone to the services/tertiary sector could be one reason why some studies have found that recent FDI into Brazil and other countries in the region has tended to increase inequality (Suanes, 2016).

Focusing on Brazil, our empirical approach tests how the level of inequality, unemployment and poverty responded over time to CDM activity. Implicitly, the approach evaluates unemployment reduction as the main channel through which income inequality and poverty might be affected. Any of these outcomes might be affected by the number of jobs created by CDM activity. The approach also tests how the relationship between these outcomes and CDM project activity is moderated by the type of CDM project (biomass, hydro, landfill, methane, wind, other). Although it is not possible to directly observe the skills involved in the jobs created, it is hypothesized that the skills required to do 'CDM jobs' varies by project type. This might mean that only project types

that create low-skill jobs impact the outcomes of interest. This would be the case if unemployment concentrates at the lower end of the skill spectrum, for example.

### 1.3.2 Data

We constructed a panel dataset of small geographic areas. The areas are Brazilian micro-regions, of which there are 558 (also referred to as ‘regions’ from here on), observed once in the year 2000 and once in the year 2010. The dependent variables measuring inequality (Theil index, Theil index for work-derived income, Gini index) and related indicators (percent of individuals economically inactive, percent of individuals in poverty, percent of income derived from work) were obtained from the UNDP’s Human Development Atlas (which uses Brazilian census data).

The independent variable relates to the extent of CDM project activity in each region. In the regressions it is measured by the number of CER credits issued to all projects in the region. To select the projects for this variable, we started with the full record of projects given in the PA and PoA database (which is publicly available on the UN Climate Change Secretariat website – see footnote 1). As of December 2019, there were 760 project records for Brazil. The earliest project appeared in November 2004 and the latest in July 2019. Since the dependent variables are observed in 2000 and 2010 only, we used only the projects where the start date of the first CER credit issuance period was in or before 2010<sup>3</sup>. There were 147 such projects.

Using the start date of the first CER credit issuance period to select projects also maximised the likelihood that the projects included in the independent variable are actual, operational projects (whose effects on the outcomes might be detected), as opposed to project plans<sup>4</sup>. The CDM project approval process works, broadly, as follows. First, a project developer registers a project with the CDM Executive Committee. Then, after an external verification, the CDM Executive Committee decides over multiple review stages if the project satisfies all of the necessary requirements to be issued CER credits, including demonstrating ‘additionality’<sup>5</sup>. Then the CDM Executive Commit-

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3. As a robustness check, we also tested a version of the variable constructed from projects that were *actually issued CER credits* in or before 2010. This is a slightly more restrictive selection criteria, yielding 101 projects. The test results were comparable to the main results as can be seen from Table 1.7 in the appendix.

4. We are grateful to an anonymous reviewer for pointing this out and constructively suggesting remedies that we have adopted here.

5. In order for a CDM project to be issued CER credits, the project developer must demonstrate that the proposed project will result in an ‘additional’ outcome, relative to a counterfactual baseline where the project did not exist (UNFCCC, 2012). Under the Mechanism, the meaning of ‘additionality’ and the methods used to assess it are flexible (Cames, Harthan, Füssler, Lazarus, Lee, Erickson and Spalding-Fecher, 2016). Additionality need not be only ‘environmental’ in the sense of avoided GHG emissions. A project can also fulfil the requirement by demonstrating ‘financial

tee issues CER credits to the project if all of the requirements have been met. Our aim in selecting only the projects that have been issued CER credits is to maximise the likelihood that the variable in the empirical tests is measuring actual on-the-ground project activity.

The PA and PoA database does not provide information on projects' detailed geographic location. This information was obtained from sections A.4.1.3 and A.4.1.4 of each project's Project Design Document (PDD). The municipality or municipalities that the project was located in were recorded and collapsed into micro-regions (there are about 10 municipalities per micro-region)<sup>6</sup>. PDDs are the only source of systematic information about projects' detailed geographic location to the knowledge of the authors. It is fully possible that the actual project design, including its geographic location, expanded or contracted or moved during the credit application process. This is a well-known limitation of PDDs (Crowe, 2013). We treat this as measurement error. The only information obtained from the PDDs is project geographic location; all other data came from the PA and PoA database.

Other independent variables were used to account for nuisance heterogeneity in the regressions. Data on the level of GDP in each region-year were obtained from the Brazilian Institute of Geography and Statistics (IBGE). Data on the level of transfers to each region-year under the Brazilian Federal social welfare programme Bolsa Familia were obtained from the Brazilian Ministry of Social Development (MDS). Data on the stock of FDI in each state-year were obtained from the annual census of foreign investment of the Central Bank of Brazil (the bank does not gather or publish FDI data below the level of the state). The remaining control variables (the percent of the population that is rural, the illiteracy rate, and the electrification rate) come from the same source as the dependent variables, the UNDP's Human Development Atlas.

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additionality' or by demonstrating a combination of both environmental and financial additionality (Paulsson, 2009). Some evidence suggests that the 'additional' outcome claimed by projects might not always be realized, even when the bureaucratic standard for demonstrating additionality is satisfied (Michaelowa and Purohit, 2007). For example, Zhang and Wang (2011) found that the emission reductions associated with CDM projects in Chinese prefectures would have happened anyway. This implies that those reductions cannot be causally attributed to the CDM. Several of the quantitative contributions to the CDM impact literature have remained agnostic on what additionality means for testing causal connections between CDM projects and the claimed outcomes (Du and Takeuchi, 2019, Mori-Clement, 2019, Mori-Clement and Bednar-Friedl, 2019). Additionality is a programme design issue that goes beyond the scope of this research but does bear on the possibility to independently evaluate the effects of the Mechanism, or its successor, econometrically. The limitations implied by additionality for this research are discussed in section 1.5.

6. The main reason for structuring the data as a panel of micro-regions, and not municipalities, was that many projects spread across multiple municipalities. Approximately 39 percent of the projects we examined spread over two or more municipalities, and 12 percent spread over more than five. Collapsing data to the micro-region level minimises the risk of falsely assuming that a CDM project exists in an area when in fact it does not.

### 1.3.3 Descriptive analysis

Table 1.1 and 1.2 describe the dependent and independent variables used in the regressions. There are 1,116 observations for all variables. Descriptive statistics are given as linear values but all of the dependent variables and some of the independent variables are logged in the regressions. All variables vary in dimensions  $t$  (year) and  $i$  (region) except for  $FDI\_state$  which varies by  $t$  and not by region but by state (Brazilian federal units, of which there are 27). The independent variable that tests the effect of CDM project activity on the outcomes of interest is the interaction of  $Year\_2010$  and  $CDM\_credits$ .  $CDM\_credits$  is the number of credits issued to all projects in the region and thus measures both the presence and scale of CDM activity.

TABLE 1.1 – *Dependent variable descriptive statistics*

Variable	Description	Min	Max	Mean
$Theil_{it}$	Theil index of income inequality (scale 0-100)	24.4	93.8	49.9
$Theil\_work_{it}$	Theil index, work-derived income only (scale 0-100)	22.6	87.0	43.7
$Gini_{it}$	Gini index of inequality (scale 0-100)	36.9	71.5	53.0
$Unemployment_{it}$	% of individuals economically inactive	0.9	28.5	8.7
$Poverty_{it}$	% of individuals in poverty	1.0	81.6	31.2
$Income\_work_{it}$	% of income work-derived	44.6	95.5	72.9

Note : 1,116 observations for all variables. In the regressions, all dependent variables are estimated in logs.

The distinction between the Theil and Gini indexes of inequality in 1.1 is worth elaborating. The Theil index measures inequality in the per capita distribution of income in the micro-region and excludes individuals with zero income from the measure. Theil captures how the distribution of income across households differs from the distribution of the population across households. When the distribution of the population across households is the same as the distribution of income, the Theil value is zero (no inequality) (World Bank, 2005). By contrast, the Gini index measures the distribution of income across households in the micro-region only, such that when the income is equally distributed across households, there is no inequality and the value is zero. Thus the main difference is that Gini does not account for the distribution of the population across households.

Figure 1.1 shows the distribution of ordinary FDI across Brazilian states and compares this with the distribution of issued CDM credits for the 147 projects. States which did not have a CDM project are excluded. For the states with a CDM project, the distribution of credits broadly approximates the distribution of ordinary FDI. Figure 1.2 shows the micro-regions that had at least

one CDM project prior to 2010. CDM projects concentrate in the more industrialized south and southeast of Brazil and in the central-west region where agricultural output is strong.

TABLE 1.2 – *Independent variable descriptive statistics*

Variable	Description	Min	Max	Median	Standard Deviation
$Year_{2010_t}$	Year = 2010	0	1	0.5	0.5
$CDM_{credits_{it}}$	# credits issued to CDM projects	0.0	67,699,487.3	236,239.7	2,927,665.9
$CDM_{credits_{biomass_{it}}}$	# credits issued to biomass projects	0.0	2,514,403.0	17,085.0	141,111.6
$CDM_{credits_{hydro_{it}}}$	# credits issued to hydro projects	0.0	1,823,686.5	19,428.3	124,959.7
$CDM_{credits_{landfill_{it}}}$	# credits issued to landfill projects	0.0	10,023,403.0	61,826.6	601,086.3
$CDM_{credits_{methane_{it}}}$	# credits issued to methane projects	0.0	478,609.0	8,151.8	39,474.7
$CDM_{credits_{wind_{it}}}$	# credits issued to wind projects	0.0	292,505.0	614.8	12,557.1
$CDM_{credits_{other_{it}}}$	# credits issued to other projects	0.0	63,118,494.0	129,133.2	2,674,747.1
$GDP_{growth_{it}}$	GDP growth rate from previous year	0.7	16.0	2.6	1.1
$Bolsa_{spending_{it}}$	Bolsa Familia transfers, 000s USD	0.0	23,969.5	808.8	1,414.8
$FDI_{state_{it}}$	Level of FDI in state, 000s USD	188.2	297,126,615.1	31,082,101.7	68,980,448.7
$Population_{it}$	Population	2,629.0	13,793,504	341,842.0	877,681.5
$Rural_{population_{it}}$	% of population rural	0.0	79.3	30.1	17.4
$Illiteracy_{rate_{it}}$	% of population 25 years or older illiterate	3.2	61.5	24.6	13.8
$Electrification_{it}$	% of population in dwellings with electricity	33.8	100.0	91.2	12.5

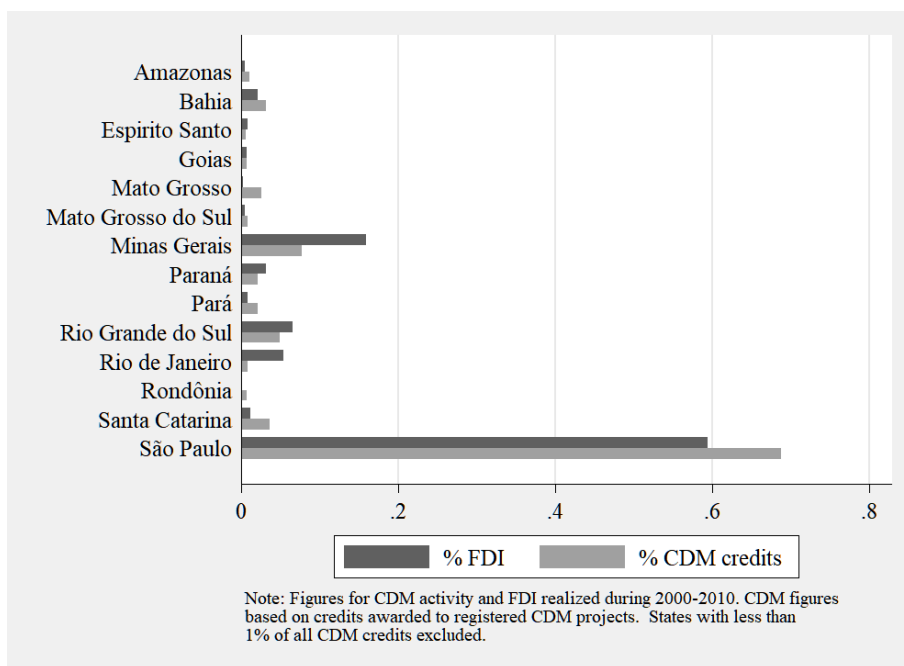
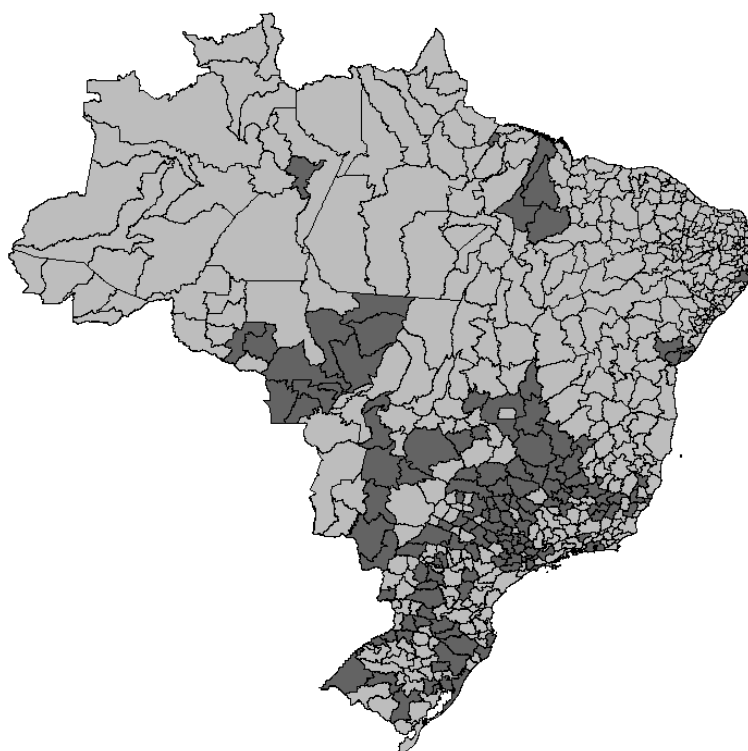


FIGURE 1.1 – Distribution of FDI and CDM credits by Brazilian state



Note : Micro-regions in dark grey received at least one CDM project in or before 2010. The projects in question are only those that were issued CER credits in or before 2010.

FIGURE 1.2 – Distribution of CDM projects across micro-regions

To give a sense of the scale of a CDM project in the context of the economic activity of a micro-region, the mean level of reported investment associated with these CDM projects is USD

30 million. The level of reported investment for the smallest project was USD 58,000 and for the largest USD 406 million. The mean annual GDP for the average micro-region was about USD 1.2 billion. Thus, the average CDM project amounts to around 2.5 percent of the average micro-region's GDP. Of the 558 micro-regions, 158 (28.3 percent) had a CDM project (or part of one, since some projects spread across several regions) by 2010.

On a project-count basis, 27.8 percent of the CDM projects included in the independent variables are categorized in the PA and PoA database as methane avoidance projects (3.4 percent of CER credits), 23.8 percent as biomass energy projects (7.2 percent of CER credits), 21.1 percent as hydro projects (8.2 percent of CER credits), 14.3 percent as landfill projects (26.1 percent of CER credits), and the rest as related to fossil fuel switching, N<sub>2</sub>O, wind, reforestation and other activities. Also at project-level, the simple correlation coefficient between log CER credits issued and log capital investment is 0.11. This figure pertains only to the 83 projects with capital investment data (for the other 64 projects, the data are missing).

#### 1.3.4 Regression model

The research design compares the change in the level of the dependent variable in the regions that had a CDM project to the same in the regions that did not. This difference-in-difference (DD) approach is well suited to policy evaluation research because it compares outcomes between a treated group and a control group over time in a non-experimental setting using observational data (Khandker et al. (2010), Wooldridge (2012), also see Du and Takeuchi (2019) and Mori-Clement (2019) for DD applications in this specific policy context). The test is operationalized in the following empirical model,

$$Theil_{it} = \alpha + \beta_1(CDM\_credits_i \times Year\_2010_t) + \beta_2(CDM\_credits_i) + \beta_3(Year\_2010_t) + X_{it} + \epsilon_{it} \quad (1.1)$$

where subscript  $i$  denotes the regions and  $t$  denotes the years 2000 and 2010.  $Theil$  is the Theil index measuring the level of inequality in the region-year (or one of the other five dependent variables).  $CDM\_credits$  is the number of credits issued to all projects in the region<sup>7</sup>.  $Year_{2010}$

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7. Five other measures of the extent of CDM project activity were also tested : the level of investment, the number of megawatts installed, the quantity of GHG reductions claimed, the number of fractional projects, and the binary presence of a project. The number of CER credits issued was chosen because it is a continuous and so more granular measure, because it has no missing values, and because it is most likely to reflect real material projects on the ground (in the



is a dummy variable that takes a value of 1 for the year 2010, the post-treatment period, and 0 otherwise.

We are interested in coefficient  $\beta_1$  on the interaction of those variables. Coefficient  $\beta_1$  estimates how the level of inequality in the areas that had CDM project activity changed between 2000 and 2010, relative to the same in the control group.  $\alpha$  is a constant,  $X$  denotes control variables, and  $\varepsilon$  is an error term. The *CDM\_credits* variable is logged in all estimations, and since all dependent variables are also logged in all estimations, coefficient  $\beta_1$  can be interpreted as an elasticity, e.g. the predicted average percentage change in the level of the dependent variable for a 1 percent change in the number of credits. This same interpretation pertains to the second set of tests of the effect of project type. In those tests, six separate *CDM\_credits* variables are included, each measuring the number of credits issued to CDM projects of each type in the region (*CDM\_credits\_biomass* for example). Each is separately interacted with *Year\_2010*.

One issue that could bias the result of our experiment design is endogenous treatment assignment. This relates to the process by which CDM projects locate in regions. The location of projects in regions is likely to be non-random. Non-random location is a problem if unobserved factors exist that affect both the location of projects and the outcome variable. For example, rapid economic growth in an area could affect the level of inequality but also signal to project developers an attractive investment opportunity (if more counter-factual emissions results in more CERs being issued to the project for example).

The DD approach mitigates this problem by comparing the change in the outcome in treated areas to the same in control areas, thus estimating the CDM effect relative to an untreated control group. We include seven time-varying controls to account for factors that could associate with both the outcome variable and the location of CDM projects.

First, Brazil experienced rapid economic growth for much of the 2000-2010 period. Depending on who these gains accrued to and in which areas, the control and treatment group areas might have been differently affected. The growth in the level of GDP in each area-year accounts for this.

Second, the elected government in Brazil during the period consolidated various federal social welfare programmes and increased spending under them (Schwartzman, 2003). Among the most significant was the *Bolsa Familia* which made small transfers to qualifying poor families (Wetzel, 2013). The level of spending in each area-year under the *Bolsa Familia* programme accounts for

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sense of the discussion in section 1.3.2.

this factor<sup>8</sup>.

Third, general FDI that had little to do with CDM could have differently affected inequality levels over time in the control and treatment groups. The Central Bank of Brazil does not report FDI figures for geographic units smaller than Federal units (state). The stock of FDI in each state, in 2000 and 2010, accounts for this.

Fourth, CDM project developers might have favoured regions where the population was growing, since these regions would also have had high expected emissions growth, all else being equal. Higher expected emissions growth could mean a larger volume of abatable emissions and so the possibility for more reductions to be achieved and CERs to be issued. The population level in each area-year is included.

Fifth, two additional variables were added reflecting the socioeconomic character of the regions, namely the illiteracy rate for individuals 25 years or older, and the percent of the population in the region residing in rural areas.

Sixth, another large policy initiative during the period was the Federal government-led *Luz para todos* ('Light for All') rural electrification programme. The effect of the programme is accounted for by a variable measuring the percent of the population living in a dwelling with electricity.

Finally, some DD designs include individual fixed effects to account for the time-invariant characteristics of individuals, in this case regions (Lechner, Rodriguez-Planas and Fernández Kranz, 2016). We do not include individual fixed effects in the main estimates for two reasons (although we include them in the robustness checks). First, the main threat to the validity of the test design is omitted factors that are time-varying and we are able to account for these with the control variables above. Second, the fact that DD compares the difference in groups over two time periods can be seen as equivalent to first-differencing the outcome variable, which achieves the same result as estimating the model with individual fixed effects.

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8. The earliest year Bolsa data were available for was 2004. We used the 2004 data for *Bolsa Familia* as a proxy for the level of social welfare support in each area in the year 2000.

## 1.4 Results

Table 1.3 shows the first set of results, which test the effect of CDM project activity in general. These estimates imply that a 1 percent increase in the number of CERs issued associates with a decrease in the level of Theil inequality in CDM regions of approximately 1.1 percent on average, compared to regions with zero credits (projects). A similar effect in magnitude and direction is found for the other inequality indicators *Theil\_work* and *Gini*, although the magnitude of *Gini* is substantially smaller (see the explanation for the differences between the two inequality measures in section 1.3.3). The results in Table 1.3 also imply that a 1 percent increase in the number of credits associates with a 1.3 percent decrease in *Unemployment* in CDM regions on average, and a 2.2 percent decrease in *Poverty* in CDM regions on average. No significant impact is found on *Income\_work*, the proportion of income derived from work.

TABLE 1.3 – General results

	<b>Theil</b>	<b>Theil_work</b>	<b>Gini</b>	<b>Unemployment</b>	<b>Poverty</b>	<b>Income_work</b>
<i>CDM_credits</i> ×	-0.011*** (-6.01)	-0.012*** (-5.82)	-0.004*** (-4.51)	-0.013*** (-3.41)	-0.022*** (-5.81)	-0.000 (-0.18)
<i>Year_2010</i>						
<i>CDM_credits</i>	0.006*** (3.86)	0.007*** (4.14)	0.002** (3.22)	0.005 (1.70)	0.006* (2.49)	0.003*** (4.70)
<i>Year_2010</i>	-0.189*** (-7.69)	-0.237*** (-8.42)	-0.115*** (-10.23)	-0.631*** (-10.88)	-0.960*** (-19.72)	-0.023 (-1.90)
<i>GDP_growth</i>	0.004 (0.97)	-0.009 (-1.73)	0.002 (1.02)	0.046** (5.06)	0.019* (2.43)	0.009*** (4.20)
<i>Bolsa_spending</i>	0.113*** (6.59)	0.053** (2.62)	0.050*** (6.41)	0.239*** (5.21)	0.539*** (14.66)	-0.073*** (-8.84)
<i>FDI_state</i>	-0.021*** (-7.08)	-0.014*** (-5.01)	-0.010*** (-7.01)	0.023*** (3.77)	-0.040*** (-8.87)	-0.012*** (-9.48)
<i>Population</i>	-0.106*** (-5.64)	-0.039 (-1.76)	-0.050*** (-5.76)	-0.259*** (-5.46)	-0.459*** (-11.84)	0.062*** (6.78)
<i>Rural_population</i>	-0.005 (-0.59)	0.050*** (5.28)	-0.005 (-1.27)	-0.341*** (-13.78)	0.093*** (5.48)	-0.003 (-0.70)
<i>Illiteracy_rate</i>	-0.025 (-1.31)	-0.037 (-1.72)	-0.005 (-0.61)	0.280*** (6.50)	0.414*** (10.98)	-0.103*** (-11.20)
<i>Electrification</i>	-0.116** (-3.09)	0.116** (2.73)	-0.164*** (-7.94)	0.077 (0.75)	-0.201** (-3.03)	-0.194*** (-8.05)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
R2	0.40	0.34	0.56	0.53	0.89	0.59
AIC	-1086.8	-794.1	-2800.0	741.4	337.5	-2273.5
DV mean	3.89	3.76	3.96	2.12	3.23	4.26

Note : All dependent variables are in logs. All independent variables are in logs except Year\_2010 and GDP\_growth. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant omitted for presentation.

Table 1.4 shows the second set of estimates. These pertain to the moderating effect of CDM project type on the same outcomes. The first set of results shows the estimates for all of the control variables, for explicitness, but these are omitted from Table 4 for presentational purposes (they remain in the underlying models). The estimates for the project type-specific model imply that methane, hydro, and to a lesser extent biomass projects associate with reduced inequality. For example, a 1 percent increase in methane project credits associates with an average decrease in *Theil* of 1.2 percent, an average decrease in *Theil\_work* of 1.3 percent, and an average decrease in *Gini* of 0.04 percent. Methane projects also associate significantly with a reduction in Poverty, biomass projects with a reduction in Unemployment and Poverty, and hydro projects with a reduction in Poverty. There is also some evidence that wind projects associate with a reduction in Unemployment and a decrease in *Income\_work* (opposite to the direction expected).

TABLE 1.4 – Project type-specific results

	Theil	Theil_work	Gini	Unemployment	Poverty	Income_work
<i>CDM_credits_biomass</i> × <i>Year_2010</i>	-0.006 (-1.75)	-0.007* (-2.09)	-0.002 (-1.53)	-0.014* (-2.50)	-0.016* (-2.08)	0.000 (0.25)
<i>CDM_credits_hydro</i> × <i>Year_2010</i>	-0.008* (-2.39)	-0.008* (-2.10)	-0.003 (-1.84)	-0.003 (-0.41)	-0.016* (-2.49)	-0.000 (-0.13)
<i>CDM_credits_land_fill</i> × <i>Year_2010</i>	-0.001 (-0.35)	-0.001 (-0.20)	0.001 (0.42)	-0.020 (-1.87)	-0.005 (-0.47)	0.002 (0.94)
<i>CDM_credits_methane</i> × <i>Year_2010</i>	-0.012*** (-5.35)	-0.013*** (-4.80)	-0.004*** (-4.08)	-0.008 (-1.59)	-0.021*** (-4.23)	-0.000 (-0.36)
<i>CDM_credits_wind</i> × <i>Year_2010</i>	0.001 (0.26)	-0.000 (-0.06)	0.000 (0.24)	-0.021* (-2.17)	-0.004 (-0.30)	-0.005*** (-3.48)
<i>CDM_credits_other</i> × <i>Year_2010</i>	-0.001 (-0.34)	-0.002 (-0.50)	-0.000 (-0.30)	-0.003 (-0.42)	-0.006 (-0.73)	-0.001 (-0.54)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
R2	0.41	0.35	0.56	0.54	0.89	0.60
AIC	-1081.5	-789.2	-2792.2	753.5	342.0	-2264.7
DV mean	3.89	3.76	3.96	2.12	3.23	4.26

Note : All dependent variables are in logs. All independent variables are in logs except *Year\_2010* and *GDP\_growth*. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant omitted for presentation.

Various additional checks were performed on these results. First, we examined the assumption, implicit until now, that each of the six outcomes can be reliably estimated by separate, independent equations. If the outcomes are not independent, then the errors across equations may be correlated (Zellner, 1962). This might be the case, for example, if an exchange rate shock altered remittance flows to Brazil in a way that changed inequality, unemployment and poverty levels simultaneously. As a robustness check, we estimated the six equations as a system using seemingly unrelated regression (SUR). SUR assumes that the errors of the individual equations are correlated and so improves the efficiency of the estimates relative to ordinary least squares (OLS) regression. Under SUR, the coefficient estimates are exactly the same as those under OLS (because the independent variables are the same across all six equations (Wooldridge, 2010)). The standard errors on the test variable increased in 5 out of the 6 equations under SUR, but so minimally (third decimal place or smaller) that we deemed them all but equivalent to the OLS estimates.

Second, we tried to improve the comparability of the regions in the control group to those in the treated group. We did this by dropping all regions in the states that did not receive a single CDM project (10 states, 230 regions) on the assumption that regions within states are more similar to each other than regions between states. In these tests, the magnitude of the coefficients diminish in all cases relative to the baseline estimates in Table 3, yet all remain statistically significant. We also tried improving control group comparability in a different way. This was by randomly selecting an equally-sized sample of regions from the untreated group. In these tests, the estimated magnitudes also shrink but the overall results are similar to Table 1.3. The results of these control group comparability tests for *Theil*, *Gini*, and *Poverty* are shown in the appendix.

Third, we tested the assumption that the outcome for the treated and control regions would have continued in parallel in the absence of the treatment, the parallel trends assumption (Wing, Simon and Bello-Gomez, 2018). We extended the panel backwards in time to include the year 1991, using census data for that year. We supposed that the same regions that had a CDM project during the 2004-2010 period had a project during the 1991-2000 period. They did not, but that is the point of the test. A significant coefficient on the interaction in this placebo test would indicate that something other than the treatment variable is influencing the outcome in the true test. Data were only available for *Theil*, *Gini*, and *Poverty* for the year 1991. Further, we had no data for *GDP\_growth*, *FDI\_state*, and *Bolsa\_spending* for 1991 so those controls could not be included. In their place, we ran the same tests with region fixed effects. Five of the six specifications (see appendix) produce no evidence contradicting the main results reported above. The only exception

is the *Gini* specification. That estimate implies that something other than CDM project activity reduced Gini inequality in the regions where CDM projects later appeared.

Fourth, we examined the decision to include only those CDM projects whose first credit issuance period began before or during 2010. The cut-off date of December 31, 2010 might exclude some projects that impacted the outcomes of interest. This would be the case if a project reduced unemployment in the construction phase during 2010, but only began to receive CER credits in 2011. To test this, we selected projects whose CER credit issuance period began before or during 2011 (154 projects) and before or during 2012 (169 projects), then re-ran the model. The results are given in Tables [1.8](#) and [1.9](#) in the appendix. They are very similar to the main results in Table [1.3](#).



## 1.5 Discussion and conclusions

We find evidence that CDM project activity drove reductions in inequality, poverty and unemployment in Brazilian regions from 2000 to 2010, relative to Brazilian regions where no CDM projects were present. This result generally satisfies multiple robustness checks. We also find that methane, hydro and to a lesser extent biomass projects drove these reductions in particular, whereas wind, landfill and other project types did not. These findings are consistent with some prior research that has found that CDM project activity facilitates sustainable development gains (Du and Takeuchi, 2019, Mori-Clement, 2019, Sutter and Parreño, 2007) but inconsistent with other studies that have found limited or no impact on such outcomes (Crowe, 2013, Mori-Clement and Bednar-Friedl, 2019, Zhang and Wang, 2011).

We interpret these results in terms of the FDI framework established in section 1.2. CDM project investment is a form of FDI or is closely related to it. General FDI that is sector-unspecific is expected to reduce unemployment and associated outcomes by creating demand for labour, and so, new jobs. However, FDI that flows specifically into primary and secondary sector activities does more to reduce unemployment than that which flows into tertiary sector activities, because it creates demand for low- and medium-skilled labour, and the workers suited to fill those jobs typically made up the unemployed part of the workforce prior to the arrival of the investment. Tertiary sector FDI by contrast creates demand for high-skilled workers, but does less to reduce unemployment because high-skilled workers tend to already have jobs. From this framework flows the inference that because methane, hydro, and biomass CDM projects reduced unemployment, they should have involved primary and secondary sector investment activities.

A caveat to this interpretation, and a limitation of our study, is that we were not able to systematically classify CDM projects in terms of economic sector or skill content from the available data. Obtaining such data and testing this idea explicitly would be a worthy direction for future research. Another limitation concerns the uncertainties that the additionality principle and its implementation in the CDM project approval process create for the generation of CDM project data (see footnote 5 in section 1.3.2). We took extensive measures to select project records that capture real, on-the-ground project activity, but the administrative process behind the creation of the data was beyond our control.

## 1.6 Conclusions and policy implications

As governments continue to work towards a post-2020 agreement on international mitigation investment, developing country governments will be especially interested in ensuring that the agreement delivers real sustainable development outcomes of the kind studied here. The concerns of these governments could be partly addressed by incorporating concrete measures of unemployment, inequality, and poverty into the negotiation process and into the final text of the rulebook that implements a post-2020 mechanism. Stipulating new measurement and reporting rules for sustainable development outcomes would provide greater assurance that progress will be made on them. The text of the rulebook could require project developers and the CDM Executive Committee (or its replacement, or successor, as applicable) to report project activity in terms of a) economic sector, b) full-time equivalent jobs created, and c) the skill level of the jobs – and do so for all three, in line with a recognized economic activity classification system.

Should governments wish to go further than measurement and reporting, these metrics could further be used to broaden the incentives that project developers have to participate in a post-2020 mechanism. From the point of view of the climate, it does not matter whether a ton of GHG reduction occurs through a landfill project or a methane avoidance project. From the point of view of unemployment, inequality and poverty outcomes, it does matter, according to our findings. A post-2020 agreement that included systematic measurement, reporting, and verification procedures for those outcomes would set the stage for providing project developers with economic incentives to prioritize projects that advanced those outcomes. Such incentives would complement and not substitute for existing mitigation incentives. Such a provision in the post-2020 rulebook could be appealing to both developing and developed countries. It would also align the sustainable development language that all governments agreed to in past high-level agreements, with concrete incentives for delivering that aspiration.

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## 1.7 Appendix A : Supplemental regressions

TABLE 1.5 – Control group comparability regressions

	<b>Theil</b>	<b>Gini</b>	<b>Poverty</b>	<b>Theil</b>	<b>Gini</b>	<b>Poverty</b>
<i>CDM_credits</i> × <i>Year_2010</i>	-0.007*** (-3.83)	-0.003** (-3.17)	-0.016*** (-4.13)	-0.008*** (-3.62)	-0.003** (-2.99)	-0.018*** (-3.92)
<i>CDM_credits</i>	0.004** (2.89)	0.002** (2.74)	0.004 (1.46)	0.005** (2.71)	0.002* (2.44)	0.006* (2.02)
<i>Year_2010</i>	-0.241*** (-8.73)	-0.130*** (-10.15)	-1.079*** (-19.76)	-0.225*** (-5.84)	-0.130*** (-7.38)	-1.050*** (-14.28)
Observations	886	886	886	544	544	544
R2	0.43	0.57	0.89	0.43	0.58	0.89
AIC	-883.1	-2249.7	329.6	-541.6	-1407.6	191.4
DV mean	3.87	3.95	3.06	3.86	3.94	2.96

*Note* : All dependent variables are in logs. All independent variables are in logs except *Year\_2010* and *GDP\_growth*. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant and control variable estimates omitted for presentation. First three models exclude all regions in the states that did not have a single CDM project. Second three models use a randomly-selected sample of regions without a CDM project as the control group.

TABLE 1.6 – *Placebo test results*

	<b>Theil</b>	<b>Gini</b>	<b>Poverty</b>	<b>Theil</b>	<b>Gini</b>	<b>Poverty</b>
<i>CDM_credits</i> × <i>Year_2000</i>	-0.003 (-1.81)	-0.003*** (-3.46)	-0.002 (-0.47)	0.000 (0.16)	-0.000 (-0.11)	0.003 (1.25)
<i>CDM_credits</i>	0.002 (1.13)	0.001* (2.23)	-0.008* (-2.50)			
<i>Year_2000</i>	0.081*** (6.87)	0.071*** (12.01)	-0.067*** (-3.60)	0.101* (2.44)	0.083*** (3.63)	-0.074 (-1.59)
Obs.	1,116	1,116	1,115	1,116	1,116	1115
R2	0.071	0.18	0.81	0.27	0.44	0.81
AIC	-1078.2	-2651.3	158.8	-2740.5	-4288.2	-2119.0
Micro-region FE	N	N	N	Y	Y	Y

*Note : Placebo tests - same treated regions, ‘treatment period’ is 2000, pre-treatment period is 1991. All dependent variables are in logs. All independent variables are in logs except Year\_2000. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant and control variable coefficients omitted for presentation.*

TABLE 1.7 – *CDM projects selected by first credit issuance (101 projects only)*

	<b>Theil</b>	<b>Theil_work</b>	<b>Gini</b>	<b>Unemployment</b>	<b>Poverty</b>	<b>Income_work</b>
<i>CDM_credits</i> × <i>Year_2010</i>	-0.011*** (-6.05)	-0.012*** (-5.97)	-0.004*** (-4.48)	-0.013*** (-3.39)	-0.022*** (-5.80)	0.000 (0.10)
<i>CDM_credits</i>	0.006*** (3.99)	0.007*** (4.21)	0.002*** (3.42)	0.005 (1.82)	0.008*** (3.33)	0.003*** (4.35)
<i>Year_2010</i>	-0.188*** (-7.67)	-0.236*** (-8.39)	-0.115*** (-10.22)	-0.631*** (-10.90)	-0.958*** (-19.74)	-0.024* (-2.01)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
R2	0.40	0.34	0.56	0.53	0.89	0.59
AIC	-1087.3	-795.3	-2800.3	741.9	340.3	-2271.7
DV mean	3.89	3.76	3.96	2.12	3.23	4.26

*Note : All dependent variables are in logs. All independent variables are in logs except Year\_2010 and GDP\_growth. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant omitted for presentation. CDM\_credits variable is constructed from only those projects that were actually issued credits before or during 2010 (101 projects rather than 147 in main results).*

TABLE 1.8 – CDM projects selected by credit issuance period starting before or during 2011 (154 projects)

	Theil	Theil_work	Gini	Unemployment	Poverty	Income_work
<i>CDM_credits</i> × <i>Year_2010</i>	-0.011*** (-6.05)	-0.012*** (-5.97)	-0.004*** (-4.48)	-0.013*** (-3.39)	-0.022*** (-5.80)	0.000 (0.10)
<i>CDM_credits</i>	0.006*** (3.99)	0.007*** (4.21)	0.002*** (3.42)	0.005 (1.82)	0.008*** (3.33)	0.003*** (4.35)
<i>Year_2010</i>	-0.188*** (-7.67)	-0.236*** (-8.39)	-0.115*** (-10.22)	-0.631*** (-10.90)	-0.958*** (-19.74)	-0.024* (-2.01)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
R2	0.40	0.34	0.56	0.53	0.89	0.59
AIC	-1087.3	-795.3	-2800.3	741.9	340.3	-2271.7
DV mean	3.89	3.76	3.96	2.12	3.23	4.26

Note : All dependent variables are in logs. All independent variables are in logs except *Year\_2010* and *GDP\_growth*. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant omitted for presentation. *CDM\_credits* variable includes projects with a crediting period starting before or during 2011.

TABLE 1.9 – CDM projects selected by credit issuance period starting before or during 2012 (169 projects)

	Theil	Theil_work	Gini	Unemployment	Poverty	Income_work
<i>CDM_credits</i> × <i>Year_2010</i>	-0.011*** (-6.17)	-0.012*** (-6.12)	-0.004*** (-4.79)	-0.014*** (-3.93)	-0.022*** (-6.05)	0.000 (0.18)
<i>CDM_credits</i>	0.006*** (4.21)	0.007*** (4.41)	0.002*** (3.85)	0.005 (1.86)	0.009*** (3.96)	0.003*** (4.43)
<i>Year_2010</i>	-0.187*** (-7.60)	-0.233*** (-8.30)	-0.114*** (-10.12)	-0.623*** (-10.78)	-0.954*** (-19.77)	-0.024* (-2.04)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
R2	0.40	0.35	0.56	0.54	0.89	0.59
AIC	-1089.6	-799.6	-2803.3	738.1	339.3	-2273.0
DV mean	3.89	3.76	3.96	2.12	3.23	4.26

Note : All dependent variables are in logs. All independent variables are in logs except *Year\_2010* and *GDP\_growth*. Estimation by OLS. T-scores in parentheses. Heteroskedasticity-robust errors. Constant omitted for presentation. *CDM\_credits* variable includes projects with a crediting period starting before or during 2012.





# 2

Local economic development through clean  
electricity generation—an analysis for Brazil and a  
staggered difference-in-difference approach



## Abstract

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*Adaptation of energy systems worldwide to move away from fossil fuels is widely accepted to be a key step in responding to the challenge of climate change. For developing countries and their development banks, this challenge is compounded by the need to ensure economic development, particularly to lift parts of the population out of poverty. In this article, we analyse the economic impacts of electricity generation projects of the Brazilian national development bank. We use a two-way fixed-effects (TWFE) estimator on a 15-year municipality-level panel with time-varying (or ‘staggered’) treatment that accounts for recent findings in the panel data analysis literature. Our study finds that electricity generation investment has weaker economic effects compared to non-electricity generation investment, and that clean electricity generation projects have smaller effects on GDP per capita and employment levels than electricity generation projects in general, while having a slightly higher effect on mean wage levels. This differentiated impact is particularly notable when it comes to the impact of investment on employment creation. This is the first study that uses microdata to analyse the different economic impacts of different types of electricity generation projects at the local level. We posit that differences in labour intensities of clean electricity generation jobs and other types of development bank investment account for these different impacts of project investments. We recommend that the cost of externalities of these projects be internalised in order for development banks and policymakers to get a fuller picture of the benefits brought about by them. Smaller economic impacts of certain development bank investments might also have negative implications for poverty reduction efforts in the country.*

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## Summary

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## 2.1 Introduction

Ever since the adoption of the Kyoto protocol in 1997, and even more so since the adoption of the Paris accord in 2015, developing countries have had to formally deal with two challenges at the same time : economic development and greenhouse gas emissions mitigation. Bringing about economic development is essential for these countries, particularly as a means to lift the population out of poverty (Dollar and Kraay, 2002), yet these countries also have a large stake in reducing CO2 emissions, not only because their emissions are rising more rapidly than those of developed countries, but also because poorer populations are much more susceptible to the effects of climate change (Dell, Jones and Olken, 2012). Do these two challenges form a synergy or a trade-off? There is a rich literature that uses models to explore both perspectives (see Köberle et al., 2021, Mathiesen et al., 2011, Scherer et al., 2018), but there is a dearth of empirical studies that use microeconomic data to analyse the interactions between these two challenges. Using microeconomic data from Brazil, in this article, we present an econometric analysis of the local economic development impacts of clean electricity generation investment, a key element in climate change mitigation, and compare these impacts to those of electricity generation investment in general, as well as other development investments. This debate in scholarly literature also extends to the policy space, most visibly in international climate negotiations where the development needs of developing countries are frequently contrasted against the need for long term greenhouse gas emissions reductions, a crucial component of which involves a transition to clean electricity production.

In this article, we combine long-term data (2003 to 2017) of the investments of Brazil's national development bank (BNDES), with municipality-level data from the annual labour report (RAIS) to analyse the broader impacts of clean electricity generation, fossil electricity generation, and non-electricity-generation projects on GDP per capita, employment levels, and wage levels in Brazilian municipalities.

We use a two-way fixed effects (TWFE) estimator on panel data with 'staggered' treatment timing to estimate the aggregate and dynamic effects of clean electricity generation, fossil electricity generation, and other development projects on three indicators of economic development : GDP per capita levels, employment levels, and wage levels in the municipality where they are located. Since the potential of reverse causality in similar econometric models has been pointed out in the literature, we use a propensity score and an Inverse Probability Weighting (IPW) to improve the comparability between municipalities, to minimise time-dependent endogeneity that might lead to

reverse causality concerns. Recent discussions around panel data analysis with varying treatment periods (also called ‘staggered’ treatment panels) have been considered and methods suggested in the literature have been used as robustness checks (see [Goodman-Bacon, 2018](#)). To our knowledge, this is the first article in the literature on policy impact assessment to take into account these concerns relating to staggered treatments.

Empirically, we consider the case of Brazil, where its national development bank (Banco Nacional de Desenvolvimento Econômico e Social, BNDES) has played an important role in spurring infrastructure development projects in the absence of private capital investments ([Hanley et al., 2016](#)). In this article, we link the Bank’s activities from 2003 to 2017 with the agenda of sustainable development, looking into its electricity generation (clean and fossil) investments and their impacts on per capita GDP levels, employment levels, and wage levels. Current literature that has dealt with impacts of the bank’s projects on employment creation has focused on its overall impact without distinguishing the types of projects ([Pereira, 2007](#), [Reiff, dos Santos and Rocha, 2007](#), [Torres Filho and Puga, 2006](#)), or has dealt with productivity impacts ([Coelho and de Negri, 2011](#)), or has focused on impacts on investment ([Barboza and Vasconcelos, 2019](#)). However, with electricity generation projects accounting for nearly 20 percent of all BNDES investments in the period 2003-2017 (amounting to 91 billion Reais or 37.6 billion USD<sup>1</sup>), the impact of these projects on economic outcomes merit our attention.

As a signatory to both the Kyoto Protocol and the Paris Accord, the country has had to take steps to restructure its electricity generation and consumption patterns to reduce its overall carbon emissions ([Santos et al., 2017](#)). These environment-and-development debates in Brazil frequently focus on deforestation. The present research relates to deforestation in two ways. First, it assesses the economic impact of energy alternatives to potentially unnecessarily destructive methods of harvesting biomass for energy. Second, it considers the extent to which BNDES investments deliver wage and employment gains at all, which themselves should reduce the deforestation rate in forested municipalities to the extent that poverty drives many of the irregular economic activities that in turn drive deforestation. Over the 20th century, Brazil was known for chronically high levels of poverty and income inequality. By integrating the narratives of economic development and the necessity of electricity generation projects to be more climate-conscious, this article also contributes to the literature of sustainable development impacts of clean electricity generation investments as

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1. Since the Brazilian Real has been very volatile with respect to the US Dollar between 2003 and 2017, an average exchange rate of 1 USD = 2.4188 BRL has been used throughout this article wherever a conversion is presented.

well as those of development bank activities.

The remainder of the article is organised as follows : section 2.2 presents in more detail a literature review of the broader macroeconomic literature and the impact assessment literature, section 2.3 sets the empirical context, with a presentation of the data and descriptive statistics, section 2.4 describes the model and the approach used to treat econometric issues, and section 2.5 interprets the results. The article concludes with a discussion and a presentation of the conclusions in section 2.6.

## 2.2 Literature review

A broad literature in macroeconomics attests to the general positive relationship between infrastructure development and public investment with output (or GDP) elasticity and employment (Abiad, Furceri and Topalova, 2016, Romp and de Haan, 2007), starting from the work of Aschauer (1989) (see Bom and Ligthart (2014) for a review). Some studies do not differentiate between types of infrastructure investment, such as Calderón and Servén (2008) who find a positive impact of infrastructure investment on GDP growth in sub-saharan Africa. Other studies using quasi-experimental methods have focused on evaluating the impacts of specific types of infrastructure investment (usually transport sector or telecommunications sector investment) and have looked at their impacts on various development-related outcome variables. Chandra and Thompson (2000), for instance find a positive impact of interstate highway construction in the US on the level of economic activity at the county level. Similarly, Banerjee, Duflo and Qian (2012) find a moderate positive causal effect of access to transportation on GDP per capita levels. When it comes to analysing energy sector investments, a significant portion of the literature focuses on analysing the impact of rural electrification on development indicators in developing countries (see, for instance, Bensch, Kluge and Peters (2011), Bernard (2012), van de Walle, Ravallion, Mendiratta and Koolwal (2015), and a meta-evaluation of the World Bank's own rural electrification projects (IEG World Bank, 2008)). This literature, however, focuses on expanding electricity access, which is related to access to the electricity distribution network (and might not necessarily involve electricity generation investments). Our present study, however, while still positioned in the impact evalua-

tion literature, looks at electricity generation projects and their impacts on GDP per capita levels, employment levels, and wage levels.

The studies closest to ours would have to be those that use quasi-experimental methods to analyse the impacts of infrastructure investments in Brazil (including other studies that analyse the impacts of BNDES investment). Some studies that have dealt with the impacts of Clean Development Mechanism (CDM) projects on sustainable development outcomes in Brazil have shown poverty-reducing and employment generation impacts of clean electricity generation investments, but do not make a comparison of those projects with fossil energy generation projects or non-electricity-generation projects (Grover and Rao, 2020, Mori-Clement, 2019, Mori-Clement and Bednar-Friedl, 2019).

Reiff et al. (2007), publishing in the BNDES journal, use municipal level data and show that BNDES investment did generate employment between 2000 and 2005, in line with similar findings for investments before 2000. This finding should not be surprising, given the high volume of investment. Using data at the municipal level, and a fixed-effects estimator, they estimate around a 0.01 percent increase in formal employment levels for each percentage increase in bank investment. Torres Filho and Puga (2006) and Pereira (2007) show that those enterprises that received BNDES funding generated more employment than those that did not receive BNDES support, and with higher wages. Their article, however, lacked the presentation of a full model (including the specific methods used to control for selection bias), and their conclusions might need to be treated with some caution.

de Sousa (2009) finds no signs of impact of BNDES actions on firms' productivity. Coelho and de Negri (2011) observe that BNDES financing positively affected the growth rates of total factor productivity, labour productivity, the number of employees, and net sales. Moreover, the firms that most benefited from BNDES financing were those with high total factor productivity. Frischtak et al. (2017) also hold that increases in BNDES investment tend to boost economic output and contend that it lowers inequality in the medium term. In an evaluation of 31 large industrial projects of the BNDES on employment and GDP per capita and their agglomeration spillover effects, Sant'Anna and Zhao (2020), using a fixed effects model with synthetic controls, demonstrate that large projects did have a significant impact (of up to a 10 percent increase) on both these variables.

There has also been some uncertainty cast on previous results in the literature showing employment creation by BNDES investments, particularly those results that appear in BNDES-produced journals. [Hanley, Pires, de Souza, Marcondes, de Faria and Sakurai \(2016\)](#) offer a sober and uncertain view of the future of the bank, in light of corruption scandals and the economic and political crisis in the country, and underscore the need for external analyses of BNDES projects and their impacts. Few econometric studies, with the exception of recent studies by [Martini et al. \(2019\)](#) and [Sant'Anna and Zhao \(2020\)](#) also take into account time-dependent endogeneity issues that might arise due to the projects' locations.

Missing from the literature is a specific insight into electricity generation projects of the Bank, as well as their impacts on employment and wage levels. To address this empirical gap, in this article we study the impact of BNDES investments in electricity generation projects on per-capita GDP levels, on employment levels, and on wage levels, specifically looking into the effects that clean electricity generation investments have compared to electricity generation investments in general, and to other development investments of the bank.

There is a part of the macroeconomics literature that has looked into the different economic impacts of clean electricity generation and fossil electricity generation. This literature suggests that while there is a correlation between energy consumption (regardless of type) and economic growth, there is also evidence to suggest that different types of energy sources might have different impacts ([Apergis and Payne, 2012](#), [Ohler and Fetters, 2014](#)). It is also not clear whether investment in clean electricity generation results in net employment creation or destruction (or neither). While some studies report a net positive economic impact ([Bulavskaya and Reynès, 2018](#), [Caldés, Varela, Santamaría and Sáez, 2009](#)), other studies have been more circumspect ([Fron del, Ritter, Schmidt and Vance, 2010](#), [Lehr, Lutz and Edler, 2012](#)). It has been noted that net employment benefits depend on factors such as origin of the equipment (domestically manufactured or imported) ([Cai, Cusumano, Lorenzoni and Pontoni, 2017](#)), and that employment benefits differ between electricity generation technologies due to different labour requirements at different project phases (construction, operation and maintenance) ([Tourkolias and Mirasgedis, 2011](#)). There is therefore reason to hypothesise that the economic and employment creation impacts of clean electricity generation and fossil electricity generation might be different. We can expect this difference because these two types of investment might require different labour intensities that in turn affect the local labour markets differently.

## 2.3 Data and descriptive statistics

Project-level data were obtained from the BNDES for the period 2003 to 2019, with information about the nature of the project, the location of the project (at municipality-level), the funding instrument used, the date of commencement of the project, and the amount invested in the project as of 2019. There were 17,874 projects in the dataset out of which 2,822 projects were electricity generation projects. Out of these electricity generation projects, 140 projects were fossil electricity generation projects and 2,682 projects were clean electricity generation projects. Only projects that were classified under the subsector ‘Electric energy generation’<sup>2</sup> were included (breakdown of classification of projects shown in Table 2.9 in Appendix A). During the course of the organisation of the data, projects that were not associated with a municipality were dropped from the dataset. Out of the 17,874 projects in the original dataset, 6,050 projects were dropped due to this lack of location data. Projects contracted before 2003 and after 2017 were also dropped (411 projects). A further 709 projects were present in the dataset but did not receive any investment, and hence were dropped. Out of the 5,560 municipalities in the country, 991 received at least one project funded by the bank, with a total of 11,115 projects in consideration for the analysis. Table 2.1 presents the relevant project-level descriptive statistics, and Figure 2.1 presents the evolution of the yearly investment by project type (shown in percent of total), aggregated at the national level.

The data were then collapsed to municipality-level data, and integrated with census data and national accounts data obtained from the Brazilian Geographic and Statistical Institute (Instituto Brasileiro de Geografia e Estatística, IBGE) as well as the *Bolsa Família* social transfer programme data. The social transfer programme data were not available for the years 2014 and 2015. As for employment and wage data, data from the annual labour report (Relação Anual de Informações Sociais, RAIS) were obtained from the Brazilian Ministry of the Economy from 2003 to 2017, at the municipality level. After the integration of these data, the data was organised as a panel dataset (strongly balanced). The panel has a time-varying treatment structure (or ‘staggered’ treatment) that presents some methodological challenges (discussed in section 2.4.1). We consider the municipality as the unit of analysis in our models. This unit of analysis seems the most appropriate,

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2. ‘Geração de energia elétrica’ in Portuguese.



given the nature of the projects that are in our dataset – the median project investment in a municipality is around 8 million BRL (around 3.3 million USD), compared to the median GDP of 43 million BRL (17.7 million USD). Tables 2.2 and 2.3 present descriptive statistics of the panel variables at the municipality-year level, and Figure 2.2 presents the mean annual growth (of each of the dependent variables) of the municipalities that received each type of project. Table 2.4 presents the correlation coefficients between the dependent and independent variables of interest. The differences seen in Figure 2.2 between those municipalities that received a project and those municipalities that did not point us to the possible endogeneity problems that might need to be accounted for while estimating a regression model. This challenge is treated in detail in section 2.4.1.

TABLE 2.1 – Project-level descriptive statistics

<b>Project type</b>	<b>Description</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Min</b>	<b>Max</b>	<b>Total</b>
Investment (all projects)	Investment in projects till 2017 (million BRL)	11,115	36.1	163.0	0.002	9,890	402,266
Investment (electricity generation)	Investment in electricity generation projects till 2017 (million BRL)	1,934	42.6	169.7	0.002	2,500	82,452
Investment (clean electricity generation)	Investment in clean electricity generation projects till 2017 (million BRL)	1819	41.1	124.6	0.04	2,500	74,759
Investment (fossil electricity generation)	Investment in fossil electricity generation projects till 2017 (million BRL)	115	66.9	158.0	0.30	1,250	7,692
Investment (non-electricity-generation)	Investment in non electricity-generation projects till 2017 (million BRL)	9,181	34.8	126.9	0.04	9,890	319,814

*Source : authors' calculations, using data provided by BNDES*

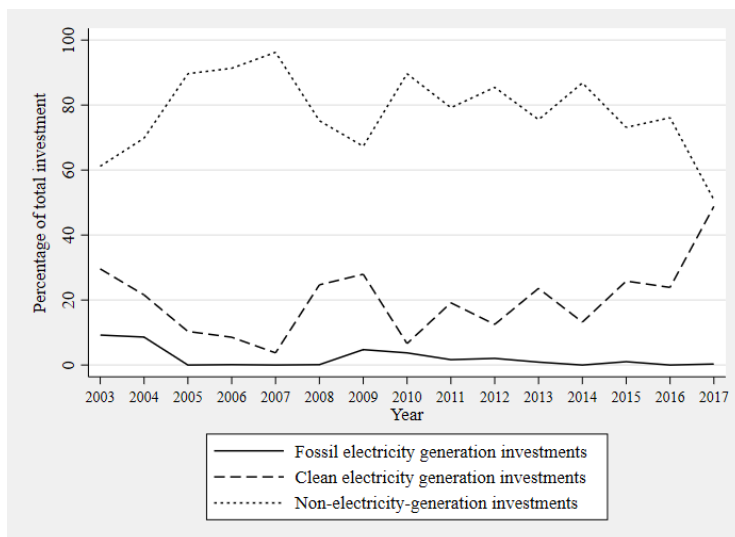


FIGURE 2.1 – Evolution of total investment over time

Source : authors depiction using data from BNDES

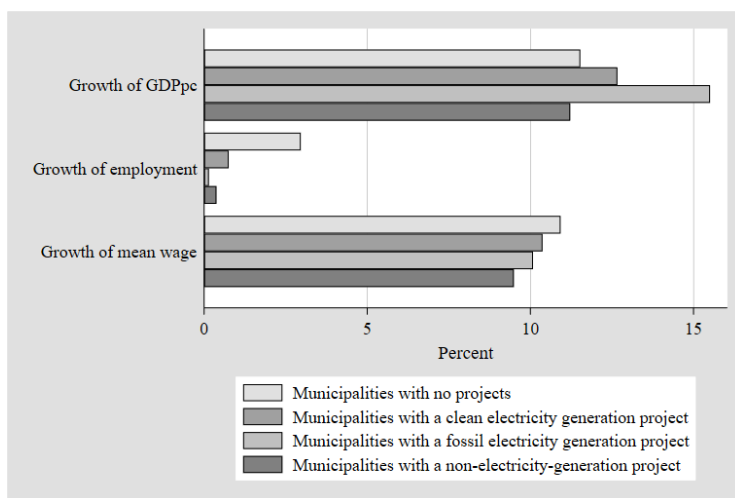


FIGURE 2.2 – Mean year-on-year growth of the three dependent variables, according to the type of project in that municipality

Note : the employment values are adjusted for population. Source : authors’ depiction using data from BNDES and the RAIS labour report from the Brazilian ministry of the economy

TABLE 2.2 – Descriptive statistics of dependent variables used (municipality-year level)

Variable	Description	N	Mean	SD	Min	Max
$GDP_{pc_{it}}$	GDP per capita (1000 BRL)	83,400	13.4	16.6	0.3	815.7
$Employment_{it}$	Total number of people employed in municipality	83,436	7,384.4	77,265.0	1.0	5,236,600.0
$Mean\_wage_{it}$	Mean monthly wage level (BRL)	83,436	1046.9	501.7	166.3	10,077.4

Source : authors' calculations, using data from BNDES, the RAIS labour report from the Brazilian ministry of the economy, and from the IBGE.

TABLE 2.3 – Descriptive statistics of independent variables (municipality-year level)

Variable	Description	N	Mean	SD	Min	Max
$Investment(total)_{it}$	Investment in all types of projects (million BRL)	83,399	4.7	116.4	0.0	13,454.6
$Investment(electricity-generation)_{it}$	Investment in all electricity generation projects (million BRL)	83,399	1.0	52.6	0.0	13,337.7
$Investment(clean-electricity-generation)_{it}$	Investment in clean electricity generation projects (million BRL)	83,399	0.9	51.9	0.0	13,337.7
$Investment(fossil-electricity-generation)_{it}$	Investment in fossil electricity generation projects (million BRL)	83,399	0.09	8.0	0.0	1,402.8
$Investment(non-electricity-generation)_{it}$	Investment per capita to non-electricity-generation projects (million BRL)	83,399	3.7	100.9	0.0	13,392.2
$Population_{it}$	Population (1000 people)	83,399	34.7	205.3	0.8	12,106.9
$Bolsa\_Familia_{it}$	Bolsa Familia cash transfers (1000 BRL)	61,130	229.5	788.9	40.0	72,081.5

Source : authors' calculations, using data from BNDES, the RAIS labour report from the Brazilian ministry of the economy, the IBGE, and Ipeadata.

TABLE 2.4 – Correlation coefficients between the main dependent and independent variables

	<b>GDPpc</b>	<b>Employment per capita</b>	<b>Mean wage</b>
Investment (total)	0.37	0.35	0.29
Investment (electricity generation)	0.16	0.13	0.13
Investment (clean electricity generation)	0.15	0.12	0.12
Investment (fossil electricity generation)	0.06	0.06	0.06
Investment (non-electricity-generation)	0.36	0.34	0.27

*Note* : all variables in logs. *Source* : authors' calculations, using data from BNDES, the RAIS labour report from the Brazilian ministry of the economy, and the IBGE.

Three dependent variables were identified as being of interest to the study, following the hypotheses presented. The first, *GDPpc* (GDP per capita), is an indicator of economic activity in a municipality-year, the second, *Employment* measures the total number of people employed in a municipality (as of December of a given year). The third, *Mean wage* measures the mean monthly wage in a municipality-year.

To construct the independent variable, we use two different (but clearly related) ways to measure the presence of a project in a given municipality-year. The simplest way is to use a binary dummy variable to denote the presence of at least one project in that municipality-year. We add detail to the independent variable by using the cumulative investment as the independent variable<sup>3</sup> (model detailed in section 2.4.2).

The binary dummy variable in question,  $d_{it}$ , was created to denote the presence of a project in a particular municipality  $i$  and in year  $t$ . A value of 1 for the  $d_{it}$  project dummy would indicate that the municipality is a ‘treated’ municipality in that year i.e. at least one project was present in that municipality in that year. If a municipality is treated it remains treated for the rest of the panel. In the case of the independent variable being Investment per capita, this would mean that municipalities being treated twice would see their BNDES capital stock increase by the amount of the incoming investments. This would mean that a project and its investment are considered immobile – if a municipality receives a project in a particular year, the project and its associated capital remains in the municipality. This is a reasonable assumption to make, since investments through the development bank are largely in infrastructure development. This is also an important

3. Descriptive statistics of the variable Investment are presented in Table 2.3. However, to aid interpretation, the variable used in the regressions is Investment per capita, denoted as  $Investment_{pc}$ .

assumption to make to estimate the model (see [Callaway and Sant'Anna, 2021](#)). The model is discussed in detail below in section [2.4](#).

## 2.4 Model

A panel data analysis using a two-way fixed effects (TWFE) estimator was used to analyse the principal research question : to investigate whether investment in the Bank's projects (eventually separated into clean electricity generation, fossil electricity generation, and non-electricity-generation projects) results in an increase of per capita GDP, employment levels, and mean wage levels. The estimator makes use of panel data for the entire period of 2003-2017 (with 15 periods), allowing for time-invariant fixed effects and year fixed effects to explore the effects of the presence of a project (the independent variable) on GDP per capita, employment levels, and mean wage levels (the dependent variables).

### 2.4.1 Dealing with econometric issues

The structure of the panel and the choice of model (further detailed in section [2.4.2](#)) present two econometric issues that might introduce bias in the estimation. The first is the endogeneity that might potentially be present in an OLS model due to non-random assignment of projects to municipalities. The second issue concerns the 'staggered' nature of the treatments of the municipalities with respect to time (i.e., when different municipalities in the panel receive investment at different points in time), and the potential bias that might be introduced by estimating a model without considering that possibility (cf. [Goodman-Bacon, 2018](#)). Since the data and methods used here present a natural quasi-experimental scenario, there is the possibility of endogeneity that needs to be accounted for, which would otherwise provide biased results in an OLS model. There is the possibility that investment flows to municipalities not in a random manner (as is required for an experimental setup), but based on certain underlying characteristics of the municipality (i.e. based on some selection criteria). In other words, an inference based on OLS estimation might include some reverse causality, since it cannot be ruled out a priori that investment flows to municipalities

that already are richer, or already have a strong industry presence, for instance. A naïve OLS estimation will also fail to take into account any pre-existing time-independent differences between municipalities, such as area, geography, or presence of existing industry, among others.

In an ideal experiment, the treatment (i.e. allocation of investments) would be random, and any differences between the levels of the dependent variables between treated municipality-years and all municipality-years would purely be due to the treatment effect. However, the magnitude of the difference between the means of the two groups appears to be larger than what we would expect for a treatment effect, and leads us to suspect that some degree of endogeneity would be present in a pooled OLS estimation.

Two strategies are employed to reduce endogeneity in the model. The first is to include municipality fixed effects in the model that would account for time-independent differences between municipalities such as geography. The second strategy involves Inverse Probability Weighting (IPW) that involves weighting the municipalities in such a way that would more closely approximate a random allocation of treatment. This is achieved by generating a propensity score that estimates each municipality's propensity to be treated based on pre-treatment characteristics of the municipality, and then by reweighting the municipalities according to their propensity to be treated. The reweighting is done according to the suggestions of [Hirano et al. \(2003\)](#), namely a weight of one for treated municipalities, and a weight of  $\hat{P}(X)/(1 - \hat{P}(X))$  for the controls, where  $\hat{P}(X)$  refers to the estimated propensity score (to be treated). This is done to ensure a more appropriate group for comparing the treated to the untreated municipalities. This is similar to the implementation of [Chen et al. \(2009\)](#)<sup>4</sup>. A similar approximation of a doubly robust estimator was used by [Ravallion and Chen \(2005\)](#), however with the loss of some observations that we overcome using IPW. The propensity score is estimated using a probit model for the treated municipalities in 2003, based on pre-treatment characteristics of the municipalities (i.e., using covariates from 2002 or the closest available pre-treatment year). The results table of this probit model are presented in [Table 2.10](#) in [Appendix A](#).

A third source of bias may arise from the structure of the panel, specifically, due to the so-called

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4. This combination of a linear regression and propensity score matching is an attempt to imitate a doubly robust estimation, or an augmented inverse propensity weighted estimator (originally developed for cross sections by [Robins, Rotnitzky and Zhao \(1994\)](#)). However, applying the same concept to a panel data TWFE estimation with unit fixed effects (in our case, municipality fixed effects) is not obvious (see [Arkhangelsky et al., 2021](#)), hence leading us to a compromise that retains (to the extent possible) external and internal validity while also retaining statistical power.

‘staggered’ nature of the treatment of municipalities. Since municipalities in our panel are treated at different periods, the standard two-way fixed-effects model (TWFE) might be biased, as noted by an emerging econometrics literature (Callaway and Sant’Anna, 2021, Goodman-Bacon, 2018). This literature essentially considers the  $2 \times 2$  difference-in-differences design (treated/untreated vs. pre/post-treatment) as the simplest way to ascertain the effect of an intervention, and Goodman-Bacon (2018) shows that a TWFE model can be decomposed into multiple  $2 \times 2$  comparisons, and that the average treatment effect on the treated (the coefficient on the variable of interest in a TWFE model) is in fact a weighted average of these individual  $2 \times 2$  combinations.

Among these individual  $2 \times 2$  combinations, there might be some combinations that effectively compare the post-treatment period of some (treated) municipalities to the pre-treatment period of some municipalities that are already treated. This could amount to a violation of the parallel trends assumption that is needed to be made for a  $2 \times 2$  difference-in-difference design, since the municipalities that are being treated as a control group are, in fact, not true controls. This could introduce a bias in the estimation, depending on the weight that these ‘spurious’ comparisons have in the panel (Goodman-Bacon, 2018), and there might also be bias in the estimations of the dynamic effects of the treatment (Sun and Abraham, 2021). In theory, the bias should reduce when the number of ‘never-treated’ municipalities is large, but the robustness of the TWFE model should be explicitly tested.

One way to test for the robustness of the TWFE model in a staggered panel would be to test for the effects of all the projects year-by-year, using a t-test to compare the treated municipalities before and after treatment. A robustness check to account for the staggered structure would be to apply the TWFE model to smaller subsets of the data, i.e., subsets defined by temporal or spatial restrictions. A difference-in-difference with multiple periods estimator has been used to perform these robustness checks as well as gather the dynamic effects (Callaway and Sant’Anna, 2021). The results of these robustness checks are mentioned in section 2.5.2.



### 2.4.2 Model specification

The fixed effects model used is as shown in equation 2.1 and equation 2.2 :

$$Y_{it} = \beta_0 + \beta_1 \cdot d_{it} + \boldsymbol{\beta} \cdot \mathbf{X}_{it} + \alpha_i + \Omega_t + \varepsilon_{it} \quad (2.1)$$

where  $Y_{it}$  is the dependent variable,  $d_{it}$  is a dummy variable that denotes the presence of a project in a municipality in a given year,  $X_{it}$  is a vector of time varying covariates,  $\alpha_i$  denotes time invariant fixed effects, and  $\Omega_t$  denotes year dummies.  $\beta_0$  denotes the intercept, and  $\beta_1, \beta_2, \dots, \beta_n$  denote the coefficients of the independent variables and covariates, and  $\varepsilon_{it}$  denotes the error term. A summary of these variables has been presented in the previous section.

In some ways, the equation 2.1 would capture the ‘pure’ effect of the presence of project investment on the outcome variables (or in other words, the average treatment effect on the treated municipalities, ATT). In addition, the model used to estimate equation 2.1 lends itself more easily to robustness checks that are detailed in section 2.5.2.

We then interact the dummy variable  $d_{it}$  with the variable *Investment* to get the variable  $Investment_{it}$ , that is the amount of BNDES project investment present in that municipality-year.  $Investment_{it}$  is subsequently used as the independent variable of interest as in equation 2.2.

$$Y_{it} = \beta'_0 + \beta'_1 \cdot Investment_{it} + \boldsymbol{\beta}' \cdot \mathbf{X}_{it} + \alpha_i + \Omega_t + \varepsilon_{it} \quad (2.2)$$

As summarised in Tables 2.2 and 2.3, the three dependent variables are *GDPpc*, (the GDP per capita of a municipality-year), employment levels in a municipality-year, and the mean wage levels in a municipality-year. The independent variables of immediate interest are the investment amounts for projects per capita<sup>5</sup>. The total investment in projects is broken down into investments in electricity generation, clean energy generation, and non-electricity-generation projects. The dynamic effects of the model are also estimated, to follow the evolution of the impacts of the projects across time periods.

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5. The *Investment* variables are used as *Investment percapita* in the regressions to aid interpretation. The significance level is robust to using *Investment* instead of *Investment percapita*.

## 2.5 Results

Table 2.5, Table 2.6, and Table 2.7 show the results of the regression, with the GDPpc, employment levels, and mean wage levels as the dependent variable respectively. Considering all projects, the bank's projects have a positive effect per capita GDP and employment levels per capita, with each additional percentage of investment per capita leading to a 0.014 percent increase of GDP per capita, a 0.013 percent increase in employment, and a corresponding 0.007 percent increase in mean wage levels. Electricity generation projects seem to have a less positive effect than non-electricity-generation projects on GDP per capita and on total employment per capita, but the same magnitude of effect for mean wage levels<sup>6</sup>. The effects of individual types of projects are interpreted in the following paragraphs.

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6. To be able to compare the magnitude of the effect size of these projects, the coefficients presented in the results tables could be compared to the coefficients of the effects of primary, secondary, and tertiary sector investments on the same dependent variables (Table 2.12 in Appendix A)

TABLE 2.5 – *Impact of per capita investment on GDP per capita*

	DV : GDP per capita		
	(1.1)	(1.2)	(1.3)
Investment per capita (all)	0.014*** (0.002)		
Investment per capita (electricity generation)		0.011*** (0.004)	
Investment per capita (non-electricity-generation)		0.014*** (0.002)	0.013*** (0.002)
Investment per capita (fossil electricity)			0.027 (0.027)
Investment per capita (clean electricity)			0.009** (0.004)
Population	-0.481*** (0.093)	-0.491*** (0.093)	-0.495*** (0.094)
Bolsa familia spending	0.007* (0.004)	0.007* (0.004)	0.007* (0.004)
Year fixed effects	Yes	Yes	Yes
Obs.	55,529	55,529	55,529
R2	0.81	0.81	0.81

*Note : Dependent variable is in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.6 – *Impact of per capita investment on employment levels per capita*

	<b>DV : Employment per capita</b>		
	(2.1)	(2.2)	(2.3)
Investment per capita (all)	0.013*** (0.002)		
Investment per capita (electricity generation)		0.006** (0.003)	
Investment per capita (non-electricity-generation)		0.016*** (0.003)	0.016*** (0.003)
Investment per capita (fossil electricity)			0.012 (0.009)
Investment per capita (clean electricity)			0.005** (0.003)
Population	-0.482*** (0.062)	-0.499*** (0.063)	-0.501*** (0.063)
Bolsa familia spending	0.005 (0.003)	0.006* (0.003)	0.007** (0.003)
Year fixed effects	Yes	Yes	Yes
Obs.	55530	55530	55530
R2	0.42	0.42	0.42

*Note : Dependent variable is in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.7 – *Impact of per capita investment on mean wage levels*

	DV : Mean wage		
	(3.1)	(3.2)	(3.3)
Investment per capita (all)	0.007*** (0.001)		
Investment per capita (electricity generation)		0.007*** (0.002)	
Investment per capita (non-electricity-generation)		0.005*** (0.001)	0.005*** (0.001)
Investment per capita (fossil electricity)			0.022 (0.017)
Investment per capita (clean electricity)			0.006*** (0.001)
Population	0.033 (0.030)	0.031 (0.030)	0.028 (0.030)
Bolsa familia spending	0.012*** (0.002)	0.012*** (0.002)	0.012*** (0.002)
Year fixed effects	Yes	Yes	Yes
Obs.	55530	55530	55530
R2	0.93	0.93	0.93

*Note : Dependent variable is in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

When projects are divided into electricity generation projects and non-electricity generation projects, a clear difference can be observed between the coefficients of each of these groups of projects on the dependent variables, as can be seen from the results tables. While electricity generation projects do have a positive and statistically significant impact on GDP per capita (0.011 percent increase for one percent increase in investment), it is lesser than the impact of non-electricity-generation projects (0.014 percent increase for one percent increase in investment). The economic impact of the bank's investments can be clearly seen, however with a difference between types of projects. When it comes to total employment as a dependent variable, the difference between electricity generation and non-electricity-generation projects is stark : electricity generation projects cause less than half the increase in total employment levels in contrast to non-electricity-generation projects (0.006 percent), which cause higher increases in total employment levels (0.013 percent) per percent increase in the respective investment. This result is surprising, since it suggests that electricity generation projects have a relatively higher economic impact without a correspondingly high effect on employment levels. When it comes to effects on mean wage levels, however, electricity generation projects have the same magnitude of effect as non-electricity-generation projects (a 0.007 percent increase per percentage of increase in investment).

This result leads us to look deeper into the types of electricity generation projects that are being invested in—when clean electricity generation projects are considered in the regression analysis (i.e. electricity generation projects that do not involve fossil fuels) and are separated from fossil electricity generation projects, the results seem to suggest that clean electricity generation projects have weaker positive effects on GDP per capita and total employment levels, but a slightly more positive effect on mean wage levels, compared to non-electricity-generation projects. A possible explanation is that an increase in employment levels might have led to an upward pressure on the price of labour (i.e. wages), and that this differentiated effect between project types is observed here because clean electricity generation projects involved higher skilled workers (hence requiring higher wage increases) compared to non-electricity-generation projects. In all the three results tables, the coefficient on the variable 'investment in electricity generation projects' is higher than the coefficients on 'investment in clean electricity projects'. However, the coefficients on the 'investment in fossil electricity projects' are not statistically significant and hence are not interpreted here. We suspect that this lack of statistical significance is due to a relatively small number of such projects in the sample. Additionally, the same regressions were repeated with a dummy variable denoting

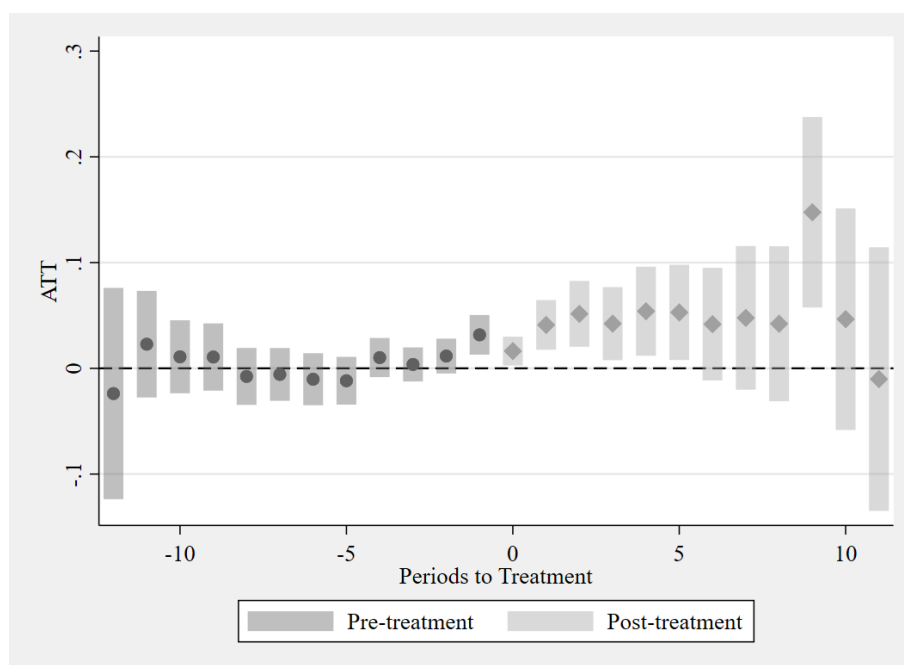
the presence of a project as the independent variable instead of the investments. The coefficients in these regressions are largely in similar proportions and can be referred to in Table 2.13, Table 2.14, and Table 2.15 in Appendix A.

These results would include only the downstream local impacts of construction and operation and maintenance of the project. Upstream benefits, including manufacturing or extraction would not typically be included, since the projects included are strictly electricity generation projects, and because we account for them starting from the moment they are implemented in the municipality. For instance, taking into account the manufacturing processes of wind turbine blades (which might take place elsewhere in the country or abroad) is not within the scope of this level of analysis.

### 2.5.1 Dynamic treatment effects

The coefficients on the independent variables presented in Tables 2.5 to 2.7 are average treatment effects on the treated municipalities (ATT) over the entire time period covered by the panel. We break down the dynamic treatment effects for the post-treatment time periods (as well as pre-treatment periods). This is done using the data from the individual  $2 \times 2$  difference-in-difference estimations obtained through the decompositions suggested by Callaway and Sant'Anna (2021), since including lags or leads of the primary independent variable in the model might lead to some biased estimations due to staggered treatment as described in section 2.4.1. Figure 2.3 shows the dynamic effects of all projects on GDP per capita, Figure 2.4 the dynamic effects on employment levels per capita, and 2.5 the dynamic effects on mean wage levels. The results of the model clearly suggest that there is an effect across time of the projects on the three dependent variables. The effect during the year of treatment are understandably slightly smaller than the effects during subsequent years, due to longer lead times required for project implementation and measurement in RAIS. While the effects on GDP per capita and employment levels per capita seem to last for around five years, the effects on mean wage levels fall slightly more quickly. While Figures 2.3 to 2.5 show effects of all projects combined, dynamic effects of electricity generation projects and clean energy generation projects are shown in Appendix A, where it can be seen that they have a smaller effect across time compared to non-electricity-generation projects, and the positive effects drop much more quickly across time. A possible explanation is due to the nature of the labour requirement for electricity generation projects, which might employ fewer people than

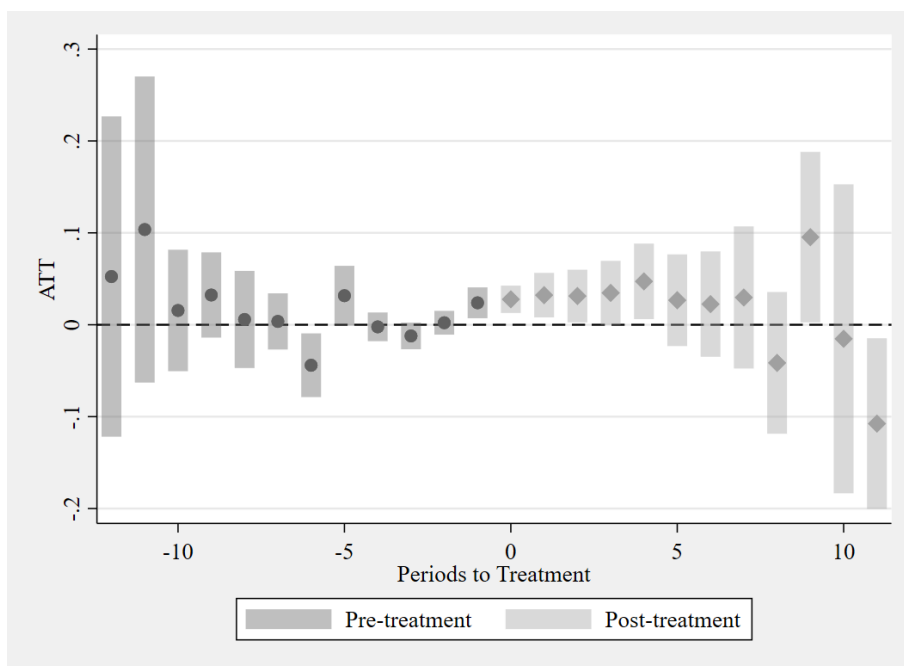
non-electricity-generation projects, especially during the operation and maintenance phases of the projects (see [Tourkolias and Mirasgedis \(2011\)](#) for a similar discussion).



*Note* : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

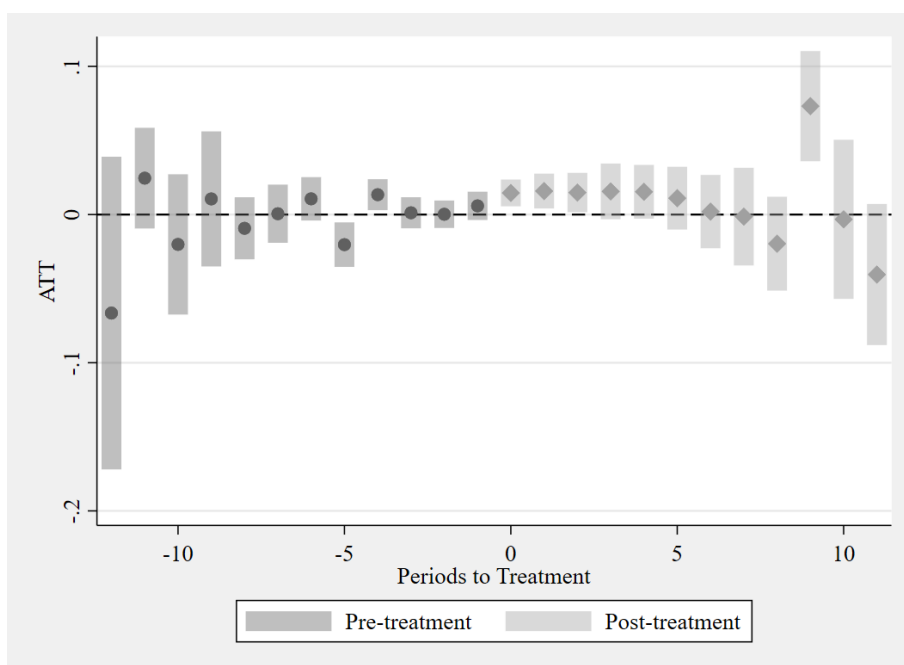
FIGURE 2.3 – Dynamic treatment effects on GDP per capita of all projects





Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.4 – Dynamic treatment effects on employment per capita of all projects



Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.5 – Dynamic treatment effects on mean wage levels of all projects

### 2.5.2 Robustness checks

To verify that the model is robust to different specifications, particularly to the staggered treatment problem mentioned in section 2.4.1, three different models were created as robustness checks. The first uses a method recently proposed by [Callaway and Sant'Anna \(2021\)](#) to decompose a TWFE model and subsequently re-compose the coefficients. In addition, we use two complementary checks to manually verify the model's robustness to different specifications. We do this by i) using a broad t-test before and after treatment to discern that a treatment effect actually exists (this could be roughly compared to the 'parallel trends test' frequently used in  $2 \times 2$  difference-in-difference designs), and ii) applying the same TWFE model (presented in equation 2.1) to subsets of the dataset, to ensure that the effect observed in the model results is also present when applying the model to subsets of the data. The manual robustness checks are explained and presented in Appendix B. In addition, since Bolsa Familia data for two years are missing, the regressions were re-estimated without the Bolsa Familia variable, and the coefficients nor the significance levels did not change appreciably.

[Callaway and Sant'Anna \(2021\)](#), in the difference-in-difference with multiple periods estimator that they develop offer a way to obtain a decomposition of the staggered TWFE model into  $2 \times 2$  difference-in-difference estimations (which have been used to obtain the dynamic effects presented in Figure 2.3). The coefficients of the individual  $2 \times 2$  estimations can be used to 're-compose' the average treatment effect on the treated (ATT) using appropriate weights ([Goodman-Bacon, 2018](#)). The specification corresponding to equation 2.1 was re-estimated using the difference-in-difference with multiple periods decomposition (using the same covariates). The ATT effects are presented in Table 2.8 below, and can be directly compared to the coefficients on the 'project dummy' variable in Tables 2.13, 2.14, and 2.15 in Appendix A. The 'never-treated' municipalities are used as controls, but using only the 'not-yet-treated' municipalities as controls do not change the coefficients or their significance radically. The improved doubly robust DiD estimator based on inverse probability of tilting and weighted least squares proposed by [Sant'Anna and Zhao \(2020\)](#) is used to gather the ATT estimates. The estimates are also robust to other methods used to compute the ATT estimates.

The ATT estimates presented in Table 2.8 below indicate that the coefficients presented in the main results tables were probably biased upward. However, the significance levels remain

comparable. It is also to be noted that while the coefficients during this robustness check are positive and significant when all projects or non-electricity-generation projects are considered, they are weaker for electricity generation projects in general or for clean energy projects. This can be seen in the Figures 2.6 to 2.13 showing dynamic effects, presented in Appendix B.

The difference-in-difference with multiple periods estimator method to compute the ATT estimates has its advantages in correcting for biased estimates of the TWFE model, but it can only consider a binary treatment as in equation 2.1 and cannot consider varying levels of treatment as can be done with the Investment variable in equation 2.2. We therefore maintain the results presented in Table 2.5, Table 2.6, and Table 2.7 – the coefficients of the Investment variable lend themselves more easily to policy interpretation than the coefficients on a dummy variable indicating the presence of a project. Also, a single ATT estimate (or indeed a TWFE coefficient presented in Tables 2.5 to 2.7 might be inadequate to capture the dynamics of the model, so it is important to take the dynamic effects presented in Figure 2.3 into consideration while assessing the model, and not merely the TWFE coefficients which only shows the presence of an aggregate effect.

TABLE 2.8 – Comparison of the ATT estimates using the difference-in-difference with multiple periods estimator to the TWFE model coefficients

	<b>GDPpc (log)</b>	<b>Employment per capita (log)</b>	<b>Mean wage (log)</b>
ATT computed through the difference-in-difference with multiple periods estimator	0.047*** (0.011)	0.034** (0.013)	0.011* (0.006)
Coefficients from Tables 2.13, 2.14, and 2.15	0.075*** (0.012)	0.058*** (0.011)	0.037** (0.006)

Note : for the purposes of the robustness check to ensure that the basic model holds, all projects were considered, without distinguishing between types of projects. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

## 2.6 Discussion and conclusions

The results of the present analysis highlight the difficulties that policymakers and development project investors might have to face when trying to tackle the double problem of needing to have positive environmental and economic outcomes on their investment (in addition to financial returns on investment). The results seem to narrate a cautionary tale about clean electricity generation investments by providing empirical evidence about the differentiated impacts of electricity generation projects on economic indicators, namely GDP per capita, employment levels, and wage levels in Brazilian municipalities. The Bank's projects in general have a positive impact on GDP per capita, employment levels, and on wage levels, a result that should be unsurprising, given the large amounts of investment. It is of more interest, however, to look at the difference between different types of projects when considering their impacts. While the contributions of electricity generation projects to positive economic outcomes are present on a superficial level (when looking at GDP per capita), a deeper look into the impacts on employment and wage levels are more telling.

The difference might be due to the difference in labour intensities between jobs created in clean energy and fossil energy sectors, since there is evidence to suggest that 'green' jobs are more skill intensive and less labour intensive than 'non-green' jobs (Consoli et al., 2016). The effects of these investments on employment and wage levels seem to lend support to this explanation, given that for clean electricity generation projects, the wage level increases are at par with electricity generation projects in general, whereas the employment generation due to these projects are much below that of electricity generation projects in general. This perhaps suggests that the economic benefits of these electricity generation investments might have been felt more by only a small proportion of the population, without affecting economic indicators at an aggregate level. More data on the labour intensities of these projects would be required in order to specifically locate the flows of labour in response to investments.

When it comes to the implications of these results, they affirm Ravallion and Datt (1996) and Loayza and Raddatz (2010)'s assertions that not all growth is equal – compared to municipalities with no BNDES investment, GDP growth per capita due to investments in clean electricity generation is lesser than GDP growth due to investments in electricity generation projects in general, and

to investments in non-electricity-generation projects in our sample (in those municipalities that did receive those projects). This might have an effect on poverty alleviation efforts in the country.

Is clean electricity generation then unequivocally bad for poverty and socio-economic outcomes? Our results show a reduced impact of clean electricity generation projects on economic output, wages, and employment, but it is important to consider that negative externalities of fossil fuel use (pollution, health, resource depletion, etc.) are not entirely internalised in the national accounts data that we use for analysis. Investing in environmental capital (in addition to ‘traditional’ physical capital) might have positive socio-economic outcomes both in the short term (pollution reduction) and in the long term (increased labour productivity, increased resilience to climate uncertainties), but these would not be captured in national accounts data. [Hallegatte et al. \(2012\)](#) propose an analytical framework that includes environmental capital as an input in their production function that might serve to internalise these aforementioned externalities. They discuss the potential trade-off between environmental outcomes and economic outcomes that might arise out of ‘clean’ investments, and identify the costs that might arise out of implementation of pro-environmental policies. They argue that these perceived costs depend on how we measure economic output. When negative externalities are internalised, some of these costs might not arise at all, or might be compensated by (relatively) smaller environmental externalities. Internalising negative externalities might also help in realising the real value of damage done by activities such as deforestation that is particularly relevant in a Brazilian context. Steps toward such an internalisation could potentially be made by correctly valuing environmental capital and socioeconomic outcomes.

However, we should be careful in contenting ourselves with rationalising a reduced effect size for clean electricity generation projects (as we see in our results) by merely identifying a lack of measurement of returns on investment in environmental capital. A reduced effect size can also be due to inefficient allocation of project capital, or it might still lie in the nature of employment created by these investments.

In the data considered in our article, we estimate that an inefficient allocation of project capital would be minimal. This is because BNDES project capital is not ‘allocated’ by any central allocating mechanism, it is rather demand-led – requests for funding of projects come from where an investor is in need of it. We therefore have reason to believe that the reduced impact of clean

electricity generation projects on GDP per capita, and employment might be due to the lower requirement of labour that clean energy investment might require, compared to projects in other sectors.

Our results seem to indicate that for development banks, investing in non-electricity-generation projects might be a more efficient pathway to better economic outcomes. However, such a conclusion would be incomplete without taking into account the reduction of negative externalities and creation of positive externalities that clean energy projects ostensibly contribute to. One of those positive externalities would also be the development of competences in innovative technologies and the development of new business models (Fankhauser and Jotzo, 2018). The present article also aims to offer an insight into how the Brazilian national development Bank might need to reorient its strategy in response to the dual challenge of positive environmental outcomes and positive socioeconomic outcomes. We also echo the call of Frischtak et al. (2017) for the Bank to adopt specific and targeted programs to those sectors that have the potential to generate larger positive externalities, socio-economic and environmental. While there is a clear positive sign for the Bank's projects due to visibly positive effects of investments in general on economic outcomes, more precise monitoring of the projects that are funded, along with more detailed information on the types of employment opportunities that are created thanks to the Bank's investment might enable the bank to (better) target their lines of financing towards to counteract the weaker socioeconomic impacts of certain types of projects such as energy projects. Clearer accounting procedures to better monitor the economic impacts of projects would also assist future analyses of these investments, with a view to increase efficiency in distribution of capital and aid.

## **Acknowledgements**

The authors would like to thank Isabel Bodas-Freitas, Mustapha Belkhouja, an anonymous reviewer at the FAERE (French Association of Environmental and Resource Economists) Working Paper series, and the participants at the FAEE (France - Association des Economistes de l'Energie) student seminar at the Université Grenoble Alpes in November 2021 for their valuable feedback and suggestions on this article.

## 2.7 Appendix A

TABLE 2.9 – Details of classification of projects into clean and fossil electricity generation projects

Classification	Name of CNAE subsector (Portuguese/original)	Name of CNAE subsector (English/translation)	Number of projects	Remarks
Clean electricity generation	Geração de energia elétrica – eólica	Generation of electric energy – wind	1367	
	Geração de energia elétrica – cogeração cana de açúcar	Generation of electric energy – cogeneration - sugarcane	269	
	Geração de energia elétrica – hidrelétrica	Generation of electric energy – hydroelectric	516	
	Geração de energia elétrica – PCH	Generation of electric energy – small hydroelectric	400	
	Geração de energia elétrica – nuclear	Generation of electric energy – nuclear	4	Category contains 4 projects. Classified as 'clean energy'
	Geração de energia elétrica – solar	Generation of electric energy – solar	34	
	Geração de energia elétrica – outras fontes alternativas	Generation of electric energy – other alternative sources	6	Category contains 6 projects of power generation using biogas
Fossil electricity generation	Geração de energia elétrica	Generation of electric energy	74	Category manually checked – most projects are biomass projects
	Geração, transmissão e distribuição de energia elétrica	Generation, transmission, and distribution of electric energy	12	Diverse small projects, but most get eventually excluded because they do not fit panel criteria
	Geração de energia elétrica – térmica	Generation of electric energy – thermal	83	
	Geração de energia elétrica – cogeração exclusiva	Generation of electric energy – 'exclusive cogeneration'	43	Project details manually checked – most projects use fossil energy
	Geração de energia elétrica – cogeração gas	Generation of electric energy – cogeneration gas	14	

TABLE 2.10 – *Probit model used to calculate the propensity score*

	<b>Project dummy (2003)</b>
GDP per capita (2002)	0.384*** (0.096)
Population (2002)	0.415*** (0.043)
Number of branches of rural bank	0.366* (0.210)
Primary sector share of GDP (2002)	-0.376 (0.365)
Secondary sector share of GDP (2002)	-0.292 (0.383)
Wage inequality (Gini) (2003)	0.824 (0.592)
Latitude	-0.003 (0.007)
Longitude	-0.006 (0.007)
Obs.	5,555
LL	-476.4

*Note : All dependent variables are in logs. GDP per capita and population are in logs. Estimation by MLE. Standard errors in parentheses. Constant omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.11 – *Lower and upper bounds of blocks of propensity score*

<b>Block number</b>	<b>Inferior of block of pscore</b>	<b>Untreated</b>	<b>Treated</b>	<b>Total</b>
1	.0010111	3,893	26	3919
2	.025	458	14	472
3	.05	302	26	328
4	.1	153	35	188
5	.2	72	20	92
6	.4	22	16	38
7	.6	2	8	10
8	.8	0	3	3
Total		4,902	148	5,050

*Note : The balancing property is satisfied. The number of blocks selected was such that the mean propensity score for treated and untreated units is not different within each block. The total number of municipalities in the table is lesser than the total in the dataset since they fall out of the common support range.*



TABLE 2.12 – *The effects of bank investment by sector on the three dependent variables*

	<b>GDPpc</b>	<b>Employment per capita</b>	<b>Mean wage</b>
Investment <sub>pc</sub> (primary sector)	0.013*** (0.005)	0.012*** (0.004)	0.006*** (0.006)
Investment <sub>pc</sub> (secondary sector)	0.009*** (0.002)	0.013*** (0.002)	0.002* (0.001)
Investment <sub>pc</sub> (tertiary sector)	0.008*** (0.003)	0.004 (0.002)	0.004*** (0.001)
Year fixed effects	Yes	Yes	Yes
Obs.	55,529	55,529	55,529

*Note : All dependent variables are in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.13 – *Impact of presence of project on GDP per capita*

	DV : GDP per capita		
	(4.1)	(4.2)	(4.3)
Project_dummy (all)	0.075*** (0.012)		
Project_dummy (electricity generation)		0.065** (0.027)	
Project_dummy (non-electricity-generation)		0.062*** (0.012)	0.062*** (0.012)
Project_dummy (fossil electricity generation)			0.104 (0.137)
Project_dummy (clean electricity generation)			0.054** (0.026)
Population	-0.469*** (0.094)	-0.473*** (0.094)	-0.475*** (0.095)
Bolsa familia spending	0.007* (0.004)	0.007* (0.004)	0.008** (0.004)
Year fixed effects	Yes	Yes	Yes
Obs.	55,529	55,529	55,529
R2	0.81	0.81	0.81

*Note : Dependent variable is in logs. Independent variable is a dummy variable denoting presence of a project (subdivided by project types) in a municipality. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.14 – *Impact of presence of project on employment levels*

	DV : Total employed per capita		
	(5.1)	(5.2)	(5.3)
Project_dummy (all)	0.058*** (0.011)		
Project_dummy (electricity generation)		0.027 (0.020)	
Project_dummy (non-electricity-generation)		0.063*** (0.012)	0.063*** (0.012)
Project_dummy (fossil electricity generation)			0.055 (0.056)
Project_dummy (clean electricity generation)			0.026 (0.021)
Population	-0.471*** (0.064)	-0.478*** (0.064)	-0.478*** (0.064)
Bolsa familia spending	0.006* (0.003)	0.007** (0.003)	0.007** (0.003)
Year fixed effects	Yes	Yes	Yes
Obs.	55,530	55,530	55,530
R2	0.41	0.41	0.41

*Note : Dependent variable is in logs. Independent variable is a dummy variable denoting presence of a project (subdivided by project types) in a municipality. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

TABLE 2.15 – *Impact of presence of project on mean wage levels*

	<b>DV : Mean wage</b>		
	(6.1)	(6.2)	(6.3)
Project_dummy (all)	0.037*** (0.006)		
Project_dummy (electricity generation)		0.045*** (0.012)	
Project_dummy (non-electricity-generation)		0.026*** (0.006)	0.025*** (0.007)
Project_dummy (fossil electricity generation)			0.074 (0.090)
Project_dummy (clean electricity generation)			0.039*** (0.010)
Population	0.039 (0.030)	0.038 (0.030)	0.036 (0.031)
Bolsa familia spending	0.012*** (0.002)	0.012*** (0.002)	0.012*** (0.002)
Year fixed effects	Yes	Yes	Yes
Obs.	55,530	55,530	55,530
R2	0.92	0.92	0.92

*Note : Dependent variable is in logs. Independent variable is a dummy variable denoting presence of a project (subdivided by project types) in a municipality. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses (adjusted for 5,050 clusters (corresponding to municipalities)). Constant and coefficients of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .*

## 2.8 Appendix B

In addition to the robustness checks using the difference-in-difference with multiple periods estimator, to manually check the robustness of the model, a ‘short-term event study’ design was implemented by choosing an arbitrary year  $t$  in the panel and constructing a window of  $\pm 3$  years around the year. Any projects that were assigned to the municipality in year ‘ $t$ ’ were treated as ‘events’, and the levels of the dependent variables before and after the ‘event’ were compared using an independent samples t-test. The main goal was to be able to discern and isolate the impact of an event (in this case the arrival of project investment in a particular year) on the dependent variables. Municipalities that received projects in any other year than year  $t$  were excluded from the analysis, in order not to confound the analysis. Two control groups were used— a) the municipality-years of treated municipalities before the ‘event’ year (i.e. the pre-treatment periods of the treated municipalities), and b) the pre-treatment years of the treated municipalities and all the never-treated municipality-years. A positive difference in means between the two comparison groups would indicate that the levels of the dependent variables were higher in the treated municipality-years compared to the control group. While this test cannot be used to infer causality (due to the lack of control for covariates), it nevertheless suggests that a difference exists between the treated and untreated municipalities that needs further analysis. The results of the independent samples t-tests using this event study design with a  $\pm 3$  year window suggest that for most years; there is a statistically significant positive effect of the presence of a project on GDP per capita in the treated municipalities. Results of the event study are presented in Table 2.16. The second robustness check would be to apply the same regression as presented in equation 2.1 to subsets of the panel, the expectation being that the model applied to subsets of the panel should also present similar results as the model applied to the whole panel. The subsets considered might be based on temporal restrictions on the original panel, or it can be based on spatial restrictions on the original panel. Temporal restrictions could be, for instance a selection of any seven consecutive years in the panel and hence creating a subset of the panel. Spatial restrictions could involve creating subsets of the panel based on certain administrative subregions of Brazil. Results of estimating the model for temporally- and spatially-restricted subsets of the panel are presented in Tables 2.17 to 2.19 (for GDP per capita as the dependent variable). The coefficients are in most cases of the same sign and statistical significance as the coefficients presented in the main results tables, although for a minority of the subsets of the panel, the coefficients are not significant.

TABLE 2.16 – Robustness check with a constructed event study design

Year	2006		2008		2010		2012		2014	
	UT +PT	PT	UT +PT	PT	UT +PT	PT	UT +PT	PT	UT +PT	PT
T-test	0.549	0.433	0.532	0.423	0.718	0.598	0.555	0.493	0.374	0.430
Test statistic	t(21593)= 5.652, p=0.00	t(341)= 3.78, p=0.00	t(21670)= 7.79, p=0.00	t(418)= 4.80, p=0.00	t(21572)= 7.25, p=0.00	t(320)= 4.95, p=0.00	t(21614)= 9.34, p=0.00	t(362)= 6.19, p=0.00	t(21446)= 5.02, p=0.00	t(194)= 4.45, p=0.00
Number of treated municipalities	11		22		18		51		32	

Note : dependent variable is *GDPpc (log)*. Treatment variable is a dummy variable denoting the presence of a project in a given municipality-year. Control groups - *UT + PT* : Untreated (i.e. never-treated) and pre-treatment period of treated municipalities, *PT* : pre-treatment period only. Only alternate years presented for ease of presentation.

TABLE 2.17 – Robustness check with temporally restricted subsets

Year	2006		2008		2010		2012		2014	
	UT + PT	PT	UT + PT	PT	UT + PT	PT	UT + PT	PT	UT + PT	PT
FE model	0.144	0.105	0.157	0.110	0.153	0.081	0.060	0.019	0.308	0.207
p-score	0.00	0.00	0.00	0.001	0.003	0.091	0.089	0.682	0.002	0.288
Number of treated municipalities	87		84		64		51		32	

Note : dependent variable is *GDPpc (log)*. Treatment variable is a dummy variable denoting the presence of a project in a given municipality-year. Control groups : *UT – Untreated municipalities (i.e. never-treated)*, *PT – pre-treatment period of treated municipalities (i.e. not-yet treated)*. Only alternate years presented for ease of presentation.

TABLE 2.18 – *Regression by macroregions (all project types)*

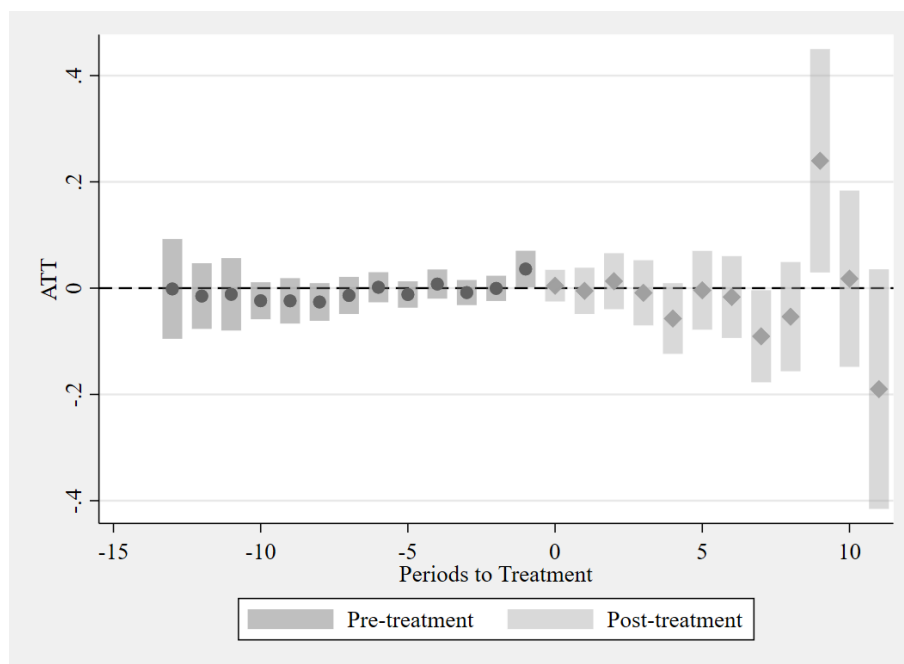
Macroregion	GDPpc				
	Centre West	North	North East	South	South East
Investment <sub>pc</sub> (all projects)	0.015*** (0.003)	0.022*** (0.007)	0.023*** (0.009)	0.006** (0.002)	0.014*** (0.003)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Obs.	4,841	4,420	15,751	12,979	17,538
R2	0.85	0.81	0.77	0.86	0.78

Note : Dependent variable is in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses. Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

TABLE 2.19 – *Regression by macroregions (electricity generation and non-electricity-generation projects)*

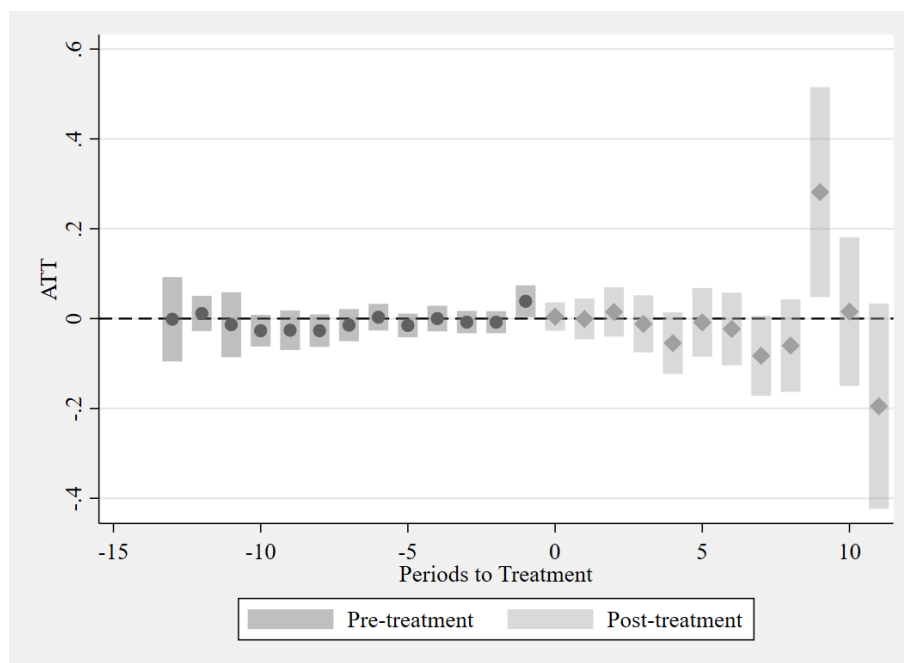
Macroregion	GDPpc				
	Centre West	North	North East	South	South East
Investment <sub>pc</sub> (electricity generation projects)	0.006* (0.007)	0.027*** (0.007)	0.025*** (0.011)	0.001 (0.003)	0.005 (0.004)
Investment <sub>pc</sub> (non- electricity-generation projects)	0.014*** (0.004)	0.014 (0.010)	0.013 (0.008)	0.009*** (0.002)	0.016*** (0.003)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Obs.	4,841	4,420	15,751	12,979	17,538
R2	0.85	0.82	0.77	0.87	0.79

Note : Dependent variable is in logs. All independent variables are in logs. Fixed effects model estimation by OLS using the demeaning method (equivalent to including municipality fixed effects). Heteroskedasticity-robust standard errors in parentheses. Constant and coefficients of population (log), Bolsa Familia spending (log), and of year dummies omitted for presentation. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .



Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Shaded area represents 95 percent confidence intervals. Model specification used as in equation 2.1. Source : authors' calculations.

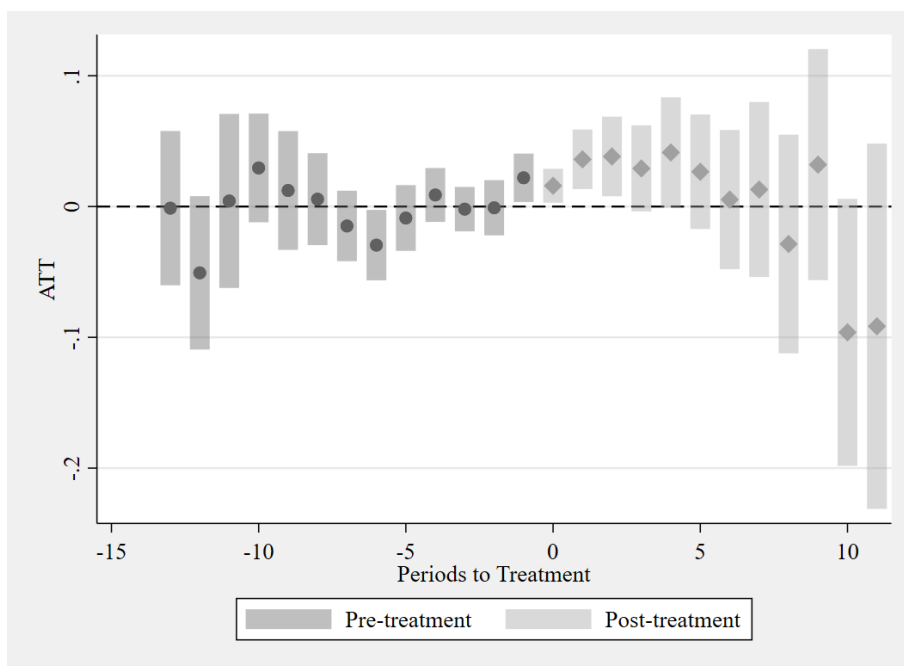
FIGURE 2.6 – Dynamic treatment effects on GDP per capita of electricity generation projects



Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

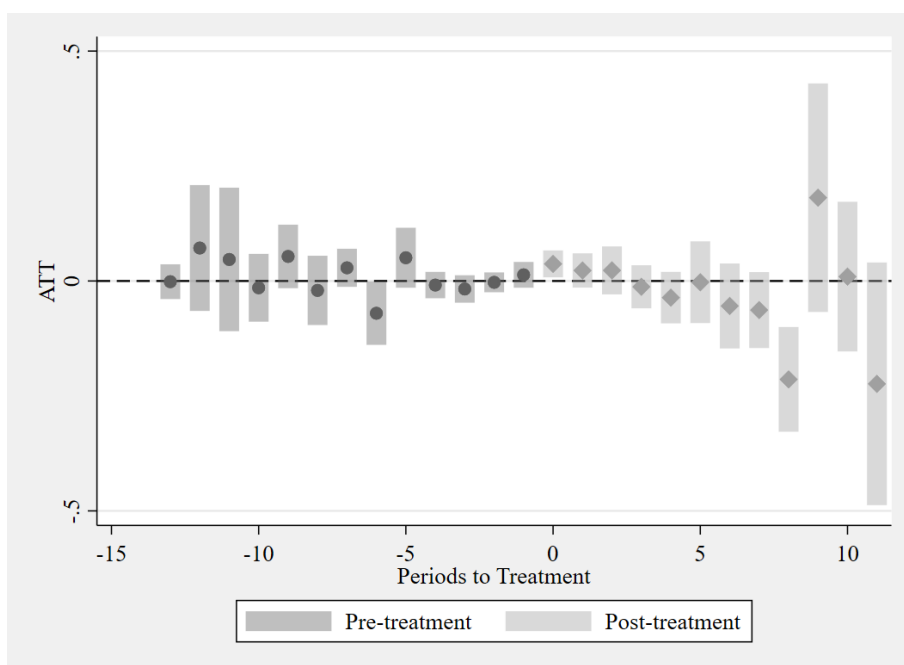
FIGURE 2.7 – Dynamic treatment effects on GDP per capita of clean electricity generation projects





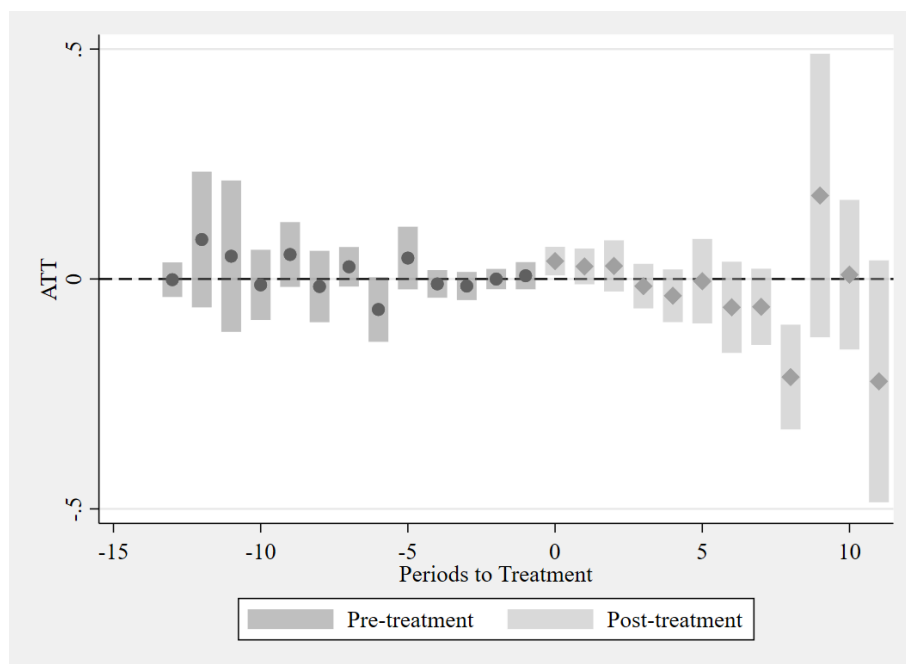
Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.8 – Dynamic treatment effects on GDP per capita of non-electricity-generation projects



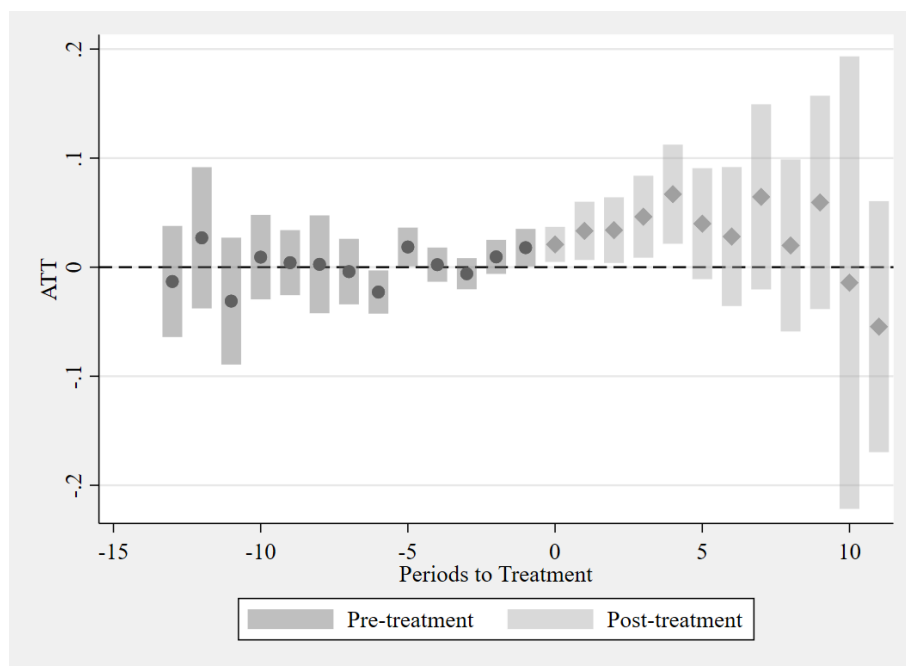
Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.9 – Dynamic treatment effects on employment levels of electricity generation projects



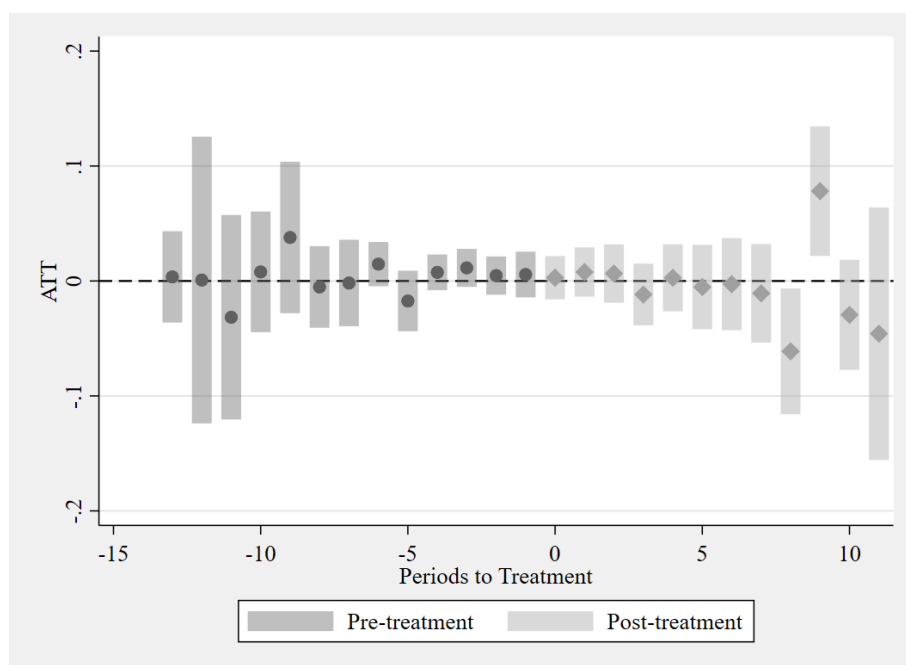
Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.10 – Dynamic treatment effects on employment levels of clean electricity generation projects



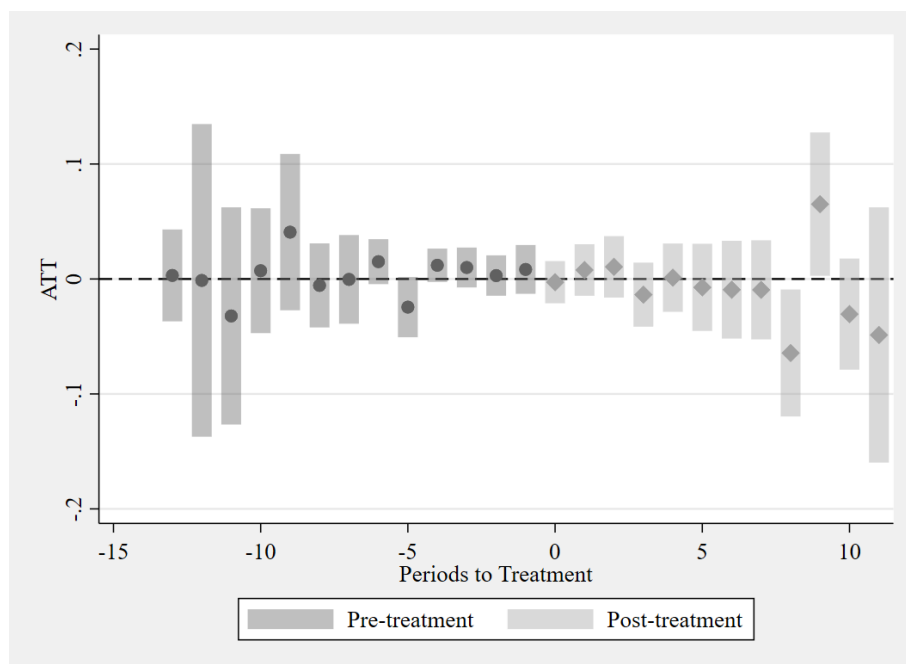
Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.11 – Dynamic treatment effects on employment levels of non-electricity-generation projects



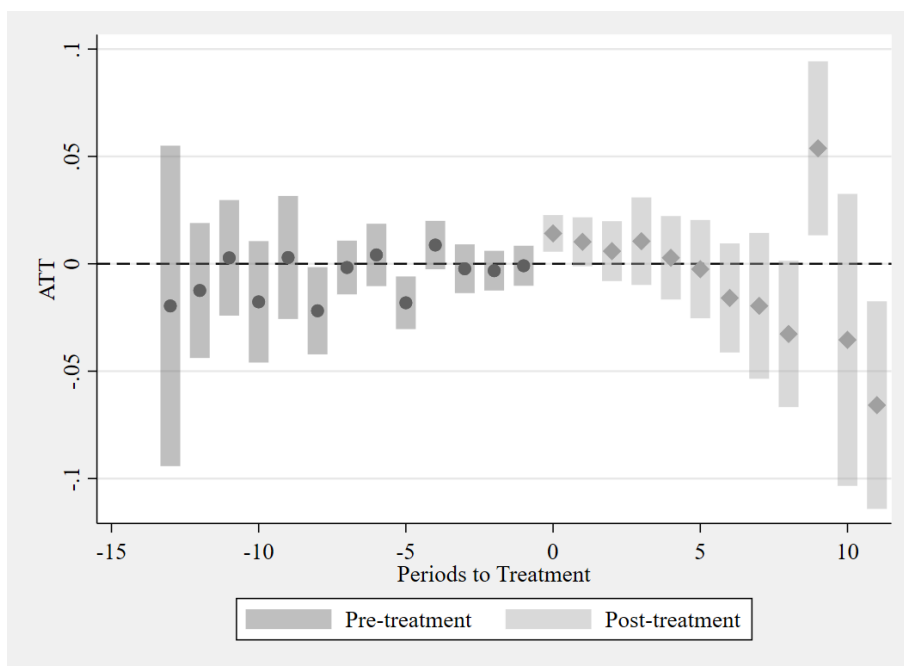
Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.12 – Dynamic treatment effects on mean wage levels of electricity generation projects



Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.13 – Dynamic treatment effects on mean wage levels of clean electricity generation projects



Note : ATT : Average treatment effect on treated. Figure generated using the *csdid* Stata package that implements a difference-in-difference with multiple periods estimator to decompose a TWFE model with staggered treatment to individual  $2 \times 2$  difference-in-difference estimations. Model specification used as in equation 2.1. Shaded area represents 95 percent confidence intervals. Source : authors' calculations.

FIGURE 2.14 – Dynamic treatment effects on mean wage levels of non-electricity-generation projects





# 3

## Wage polarisation in Brazil examined using policy evaluation methods

*A study from São Paulo state using an unconditional quantile treatment  
effects estimator*



## Abstract

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*The question of the Brazilian labour market polarising and its repercussions on wage inequality has recently started receiving attention in the labour economics literature. At the same time, this question is of interest to policymakers and national development banks as well, since the country represents a large emerging economy that has had a recent history with high social inequalities. Using national development bank investments in physical capital as an identifying factor, and an unconditional quantile treatment effects estimator (UQTE), signs of incipient wage polarisation in São Paulo state are found that seems to confirm upcoming literature that deems this polarisation as being generally pro-poor (Firpo et al., 2021), as seen in some other developing countries. These signs are generally consistent with what would be expected from Skill-Biased Technological Change (SBTC) and Routine-Biased Technological Change (RBTC). These results can serve to inform policy debates around the place of wage inequality as a part of sustainable development.*

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## Summary

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### 3.1 Introduction

Wage inequality and income inequality are seen as important components of sustainable development, especially in the case of developing countries that often have other, often competing, exigencies (Scherer et al., 2018). While income inequality in many developing countries has seen a downward trend in the past twenty years, there are concerns that the job market's response to investment in new technologies might harm the cause of inequality reduction through processes of job market polarisation brought about by Skill-Biased Technological Change (SBTC), a concept that eventually evolved into Routine-Based Technological Change (RBTC) (Acemoglu and Autor, 2011).

Brazil has seen a decreasing trend in income inequality since the 2000s, with the Gini index of income inequality falling from 59.0 in 1999 to 53.3 in 2017. The discourse concerning income inequality in the 1980s revolved around the role of returns to education on wages, and the decreasing income inequality in the 2000s was largely credited to improvements in the educational system in the country. In parallel, increases in the minimum wage, a reduction in discrimination in the labour market, and a formalisation of the labour market were also associated with reduced income inequality (de Souza, 2017). Part of this reduction is also attributed to social welfare programmes such as *Bolsa Familia* (Barros, 2007), but the role of other public institutions needs to be better examined.

The Brazilian national development bank (BNDES, hereafter also simply referred to as the Bank) is one such institution which has regularly invested substantial amounts in the economy. The BNDES has regularly invested amounts of around 2 percent of national GDP, and in times of economic downturn, has arguably been used as an instrument of fiscal policy, with its investments reaching up to 4.5 percent of national GDP in 2009.

As a public institution, the BNDES' role in contributing to development in the country merits examination. In this article, the contribution of the Bank's programmes to development objectives is analysed, namely to its distributional impacts, which in turn relates to sustainable development objectives.

A major component of the Bank's investment is in new technology, particularly in physical

capital. These investments are intended to better equip Brazilian industries by way of modernising machinery (including through the purchase of information technology), or, in the case of energy technologies, by investment in clean energy technologies such as wind, solar, or hydroelectric energy generation projects. There exists a large literature that examines technological innovation and its distributional impacts. This literature examines, among other distributional effects, the phenomenon of job polarisation, which was initially focused on skill-biased technological change (SBTC), and later evolved to routine-biased technological change (RBTC) (Goos and Manning, 2007, Katz and Murphy, 1992). Job polarisation refers to the relative increase in the number of high-skilled jobs relative jobs involving medium or low skills (the analogue in terms of occupational wages is termed as wage polarisation) (Acemoglu and Autor, 2011). The job polarisation hypothesis was later seen in certain countries or markets to be U-shaped, indicating a relative decline in medium-skilled jobs relative to both low- and high-skilled jobs (Autor and Dorn, 2013).

The contributions of this article are twofold. First, it extends the literature on labour market polarisation by using microdata (at the worker level) to test for wage polarisation in a Brazilian state, whereas the bulk of the extant literature deals with developed countries. Second, whereas most studies in this domain use changes over time periods to measure labour market polarisation, this article uses exposure to development bank investment as the identifying factor to discern labour market polarisation, which is inspired from the literature on policy impact evaluation. In addition, few studies use a dataset that is representative of all workers in a region in a developing country, which this article uses. The primary objective of the article is to offer policy recommendations to BNDES and other stakeholders by presenting the wage inequality impacts of the Bank's investments using recently-developed econometric methods (unconditional quantile regression).

The remainder of this article is structured as follows : section 3.2 reviews the extant literature, section 3.3 discusses the data and provides descriptive statistics of the data, section 3.4 discusses the estimation strategy, section 3.5 presents and discusses the results, and section 3.6 concludes with policy recommendations.

## 3.2 Literature review

There is a large literature that shows polarisation of the labour markets in various countries. Skill-biased technological change has been widely considered to have played a central role in this polarisation of employment and wages in favour of highly skilled workers (Katz and Murphy, 1992). This hypothesis has since been nuanced in order to focus more on routine versus non-routine tasks involved in jobs, and therefore a routine-biased technological change that favours jobs that involve non-routine tasks that are less prone to automation (or in general, technological innovation that might render them obsolete) and to the loss of jobs involving routine tasks (Autor, Katz and Kearney, 2008, Autor, Levy and Murnane, 2003), hence resulting in a U-shaped polarisation. Recent evidence even suggests that polarisation might date back to as early as the 1950s (Bárány and Siegel, 2018).

Labour market polarisation has been variedly characterised, primarily through wage polarisation and job polarisation (also termed employment polarisation) (Acemoglu and Autor, 2011), but also sometimes through polarisation of working hours (da Silva, Laws and Petroulakis, 2019). Wage polarisation, in particular, has been shown in many studies for many countries and markets (cf. Autor and Dorn (2013), Autor, Katz and Kearney (2008)), but studies have also noted that wage levels (in the US) are not polarised in the same way across time periods, even when there is job polarisation in the concurrent time period (Acemoglu and Autor, 2011, Longmuir et al., 2020). The relationship between job polarisation and wage polarisation is hypothesised to be due to changes in labour demand not being uniform across the distribution – more specifically, due to routine jobs suffering a loss in demand compared to non-routine jobs (Autor et al., 2008), hence leading to increased inequality. Some authors have argued that the relationship might be supply-driven instead, when middle-skilled workers who are displaced move to the bottom of the wage distribution, hence pulling down wages (Beaudry, Green and Sand, 2014).

This polarisation of the labour market has been shown for various countries, especially in the developed world – for the United States (Autor, Katz and Kearney, 2006), in Europe and in the United Kingdom (Goos, Manning and Salomons, 2009, Goos and Manning, 2007), and in Canada (Green and Sand, 2015). Labour market polarisation is generally expected to be slower in developing countries, and limited evidence exists for polarisation in the developing world – Azam (2012) demonstrate a slight polarisation in wages in India between 1993 and 2004, similarly to

Sarkar (2017) in India in the 1990s and 2000s, and Bhorat, Lilenstein, Oosthuizen and Thornton (2020) show it for South Africa between 2000 and 2015, attributing the trend, at least partially, to SBTC. A slower pace of technology adoption, and offshoring of routine tasks from developed to developing countries are likely responsible for this lack of polarisation observed in these countries.

In the Brazilian or Latin American context, few studies exist that deal with labour market polarisation in depth, but the subject has recently started gaining attention. Firpo, Portella, Riva and Ubida (2021) use data from the PNAD survey in Brazil to show a conflicting picture of wage polarisation which was pro-poor between 2003 and 2012 but pro-rich between 2012 and 2019. They also find little evidence for job polarisation in the same periods. Maloney and Molina (2019) find ‘incipient’ signs of job polarisation in Brazil and Mexico, while finding polarisation to be scarce in developing countries in general (in contrast to developed countries). Increasing automation has shown by Gasparini et al. (2021) to affect workers in routine-intensive occupations, but they find no evidence for labour market polarisation, similar to the evidence found by Beylis et al. (2020). There are also few studies (such as the study of Reinhold (2016)) that explicitly attempt to focus on units smaller than the country-level, which is also much needed, considering the large size of the certain countries and labour markets like Brazil.

In order to measure the presence of labour market polarisation (or the lack thereof), most studies available in the literature cited above compare the occupational shares of employment or real wage levels across time periods, to measure job polarisation and wage polarisation, respectively, while simultaneously measuring the increase in technological innovation. In the present article, an alternate way is proposed to elicit the presence or absence of labour market polarisation in São Paulo state. The population’s exposure to investment by BNDES (largely physical capital) over a span of 10 years is used as identification. This is an approach inspired by the policy evaluation literature that seeks to approach a natural experiment to the extent possible using a suitable identification factor.

The majority of the BNDES’ investments that are considered in this article come from the Bank’s *FINEM* line of financment, and can be best described as investments in physical capital<sup>1</sup>. Given the position of the Bank as an instrument of state (fiscal) policy, analytical approaches commonly found in the policy impact evaluation literature are used to perform this study.

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1. With some exceptions : certain forms of intellectual property as well as software are also eligible.

A large section of the policy impact evaluation literature focuses on the effects of physical capital on the economic output of developing countries. The investments studied are typically rural electrification projects (e.g. [Bensch, Kluge and Peters \(2011\)](#), [van de Walle, Ravallion, Mendiratta and Koolwal \(2015\)](#)), or public infrastructure projects like access to the road or rail network (see [Banerjee, Duflo and Qian \(2012\)](#), or [Hooper, Peters and Pintus \(2018\)](#)). While the studies generally show a positive economic impact of these investments, the effect is often heterogeneous based on the type of investment. There is, therefore, the need to consider each type of investment separately. This is in itself not surprising, given that different policy interventions and public investments are meant to target different beneficiaries. Rural electrification, for instance, has been shown to have a positive economic impact on previously unserved populations ([Lipscomb et al., 2013](#)), whereas high-speed rail development has been shown to economically benefit larger urban areas while coming at the cost of areas that are bypassed ([Qin, 2017](#)).

### 3.2.1 From a policy evaluation perspective

Wage impacts, and specifically, poverty impacts of policy interventions have been studied in various settings in the policy impact evaluation literature. In an evaluation of infrastructure interventions and interventions in expanding access to financial institutions, [Khandker and Koolwal \(2010\)](#) study their impacts on income in rural areas and on poverty in Bangladesh. They find that expanding infrastructure in rural areas by means of village electrification, access to paved roads, and irrigation, have generally led to increases in income and consumption levels. However, they note that these impacts have been heterogeneous across the wage distribution, and that the poor have not necessarily been the beneficiaries of these policy interventions. In their study, only the expansion of micro-credit access was linked to benefits for the poorest. In Brazil, [Cavalcanti et al. \(2016\)](#) use the Quantile Treatment Estimator (QTE) of [Firpo \(2006\)](#) to assess the impact of the implementation of the *Bolsa Familia* benefit transfer programme on the labour market. They look specifically at the effect that receiving welfare benefits has on the number of hours worked by individuals and on wages of individuals at different quantiles of these variables. While the substantive scope of their study is quite different from the scope of this present article, the scope of the empirical content of their study is similar to that of the present article, since their study also involves the use of microdata in Brazil from a policy evaluation perspective.

Quantile regression techniques have been used in the development economics literature that pertains to environmental impacts. [Albulescu et al. \(2019\)](#), for instance, use a quantile regression approach to test the Environmental Kuznets Curve hypothesis for 14 countries in Latin America. [Gamper-Rabindran et al. \(2010\)](#) use conditional quantile regression to estimate that targeting piped water access towards beneficiaries in the higher quantiles of Infant Mortality Rate is likely to have larger impacts on reducing infant mortality.

The use of unconditional quantile regressions (UQR), particularly using the Recentered Influence Functions (RIF/RIF-OLS) method has gained popularity since its introduction in the literature by [Firpo, Fortin and Lemieux \(2009\)](#). Numerous studies have since used this method to analyse wage distributions. [Azam \(2012\)](#) uses a UQR to document the evolution of wage levels in India between 1983 and 2004, and finds signs of a U-shaped wage polarisation between 1993 and 2004. [Giangregorio and Marta \(2021\)](#) attempt to explain changes in the wage distribution in Italy in the period 2007-2017 and claim that SBTC might only partially explain the changes in the distribution and in wage inequality. [Bhorat, Lilenstein, Oosthuizen and Thornton \(2020\)](#) analyse the case of South Africa between 2000 and 2015, and find a U-shaped curve in wage increases across the wage distribution, using a UQR. Finally, [Firpo et al. \(2021\)](#) primarily use the UQR method to analyse wage level changes in Brazil between 2003 and 2019.

Responding to the question of distributional impacts of investments is important because it gives us a better insight into the mechanisms behind the reductions in income inequality that have been observed in Brazil over the past two decades. This article responds to this question by comparing the wage levels (used as a proxy for skill) of two sets of populations, one of which was exposed to development bank investment and the other unexposed. Using quantile regression methods inspired by the policy impact evaluation literature, the analysis tests if there is wage polarisation observed in São Paulo state between 2003 and 2013.

From a policy perspective, the study aims to offer insight and recommendations on the impacts of development bank investments, with a view to better compare the Bank's sustainable development priorities with the actually realised effects, and to continue the discussion on the place of wage inequality in the broader concept of sustainable development.



### 3.3 Data and descriptive statistics

The data used for this study is a cross-sectional dataset of 5 percent all persons included in the RAIS annual labour report (*Relação Anual de Informações Sociais*) in the federal state of São Paulo (SP) for 2013, covering around 20 million workers (the sample hence consisting of around 1 million workers). Employers are required to declare to the RAIS, and the report concerns individual employees and details concerning their employment (such as wage and working hours), as well as general socio-demographic details (such as age, sex, and municipality of residence). The data available was anonymised. This report covers all workers in the formal employment sector, and does not cover unpaid work, remuneration outside of an employer-employee relationship, or informal workers. Since the data are employer-reported, only gross earnings through employment are considered, and therefore does not include other sources of income such as rent, interest accrued on savings or capital gains. Taxes and social contributions are also not taken into account. Though the data is a cross-section and does not explicitly include a time-varying component, the analysis is indeed an exploration of the accumulated impacts of exposure to BNDES investment over a period of 10 years (since the investments in the data start from 2003). This effectively amounts to a natural experiment with the population's exposure to BNDES investment as an identifying factor.

To model this natural experiment, at a basic level, two groups of workers are compared : 1) those who live in a municipality with any exposure to BNDES investment since 2003, and 2) those who live in a municipality without exposure to BNDES investment. This comparison between workers exposed and unexposed to BNDES investment is retained for all the models presented in this article.

The established literature that looks at determinants of wage inequality is instructive when it comes to the inclusion of control variables (Fournier and Koske, 2012, Mincer, 1958). Accordingly, some available variables from the RAIS report are used for this purpose. Age, weekly worked hours, and gender have been typically used in the literature as control variables, and are also used in the present study.

Investment data available from BNDES (around 4,000 investments) are also integrated to the

dataset. Detailed information on the type of investment is scarce<sup>2</sup>. The location (municipality) of the investment is known, and it is known that these investments could broadly be classified as investments in physical capital (such as electricity generation), based on the types of capital that are funded by FINEM (BNDES, n.d.). A broad classification of the sectors of investment is shown in Table 3.8 in Appendix A. The analysis for this article makes use of an anonymised version of the RAIS labour report, and hence it was not possible to know which individual workers benefitted from BNDES investments to individual workers or firms. A visual representation of the locations of BNDES investment is shown in Figure 3.1

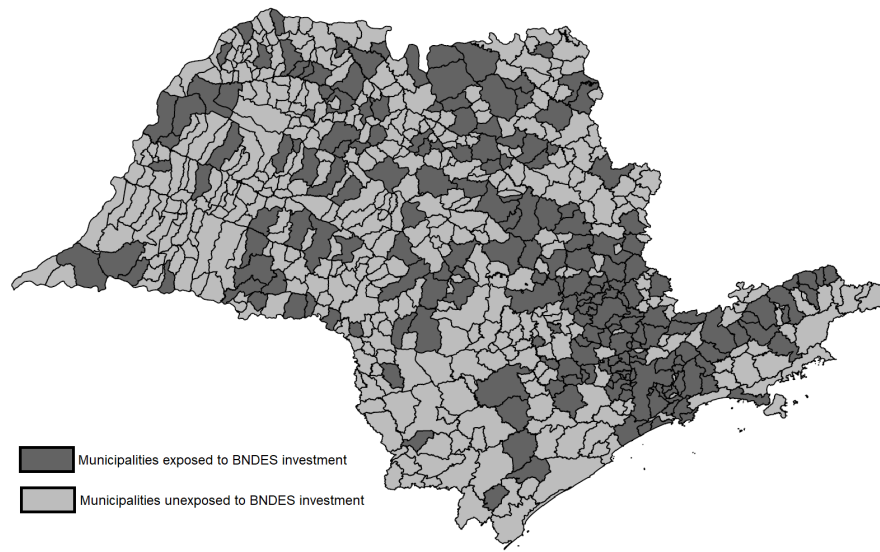


FIGURE 3.1 – *Geographical distribution of BNDES investment among municipalities in São Paulo state*

Table 3.1 presents some descriptive statistics and distributional statistics of monthly wage of workers in the sample, which is the dependent variable used in the regression (and a comparison of monthly wages between the exposed and unexposed groups of workers). Table 3.2 presents the independent variables used in the regressions and their descriptive statistics. A table of correlations between the independent variables is presented in Table 3.7 in Appendix A. In addition to these variables, the municipality of residence of each worker in the sample was also known, and municipality fixed effects were included in the regressions as a covariate.

2. The sector for which the investment is destined is known, but it is unclear for what specific purpose the investment is for, as well as the type of employment it creates/replaces.

TABLE 3.1 – Descriptive statistics of monthly wage of workers in Reais (BRL) (dependent variable)

	All	Exposed workers	Unexposed workers
<i>Percentile</i>			
10th	773	776	755
25th	955	963	900
50th	1,278	1,296	1,143
75th	2,092	2,161	1,637
90th	3,828	4,004	2,479
<i>Other statistics</i>			
N	1,076,702	965,955	110,747
Mean	2,126	2,193	1,546
SD	2,979	3,091	1,595
Min	203	204	204
Max	100,169	100,169	85,509

Note : 1 BRL = ~0.33 EUR. Source : Authors' summary, based on data from the RAIS report

TABLE 3.2 – Descriptive statistics of independent variables

	N	Mean	SD	Median	Min	Max
Dummy for exposure to investment	1,076,702	0.9	0.3	1.0	0.0	1.0
Age (years)	1,076,702	34.4	11.5	32.0	11.0	99.0
Education level (ordinal scale of 1 (illiterate) to 11 (doctorate))	1,076,702	6.6	1.7	7.0	1.0	11.0
Sex (1-Male/2-Female)	1,076,702	1.4	0.5	1.0	1.0	2.0
Working hours (hours per month)	1,076,702	41.8	5.4	44.0	1.0	44.0
GDP per capita of municipality of residence (nominal, 1000 BRL)	1,076,702	45.8	25.4	47.5	6.6	242.9

*Source : Authors' summary, based on data from the RAIS report, from IBGE, and from BNDES*

As is often common practice with wage data used for quantile regression (Angrist and Pischke, 2008), the wage data is transformed to logs, which does not affect the ranking of each worker in the dataset. The wage distribution is as shown in Figure 3.2.

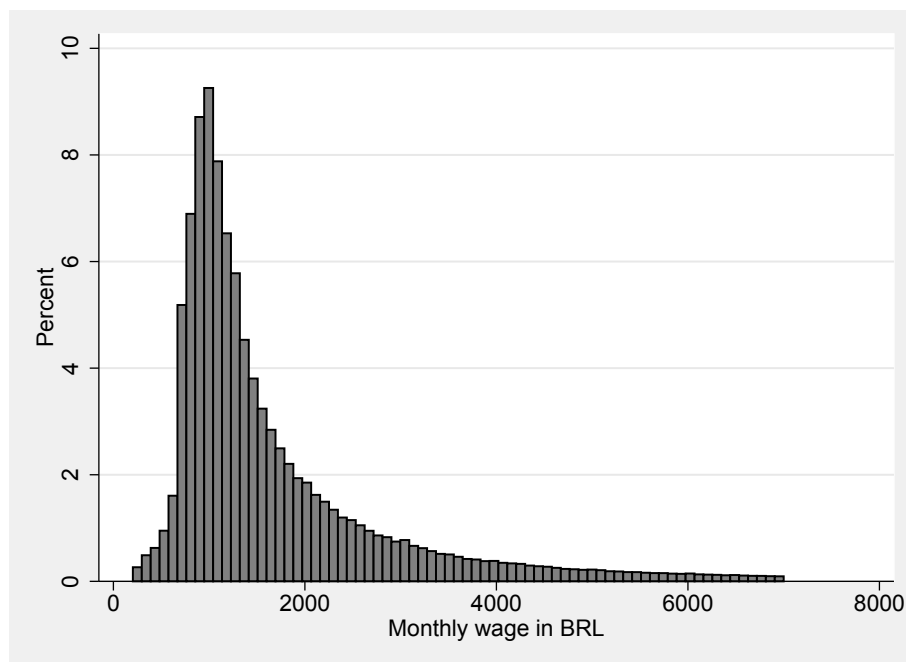


FIGURE 3.2 – *Distribution of wage, truncated at 7000 BRL for presentation purposes. Source : authors' depiction, based on data from RAIS.*

The data presents certain challenges and limitations for estimation due to the specificity of the data available. The data is at the worker level, but due to lack of data, it was not possible to match the treatment (presence of a BNDES investment) to each worker (i.e. it was unknown which worker was directly affected by the presence of a BNDES investment).

As a first step in implementing the research design, a comparison of workers exposed and unexposed to treatment is shown in Table 3.1. The comparison shows a clear difference between workers exposed to BNDES investment and those unexposed, but this difference is very likely to be driven by endogenous assignment of Bank investment, and a simplistic model would have an omitted variable bias. Without taking into account municipality-specific effects, the endogeneity could arise out of the fact that incoming investment might simply just flow to those regions where the corresponding labour market is more dynamic. The estimation strategy and the response to these challenges are discussed below in section 3.4.

### 3.4 Estimation strategy

The effect of exposure to a BNDES investment is likely to vary across workers. As is inherent in the method, an OLS regression would ‘regress to the mean’, hence leaving us without an estimate for other values of the dependent variable that may lie anywhere else along the distribution. This is the primary interest in using techniques of quantile regression to search for impacts on the wage distribution, as has widely been used in the literature that analyses wage inequality ([Angrist and Pischke, 2008](#)).

Two variants of quantile regression are seen in the literature, namely conditional quantile regression (CQR) and unconditional quantile regression (UQR). The CQR method, introduced by [Koenker and Bassett \(1978\)](#), and its extension, the conditional quantile treatment effects estimator (CQTE), in the present article’s empirical case, would estimate the effects of the exposure to a BNDES investment (here an independent variable), on a their wage at a given quantile, given a set of covariates. CQR does not allow for the rank of the worker in the wage distribution does not change in response to the treatment. The regression coefficient is then the difference in the values of the dependent variable at the given quantile between treated and untreated groups ([Fournier and Koske, 2012](#)) (in the case of the present paper, the group that is exposed to investment and the group that is unexposed). The coefficient on an individual variable in a CQR responds to the question : ‘By how much does the wage of a worker (at a given conditional quantile) change if they are now exposed to Bank investment?’. Computationally, a CQR is estimated using the method of Least Absolute Deviation (LAD) at each quantile that requires estimation, a method that seeks to minimise the absolute values of the residuals at each quantile, and is computed using a linear programming algorithm.

What is of more interest, however, to respond to the hypotheses set out in section 3.2, is the unconditional quantile treatment effects estimator (UQTE), using techniques introduced by [Firpo et al. \(2009\)](#) and [Firpo \(2006\)](#). UQTE is useful to assess the impact of exposure to a BNDES investment on the wage distribution of the population exposed to investment (treated) as a whole, relative to those populations that were not exposed to the investment (untreated). This method involves constructing a counterfactual distribution of the treated group that did not receive treatment. This method implicitly ‘allows’ workers to change their rank without affecting the interpretation

of the regression, and the Quantile Treatment Effects (QTE) obtained are the difference in medians of the whole distribution ‘before’ and ‘after’ treatment. The UQTE, therefore, seeks to respond to the question ‘By how much did wages (of those at a given unconditional quantile) change *because* of exposure to Bank investment?’ (Rios-Avila and Maroto, 2022). Firpo et al. (2009) also show the relationship between UQTE and Conditional Quantile Treatment Effects (CQTE) is that it is possible to derive UQTE as a weighted average of all CQTE.

The estimation of the UQTE can be done using recentered influence functions (RIF) of the statistic to be estimated. RIFs have some useful properties that allow for UQTE to be computed using OLS. To summarise the utility of RIFs in this context, a brief explanation of influence functions is offered in Appendix B.

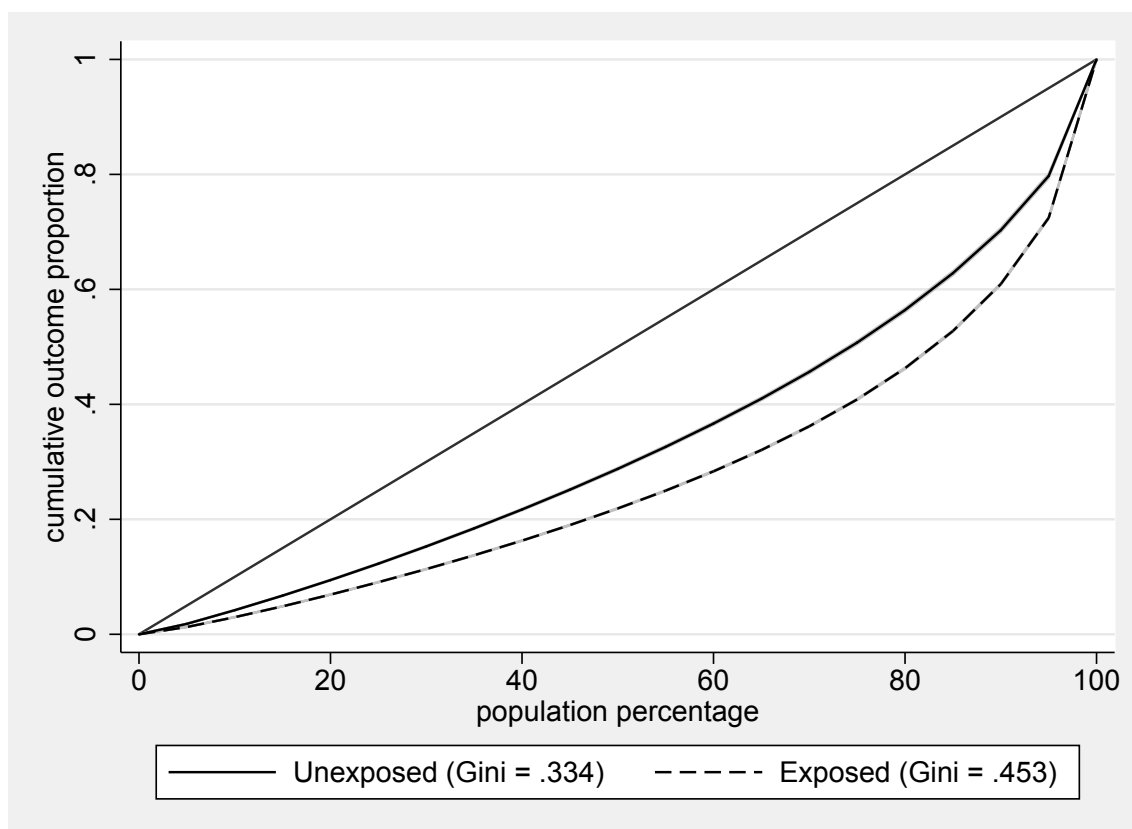


FIGURE 3.3 – Lorenz plot comparing the wage distributions of the populations exposed and unexposed to BNDES investment. Source : author’s depiction based on data from RAIS and BNDES.

Figure 3.3 presents a Lorenz curve to compare the wage distributions of the populations exposed to the bank’s investment and those unexposed to it. It is immediately seen that the distributions are different, and that the wage distribution of the population unexposed to the investment is a more ‘equal’ distribution (in the sense of approaching perfect wage equality). However, this figure, wi-

thout context, can be misleading – investment flows might not be random (which it needs to be, for a perfect natural experiment) and might depend on a range of factors, including the labour market conditions (availability of skilled and unskilled labour), associated infrastructure required for the functioning of an industry (access to raw material, ports, etc.), and where applicable, the geographical suitability of the region (for instance, for wind or solar power installations). In other words, a regression with wage as the dependent variable would likely suffer from endogeneity issues.

Two strategies were used to account for potential endogeneity : the first is the reweighting based on Inverse Probability Weighting (IPW) that weights observations based on their propensity to be exposed to BNDES investment. The second is to include municipality fixed effects that would account for municipality-specific effects. Workers that were extremely likely to be exposed to a BNDES investment and workers extremely unlikely to be exposed were excluded (‘trimmed’) from the analysis since the UQTE is sensitive to extreme values of the propensity score<sup>3</sup> (Rios-Avila and Maroto, 2022).

To delve deeper into the differences in the wage distributions of the populations exposed and unexposed to investment, the difference in wage inequality can be quantified by comparing standard inequality measures between the two populations. While there is a visible difference between the curves in Figure 3.3, this difference might be due to unobserved municipality-specific effects (a worker’s geographical location for instance). Municipality-specific fixed effects can be controlled for and inequality measures between the two groups can be compared, which is done in section 3.5.

Once the quantile treatment effects are estimated, the potential factors that might explain the observed patterns are investigated. As mentioned in the literature review, wage levels have often been used as an indicator for the skill content of jobs (and workers). Occupational sector classification is another way of determining the skill content of jobs, particularly relevant in testing for RBTC. Following the RBTC hypotheses to explain wage polarisation, one would expect certain occupational sectors to be more impacted than others by exposure to investment over the ten-year period. After comparing the wage levels of exposed and unexposed populations categorised by occupational sector, an OLS regression (using the same covariates as for the quantile regressions) is used to investigate if, on average, exposure to a BNDES investment by workers in certain occu-

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3. Workers corresponding to a propensity score of less than 0.1 and greater than 0.9 were excluded.



pational sectors leads to higher (or lower) wages compared to those who were unexposed.

Occupational wages have been often used as a proxy for skill content (Goos et al., 2009). Nevertheless, approaches based on associating tasks with occupational categories are also rather common (Firpo, Fortin and Lemieux, 2011, Sulzbach, 2020). In this article, occupational wages are used as a proxy for the skill and routine content of jobs.

### 3.5 Results and discussion

TABLE 3.3 – *Quantile treatment effects on treated (exposed to investment)*

Treatment effect on treated : exposure to BNDES investment	No controls	No controls, with IPW	Controls	Controls, with IPW
Mean ( <i>lnwage</i> )	0.199***	0.155***	0.056***	0.058***
Robust SE	(0.001)	(0.017)	(0.020)	(0.020)
10th quantile ( <i>lnwage</i> )	0.037***	0.036***	0.096***	0.099***
Robust SE	(0.001)	(0.013)	(0.019)	(0.019)
25th quantile ( <i>lnwage</i> )	0.072***	0.065***	0.096***	0.100***
Robust SE	(0.001)	(0.013)	(0.019)	(0.020)
50th quantile ( <i>lnwage</i> )	0.127***	0.119***	0.019***	0.040
Robust SE	(0.001)	(0.020)	(0.023)	(0.027)
75th quantile ( <i>lnwage</i> )	0.283***	0.204***	-0.036	0.004
Robust SE	(0.003)	(0.034)	(0.037)	(0.044)
90th quantile ( <i>lnwage</i> )	0.489***	0.345***	0.100**	0.051
Robust SE	(0.004)	(0.032)	(0.050)	(0.038)
<i>Measures of wage inequality</i>				
90-10 Inter-quantile ratio ( <i>wage</i> )	1.898***	1.392***	-0.540***	-0.725***
Robust SE	(0.016)	(0.131)	(0.200)	(0.187)
90-50 Inter-quantile ratio ( <i>wage</i> )	0.969***	0.467***	-0.008	-0.179
Robust SE	(0.009)	(0.090)	(0.124)	(0.119)
50-10 Inter-quantile ratio ( <i>wage</i> )	0.144***	0.127***	-0.169***	-0.408***
Robust SE	(0.002)	(0.026)	(0.045)	(0.050)
Gini ( <i>wage</i> )	0.118***	0.070**	0.066***	0.057***
Robust SE	(0.001)	(0.032)	(0.012)	(0.013)

Note : Estimated by RIF-OLS (the dependent variable is the RIF of the distribution statistic). All models provide estimations for overall treatment effects for exposure to BNDES investments. Model specifications alternate between including and not including controls and Inverse Probability Weighting. The constant and coefficients on the covariates : age, sex, working hours, and municipality fixed effects are omitted for presentation. \*p<0.1, \*\*p<0.05, \*\*\*p<0.01.

It can be seen broadly from Table 3.3 that exposure to a project has had an unequal impact on wage levels across the wage distribution, with relatively positive impact on wages on those in the lower percentiles of the wage distribution, (0.099 percent increase in wage levels for those in the 10th percentile). For those in the middle percentiles of the wage distribution, the wage impacts of exposure to a BNDES investment are relatively lower or negative. For those at the highest percentiles of the wage distribution, exposure to a BNDES investment seems to have had a slightly

positive impact on their wages, however, the regression coefficient is statistically insignificant. This polarisation towards the lower wage quantiles (pro-poor wage polarisation) is consistent with what [Firpo et al. \(2021\)](#) find for the entire country in roughly the same time period. In a similar vein to the findings of [Firpo et al. \(2021\)](#), there are also clear signs of ‘incipient’ wage polarisation in the form of a U-shaped curve, since the regression coefficients for the upper quantiles barely fall short of statistical significance.

Wage levels are best seen as an indicator for aggregate labour demand, and the zero (or negative) impact of exposure to investment on wages in certain quantiles might be indicative of a reduced labour demand for those exposed to the investments, compared to those unexposed – a demand-driven effect documented in the literature ([Autor et al., 2008](#)).

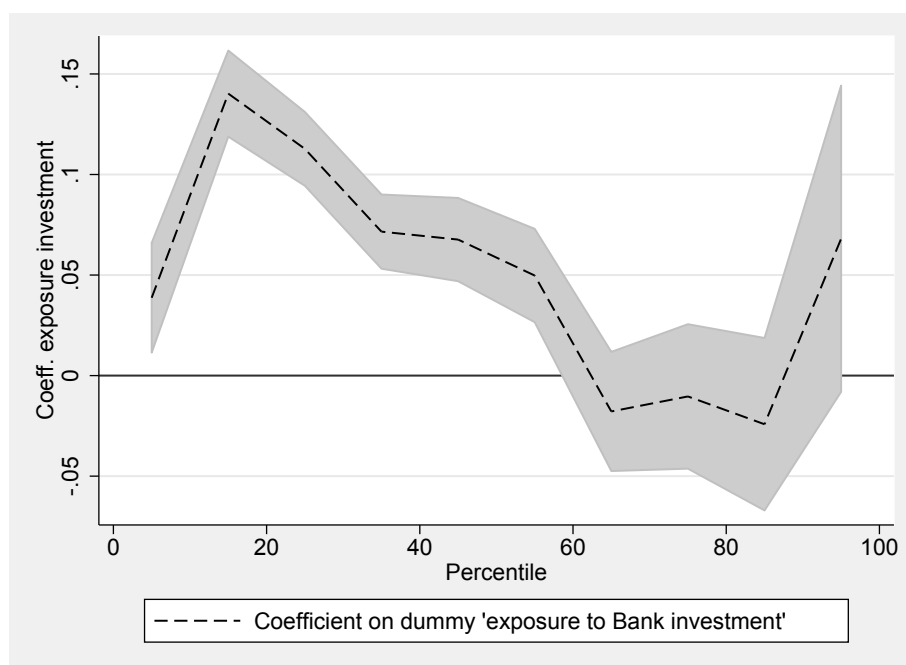


FIGURE 3.4 – Plot of the quantile treatment effects of exposure to BNDES investment (Y-axis shows the coefficient on the project dummy at each percentile (calculated for every 10th percentile, starting from the 5th)). Shaded area represents 95 percent confidence intervals.

### 3.5.1 Different impacts across occupational sectors

Along with wage levels, the occupational sector of a worker’s job are an alternative way of measuring the skill content of jobs (or the ‘routine’ content of jobs, in the context of RBTC). Table 3.4 compares the mean wages between the exposed and unexposed groups, and it is seen that there exists a positive difference between the two groups. Once controlled for covariates,

however (age, sex, weekly working hours), the picture begins to resemble more what would be expected to be seen with SBTC. The Table 3.5 shows the OLS regression coefficients of the wage levels of exposed versus unexposed groups of workers, separated by occupational sector. Many occupational sectors see a positive change in wage levels between exposed and unexposed workers, controlling for the same covariates as in equation 3.5 and including municipality fixed-effects. Those occupational sectors that are clearly the most skilled (high level managers/high level civil servants) show a higher increase in wage levels than those in clearly middle-skilled jobs (mid-level technicians). Workers in the service sector also show a relatively high wage level increase, whereas workers in agriculture/forestry and in construction/manufacturing/metal show a zero or even negative wage elasticity. The combination of these trends point towards SBTC-induced wage polarisation. However, a limitation of the dataset used in this study is that it lacks a matching of occupational sectors to tasks and their ‘routine intensity’, an approach attempted by [Autor and Dorn \(2013\)](#) and [Firpo et al. \(2021\)](#), among others. The challenges in attempting this matching in the Brazilian context has been documented by [Sulzbach \(2020\)](#), but it remains a promising avenue for future research.

Another way of measuring the skill content of a job is by measuring the educational level required to function in that job ([Card and DiNardo, 2002](#)). Performing the above-mentioned OLS regressions by education level, however, the same U-shaped ‘hollowed out’ curve is not seen. In many ways this is similar to the lack of a U-shaped curve noted by [Firpo et al. \(2021\)](#) but rather a trend of higher benefits of exposure to investment for those with higher education levels.

A potential alternate measure to measure labour market polarisation, namely ‘working hours polarisation’ has been evoked in the literature ([da Silva et al., 2019](#)). However, while there seems to be a difference between the average working hours between exposed and unexposed groups, most of these effects seem to reduce or vanish when covariates are controlled for.

Occupational sector	N	Mean wage (all)	Mean wage (exposed)	Mean wage (unexposed)	Difference in means (exposed - unexposed)	p-value (t-test)
Agriculture/forestry	34,831	1,283.7	1,344.1	1,208.6	135.4	0.00
Services/shop sellers	264,774	1,322.5	1,341.8	1,137.2	204.6	0.00
Construction/ electricians/textile/...	246,709	1,654.5	1,681.2	1,449.5	231.6	0.00
Administrative services workers	218,622	1,720.3	1,737.6	1,533.3	204.2	0.00
Metal/paper/ food/energy/...	35,978	1,814.6	1,868.3	1,483.3	385.0	0.00
Maintenance/repair	24,783	2,164.4	2,245.5	1,791.8	453.6	0.00
Mid-level technicians	121,414	2,575.7	2,622.3	1,911.7	710.5	0.00
Armed forces/ police/ fire-fighters	5,049	3,614.7	3,639.0	1,654.8	1,944.2	0.00
Professionals of the sciences and arts	83,727	4,707.8	4,877.7	2,893.2	1,984.1	0.00
Senior civil servants/ executives	40,487	6,564.9	6,887.8	3,076.9	3,810.9	0.00

TABLE 3.4 – Comparison of mean wages by occupational sector (ordered by mean wage of occupational sector)

### 3.5.2 Robustness checks and limitations

As the first robustness check, the estimation was repeated for a year other than 2013 – in this case for 2006. A similar shape of the curve as seen for 2013 (Figure 3.4) could be expected to be seen again, but with a reduced effect size, which is largely what is seen in Figure 3.5, with the U-shaped curve present again (the effect size seems to be even smaller for the lowest quantiles, however).

Secondly, A placebo test is performed by assigning exposure to investment randomly across municipalities. There should not be any effect of exposure to investment on wage levels that is observed, which can be ascertained in Figure 3.6 (note the modified scale of the Y-axis).

It is important to nuance these findings by specifying that wages are only one component of an individual's income (and in turn, their wealth). In addition, the data that is used in this article pertains to formal employment that is reported to the RAIS report, and does not include informal employment or workers in the shadow sectors.

TABLE 3.5 – OLS regressions on changes in mean wage levels by occupational sector (ordered by mean wage of occupational sector)

Occupational sector	Regression coefficient (monthly wage (log))
Agriculture/forestry	-0.003
Robust SE	(0.111)
Services/shop sellers	0.145***
Robust SE	(0.024)
Construction/electricians/textile/...	0.046
Robust SE	(0.03)
Administrative services workers	0.097**
Robust SE	(0.041)
Metal/paper/food/energy/...	-0.470**
Robust SE	(0.20)
Maintenance/repair	0.037
Robust SE	(0.11)
Mid-level technicians	0.264***
Robust SE	(0.088)
Professionals of the sciences and arts	0.016
Robust SE	(0.117)
Senior civil servants/executives	0.180
Robust SE	(0.213)

Note : Estimated by OLS. The independent variable of interest is a dummy variable for exposure to BNDES investment. The constant and coefficients on the covariates : age, sex, working hours, and municipality fixed effects are omitted for presentation. \*p<0.1, \*\*p<0.05, \*\*\*p<0.01.

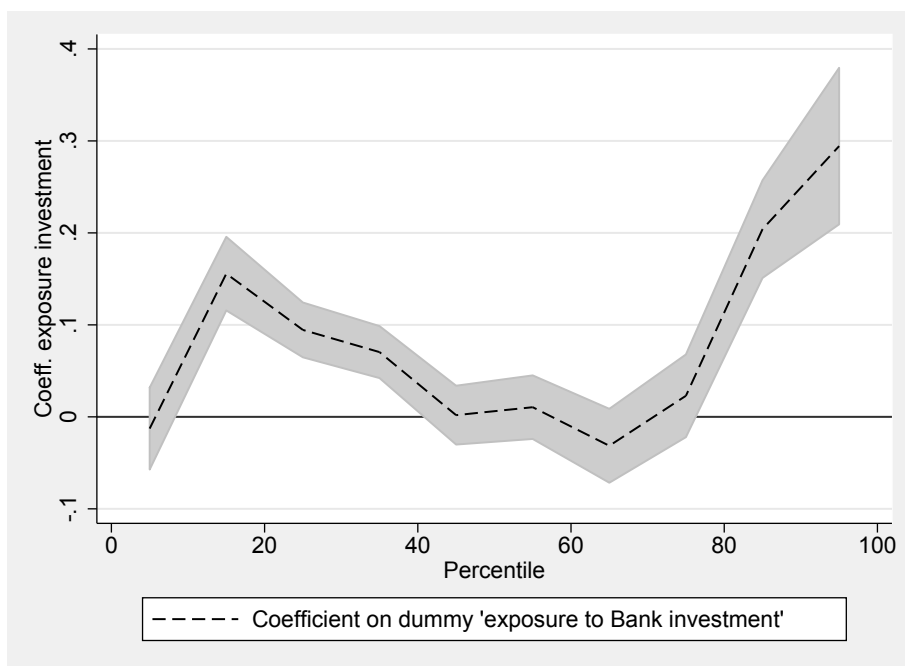


FIGURE 3.5 – Results plot for the year 2006 (sample of 5 percent) (Y-axis shows the coefficient on the exposure dummy at each percentile (calculated for every 10th percentile, starting from the 5th)). Shaded area represents 95 percent confidence intervals.

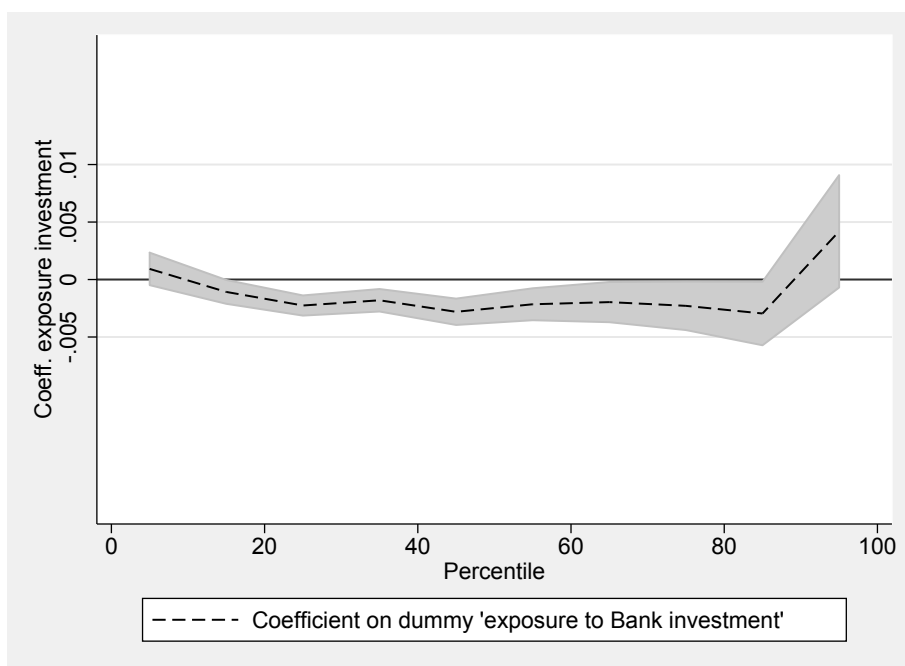


FIGURE 3.6 – Results plot for the year 2013 (sample of 5 percent) with random exposure to treatment (Y-axis shows the coefficient on the project dummy at each percentile (calculated for every 10th percentile, starting from the 5th)). Shaded area represents 95 percent confidence intervals.

As noted previously, the approach used in this paper that uses wage levels as a proxy for skill levels can only expect to test the presence of labour market polarisation through SBTC. A more accurate matching of occupational sectors and the tasks involved in them needs to be done in order

to ascertain if the routine content of jobs actually plays a role in wage polarisation. More work is also needed to explain the lack of a U-shaped curve observed when using alternate measures of the skill or routine content of jobs.

The lack of a true panel structure with individual worker identifiers in the data hinders an analysis that includes a time trend, which would be even more effective to account for time-varying effects. This is a direction for future research that could potentially exploit the time dimension to extract further insights and evolutions of the labour market across time.

Finally, it is to be noted that this article is concerned with São Paulo state, which occupies an important place in the Brazilian economy. Other states (not to mention other regions in the developing world) might present different responses to incoming developing investment, which need to be considered on their own merits. Nevertheless, analysis of the case of São Paulo, as presented in this paper, might be useful for regions that share similar characteristics, and might ultimately represent a piece of a larger puzzle that is unfolding in this literature.

### **3.6 Conclusion**

The literature that analyses labour market evolutions in developing countries, and in particular labour market polarisation, is growing. In the context of São Paulo state in Brazil between 2003 and 2013, the present article provides evidence to support [Firpo et al. \(2021\)](#)'s demonstration of a largely 'pro-poor' growth in wage levels for roughly the same period. There are, however, small signs of a U-shaped polarisation of wage levels, with middle-skilled workers facing stagnant wage levels. There is indication to suggest that higher-skilled occupations have seen large wage level increases, followed by those in the lower-skilled service sectors. Certain sectors even see a reduction in wage levels, possibly due to reduced demand for routine tasks. A large literature that deals with SBTC and RBTC focuses on developed countries has documented this phenomenon in certain developed countries, but this article adds to an increasing number of articles that show signs of 'incipient' labour market polarisation. Further research is however needed to confirm these trends.



An alternate identifying factor that is not yet seen in the literature has been exploited to test for the presence of wage polarisation. The exposure (or the lack thereof) of the population to BNDES investment since 2003 has been used to compare two groups of the population – the exposed population has been exposed to increased public sector investment, and specifically to new equipment in the form of physical investments.

In terms of policy impacts and recommendations, the effect of exposure to BNDES investment on wage inequality is not uniform – there seems to be a reduced lower-tail inequality, as well as a reduced 90-10 interquartile ratio, whereas the Gini index slightly increases. This contributes to the discussion on the place of wage inequality in sustainable development, and the various ways of measuring inequality. Most importantly, the results presented here aim to provide impetus to national development banks, and the BNDES in particular, to take into account the distributional impacts of their investments, with all its nuances, and to better formulate their responses to the challenges posed by the need for sustainable development. The beginnings of the increased awareness of socio-economic factors in sustainable development can be seen of late : the BNDES has recently approved an internal ‘Social, environmental, and climate policy of the BNDES system’, approved on 7 June 2022 that does explicitly recognise socio-economic aspects in addition to environmental aspects of sustainable development ([BNDES, 2022](#)).

The recommendation would naturally be for more development banks to establish similar or more ambitious policies. Practically, the recommendation would be for the BNDES and other development banks to systematically measure the skill and routine content of the actual employment created due to their investments. That would allow for more accurate and effective evaluation of the Bank’s investments and of development investments in general as pertaining to labour market polarisation due to SBTC or RBTC, in line with including reductions in wage inequality in notions of sustainable development.

## **Acknowledgements**

The author would like to thank the participants at the IREGÉ laboratory seminar in March 2022 for their valuable feedback on this article.

### 3.7 Appendix A

TABLE 3.6 – *Brazilian classification of occupations (CBO) 2002 – broad groups*

Code	Group	Competence level
0	Armed forces, police, and firefighters	NA
1	Senior civil servants, executives of public interest organisations, of companies, and business owners	NA
2	Professionals of the sciences and arts	4
3	Mid-level technicians	3
4	Workers in administrative services	2
5	Workers in services, sellers in shops and markets	2
6	Workers in agriculture, forestry, fisheries, mechanisation of agriculture	2
7	Workers in production of industrial goods and services <ul style="list-style-type: none"> <li>- Extractive industry and civil construction</li> <li>- Transformation of metals and composites</li> <li>- Manufacturing and installation of electrics/electronics</li> <li>- Assembly of precision and music instrument</li> <li>- Jewellers, glazers, ceramists</li> <li>- Textile, tanning, apparel, and graphic arts</li> <li>- Woodworking and furniture</li> <li>- Workers in transversal functions</li> <li>- Artisanal workers</li> </ul>	2
8	Workers in production of industrial goods and services <ul style="list-style-type: none"> <li>- Continuous processes workers and other industries</li> <li>- Metal and construction materials</li> <li>- Paper and cellulose</li> <li>- Food, drinks, and tobacco</li> <li>- Energy and water utilities</li> <li>- Operators of other industrial installations</li> </ul>	2
9	Maintenance and repair workers	2

TABLE 3.7 – *Correlation coefficients between independent variables*

	Wage	Age	Working hours	Sex
Wage	1.00			
Age	0.21	1.00		
Working Hours	-0.06	-0.05	1.00	
Sex	-0.08	-0.03	-0.15	1.00

Source : Author's summary, based on data from the RAIS report. Working hours refer to the number of hours worked monthly. Sex - 1 : Male, 2 : Female

TABLE 3.8 – *Description of investment types in São Paulo state between 2003 and 2013*

Sector	Number of projects	Investment (million BRL)
Infrastructure	1130	40.42
Industry	1277	30.08
Services	608	12.41
Agriculture and fisheries	169	2.00
Total	3184	84.91

Source : Author's summary, based on data from BNDES.

TABLE 3.9 – Descriptive statistics of monthly wage by education level (in BRL)

Education level	All			Exposed			Unexposed		
	N	Mean	Median	N	Mean	Median	N	Mean	Median
Illiterate	46,174	1,266.3	1,101.1	37,396	1,295.2	1,123.0	8,778	1,143.2	1,010.0
Till 5 <sup>th</sup> year of primary education	502,306	1,445.8	1,183.6	410,797	1,473.0	1,198.2	91,509	1,323.7	1,123.8
5 <sup>th</sup> year of primary education	685,004	1,505.9	1,201.9	553,524	1,539.1	1,216.2	131,480	1,366.1	1,148.2
6 <sup>th</sup> to 9 <sup>th</sup> year of primary education	1,213,423	1,474.8	1,168.2	1,036,807	1,498.5	1,176.6	176,616	1,335.7	1,116.0
Primary education completed	2,464,264	1,479.6	1,158.3	2,143,711	1,503.4	1,168.2	320,553	1,320.3	1,094.2
High school not completed	1,707,165	1,306.5	1,040.6	1,507,980	1,320.7	1,045.1	199,185	1,198.9	1,008.3
High school completed	10,536,139	1,607.3	1,198.6	9,538,028	1,629.0	1,205.7	998,111	1,399.6	1,117.8
Bachelor degree not completed	860,174	2,449.7	1,669.4	811,956	2,486.5	1,695.9	48,218	1,829.9	1,295.4
Bachelor degree completed	3,413,311	4,864.8	3,106.9	3,190,502	4,990.9	3,202.0	222,809	3,059.0	2,138.7
Masters degree	72,639	6,143.9	3,851.0	67,580	6,339.0	4,017.0	5,059	3,537.6	2,361.7
Doctoral degree	33,448	9,172.0	7,934.7	32,174	9,357.7	8,268.4	1,274	4,481.2	3,055.8
Total	21,534,047	2,130.7	1,289.0	19,330,455	2,197.7	1,304.5	2,203,592	1,542.5	1,150.3

Source : Author's summary, based on data from the RAIS report

TABLE 3.10 – Descriptive statistics of monthly wage by occupational sector (in BRL)

	All			Exposed			Unexposed		
	N	Mean	Median	N	Mean	Median	N	Mean	Median
0-Armed forces/police/firefighters	102,644	3,633.3	3,160.3	102,339	3,639.1	3,160.3	305	1,694.9	1,169.1
1-Senior civil servants/executives	808,709	6,556.9	3,321.1	738,474	6,887.9	3,559.1	70,235	3,076.9	1,916.7
2-Professionals of the sciences and arts	1,685,138	4,727.1	3,242.6	1,557,141	4,877.8	3,391.3	127,997	2,893.7	2,100.5
3-Mid-level technicians	2,433,315	2,576.6	1,836.8	2,276,679	2,622.4	1,874.3	156,636	1,911.8	1,431.0
4-Administrative services workers	4,364,947	1,722.9	1,151.8	4,050,289	1,737.6	1,155.2	314,658	1,533.4	1,117.9
5-Services/shop sellers	5,293,873	1,323.8	1,032.3	4,826,652	1,341.8	1,039.6	467,221	1,137.2	973.0
6-Agriculture/forestry	701,167	1,284.7	1,082.5	393,562	1,344.1	1,126.3	307,605	1,208.6	1,026.5
7-Construction/electricians/textile/...	4,924,368	1,654.2	1,307.8	4,350,699	1,681.2	1,319.3	573,669	1,449.6	1,236.3
8-Metal/paper/food/energy/...	713,541	1,805.1	1,360.2	596,170	1,868.4	1,397.3	117,371	1,483.4	1,205.5
9-Maintenance/repair	499,637	2,186.8	1,626.0	434,950	2,245.5	1,673.5	64,687	1,791.8	1,341.3
Total	21,527,339	2,130.6	1,288.9	19,326,955	2,197.6	1,304.4	2,200,384	1,542.3	1,150.0

Source : Author's summary, based on data from the RAIS report. The numbers preceding each occupational sector correspond to their CBO classification.

### 3.8 Appendix B

This appendix briefly describes the background relevant to Recentered Influence Functions (RIFs), which are used in the unconditional quantile effects estimator (UQTE).

If  $v(F_Y)$  is a statistic (mean, median, quantile, Gini, etc.) of a given distribution  $Y$ , the introduction of a new observation  $y_i$  would change the distribution  $F_Y$  to  $G_Y$ , in the direction of  $H_{y_i}$ . This can also be thought of as the effect of an infinitesimally small change  $\varepsilon$  in  $F_Y$ . The Influence Function (IF) is a measure of the rate of change of the distributional statistic due to this infinitesimal change  $\varepsilon$  in the original distribution.

The IF can be formally defined as :

$$IF\{y_i, v(F_Y)\} = \lim_{\varepsilon \rightarrow 0} \frac{v\{(1-\varepsilon)F_Y + \varepsilon H_{y_i}\} - v(F_Y)}{\varepsilon} = \frac{\partial v(F_Y \rightarrow H_{y_i})}{\partial \varepsilon} \quad (3.1)$$

The Recentered Influence Function (RIF) can be defined as :

$$RIF = \{y_i, v(F_Y)\} = v(F_Y) + IF\{y_i, v(F_Y)\} \quad (3.2)$$

RIFs have some useful properties such as :

$$\int RIF\{y, v(F_Y)\} dF_y = v(F_Y) \quad (3.3)$$

This implies that the expected value of RIFs constructed using all values of  $y_i$  is the statistic itself (making them useful for estimation through OLS) (Rios-Avila, 2020).

Since the interpretation of the coefficients on the RIFs are valid only for infinitesimally small changes in the distribution, Firpo and Pinto (2016) suggest methods to estimate treatment effects when the independent variable is binary.

The treatment effect can be defined as :

$$\Delta \hat{v} = v(\hat{F}_{Y_1}) - v(\hat{F}_{Y_0}) \quad (3.4)$$

Where  $F_{Y_1}$  refers to the distribution of the treated individuals, and  $F_{Y_0}$  pertains to the distribution

of the untreated individuals (both of these are estimated), and  $v$  is any distributional statistic.  $F_{Y_0}$  amounts to an unobserved counterfactual.

The properties of equation 3.4 and those of IFs and RIFs mentioned above can be used in a linear regression equation that would allow for the inclusion of additional variables as controls. The equation to be estimated is :

$$RIF\{y, v(F_Y)\} = X_1\beta_1 + \mathbf{X}'\beta + \varepsilon_i \quad (3.5)$$

where  $X_1$  is the independent variable of interest, and  $\mathbf{X}'$  is a vector of covariates.  $v(F_Y)$  represents the distributional statistic of interest, in this case the value of the wage distribution at a given quantile. As for the interpretation of the coefficient  $\beta_1$  (for instance), it would be the change in the distributional statistic for each unit increase in the unconditional mean of  $X_1$  (Rios-Avila, 2020). In the present model,  $X_1$  is a dummy variable to denote exposure to BNDES investment, and the dependent variable is the log of the wage. For example, if one wants to consider the 50th percentile (median) of the wage distribution,  $v(F_Y)$  would be  $q_Y(\tau)$ , and  $\beta_1$  would indicate the percentage change in  $q_Y(0.5)$  (the wage at the 50th percentile) for a unit change in  $X_1$  (which, in this case would mean : unexposed to investment to exposed to investment)

However, equations 3.4 and 3.5 hold only under an assumption of unconfoundedness (of exposure to investment), which might be a strong assumption to make. A non-parametric method can be used to control for confounding. Firpo (2006) and Firpo and Pinto (2016) offer a way to perform the regression by weighting individuals according to their propensity to be treated, amounting to an Inverse Probability Weighting (IPW), hence giving an unbiased estimate. The propensity to be exposed to treatment is calculated using a probit model with the variables *age*, *sex*, and *GDPpc* of municipality of residence as explanatory factors. The reweighting ensures that those workers most likely to be exposed to investment are weighted lesser in the regression, and the inverse for those less likely to be exposed to treatment.





## General Conclusion

The three chapters of this thesis look at different aspects of sustainable development in Brazil using different perspectives (macro-meso-micro level) using rich spatially-organised datasets at each level of analysis (macro-meso-micro) and detailed data of development projects. With the help of recently developed econometric methods, the impact of investments in development have been studied, and their socio-economic externalities quantified. While environmental aspects play a central role in sustainable development, many, including the United Nations, have accepted the view of sustainable development that includes broader socio-economic aspects of development as well, as evidenced by the UN Sustainable Development Goals, among others. In Brazil, development investment has come through different channels – some are more direct in the form of state involvement in development projects such as through the national development bank BNDES, whereas others are more indirect, such as investment that comes in thanks to mechanisms such as the Clean Development Mechanism. In this thesis, these two channels of development investment are examined in order to elicit and quantify their socio-economic impacts, notably on employment, wage levels, and inequality.

The CDM, having its origins in the Kyoto protocol, was an attempt to balance the achievement of the carbon mitigation targets of signatory countries with the development needs of non-Annex-I countries. In the first chapter of the thesis, it was found using a difference-in-differences model that CDM projects in Brazil led to reductions in income inequality, poverty, and unemployment between 2000 and 2010. Notably, these reductions depend on the type of project. Methane avoidance, hydroelectric, and biomass projects were the project types that drove these reductions. Using theories of FDI inflows and their effects on the labour market, it was theorised that the differential impacts of different project types might be due to the sector in which employment was created due to these investments. More specifically, it was proposed that increased employment in the primary and secondary sectors leads to higher reductions in income inequality, poverty, and

unemployment, compared to the tertiary sector. Despite legitimate concerns in the literature about the additionality of these projects, the study offers a policy evaluation that aims to guide ongoing and future international climate negotiations by calling for more close project monitoring as well as for a closer consideration of socio-economic impacts in addition to environmental impacts in the design of future CDM-like mechanisms.

A deeper look into the differentiated socio-economic impacts of energy generation investment was offered in comparison with non-energy-generation investment in the second chapter. The investments of the Brazilian national development bank, BNDES, were analysed to this effect. The general finding is that of weaker effects on economic output, employment levels, and on wage levels of energy generation investments compared to non-energy-generation investments, and within energy generation investments, clean energy generation investments seem to have a smaller impact on these three socio-economic indicators. The literature points to the possibility of the differing labour intensities between project types might contribute to these different impacts. This research opens the question on what sustainable development really entails, particularly for a development bank such as the BNDES, and to what extent socio-economic impacts of investments need to be taken into account in addition to the environmental impacts.

In line with the theme of analysing the macroeconomic impacts of development bank investment, the third chapter turns to the question of wage polarisation in São Paulo state in Brazil over a period of ten years, between 2003 to 2013. The question of wage polarisation in response to investment in new technologies – a question well researched in the labour economics literature pertaining to the developed world – was analysed in the context of a Brazilian state, hitherto not studied in detail. Using recent methods in econometrics, evidence for wage polarisation is found that is consistent with Skill-Biased Technological Change (SBTC). This has implications for labour market policy, especially as it pertains to questions of wage inequality.

While there is presently an increased impetus across the world to achieve emissions mitigation targets in the light of the Paris Agreement and successive COPs, there remains the need to consider sustainable development in all its dimensions. This thesis therefore represents a step further in integrating socio-economic factors in the ambit of sustainable development, and this is achieved using the concept of externalities of development investment. Quantifying and evaluating these externalities, socio-economic and environmental alike would allow for a more accurate

and comprehensive pricing in, or internalisation, of all the effects that sustainable development investment implies – positive and negative. This in turn would facilitate a more efficient allocation of resources and set more appropriate market signals that would expedite the progress towards the goals of sustainable development, in the sense of the term developed by the 1992 Rio Declaration on Environment and Development. The policy recommendations that follow the three articles of the thesis are therefore in this direction.

Firstly, the task of the researcher or evaluator would be made easier (or possible at all) if socio-economic outcomes as well as investment characteristics are better monitored and measured. For policymakers and administrators in Brazil and in other countries, concretely, this implies the reliable and systematic collection of socio-economic data relating to beneficiaries as well as data on the employment generated (or lost, as the case may be) directly as a result of these investments.

Secondly, an efficient and effective allocation of resources and capital by national administrative bodies and by development banks should take into account the exigencies of, ideally, all aspects of sustainable development as per the SDGs, but particularly the environmental and socio-economic aspects. Extreme poverty and inequalities are still present in many countries, particularly among developing countries, and policymakers are faced with the need to respond to a multitude of sustainable development objectives. An improved quantification of externalities, as is done in this thesis, aims to guide policymakers and administrators toward a more efficient allocation of development investment and a more effective implementation of development projects. The phenomenon of labour market polarisation, in particular, could be of rising concern to populations even in developing countries or its regions. Inklings of an increased awareness of socio-economic factors in sustainable development can be seen at the BNDES. The Bank, on 7 June 2022 approved a ‘Social, environmental, and climate policy of the BNDES system’, that provides recognition of socio-economic aspects in addition to environmental aspects in notions of sustainable development (BNDES, 2022).

Thirdly, ongoing and future international climate negotiations are an important platform to reinforce the importance of sustainable development prerogatives in international mitigation finance destined towards developing countries. An efficient allocation of mitigation resources can only be in the service of reaching the climate targets agreed in the Paris Agreement. Some progress in considering sustainable development goals in the successor to the Kyoto-era CDM has been made,

but a more comprehensive consideration of socio-economic factors in addition to environmental goals needs to be strived for.

The three chapters offer perspectives at different scales – starting from a macro-scale analysis more relevant to international climate policy to a meso-scale relevant at a (Brazilian) national scale, to a micro-scale analysis pertaining to workers in a Brazilian federal state. In sum, the three chapters each analyse an aspect of sustainable development that is currently under question in contemporary public policy. The findings, grounded in the economics literature, intend not only to provide policymakers insight into the socio-economic externalities of development investments, but also to reinforce the role of socio-economic factors in broader notions of sustainable development.

In continuation with the work presented in this thesis, I would like to capitalise on recent advances in econometric evaluation methods to analyse measures and policies in the environmental and development economics domains. Analyses of developing countries present a particularly interesting case since reliable data is often scarce, and evaluations of policy implications of such studies might potentially be very valuable for the policymakers concerned, not to mention the populations themselves. At the micro-level, exploring questions of acceptance of emissions mitigation policies and measures, especially in developing countries, is also a trajectory worth exploring. Experimental approaches have been used in the literature to test similar questions, and I look forward to working with similar or complementary methods to respond to the problematiques treated in this thesis.



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# Investissement dans le développement durable au Brésil et externalités socio-économiques : trois essais empiriques

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## Résumé

À l'heure où les effets du changement climatique anthropique deviennent visibles et où l'on attend des pays qu'ils contribuent aux réductions des émissions de gaz à effet de serre, les débats se concentrent souvent sur les pays en développement, considérés comme les moteurs de la croissance économique – une croissance qui entraîne une amélioration des conditions socio-économiques, notamment en ce qui concerne la création d'emplois et la réduction des inégalités sociales et de la pauvreté. Ces pays sont depuis longtemps confrontés à un dilemme politique qui oppose les préoccupations environnementales, d'une part, et les besoins de développement, d'autre part. Le concept de développement durable vise donc à donner une orientation au monde en développement qui tienne compte des facteurs environnementaux et sociaux (entre autres). En utilisant des méthodes d'évaluation économétriques, cette thèse examine de manière critique les impacts que les investissements dans le développement (durable) ont eu sur les indicateurs socio-économiques au Brésil, en particulier sur l'inégalité des revenus et la création d'emplois.

**Mots-clés :** développement durable, méthodes économétriques, Brésil

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## Abstract

In the present era where the effects of anthropogenic climate change are becoming visible, and where countries are expected to contribute to emissions mitigation, the spotlight is often on developing countries, which are often considered to be engines of economic growth – growth that leads to improved socioeconomic conditions, including employment creation and reductions in inequalities and poverty. These countries have long faced a policy dilemma that pits environmental concerns on the one hand with development needs on the other. The concept of Sustainable Development therefore aims to give a direction to the developing world that takes into account environmental and social factors (among others). Using econometric evaluation methods, this thesis critically examines the impacts that (sustainable) development investment has had on socio-economic indicators in Brazil, especially on income inequality and employment creation.

**Keywords :** sustainable development, econometric methods, Brazil