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‘Money and (dis)connection’: Income inequality and network disadvantage as barriers to sustainable technology adoption

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This thesis is submitted for the degree of Doctor of Philosophy

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the preface, specified in the text, and part of Chapter 2, which was written together with Dr. Maria Abreu (80 per cent of the research in that chapter was produced by me).

This thesis is not substantially the same as any work that has already been submitted before for any degree or other qualification except as declared in the preface and specified in the text.

This thesis does not exceed the regulation length, including footnotes, references and appendices.

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Summary

Scholars have highlighted the role of income distribution as a fundamental factor to understand consumption, health, adoption of technologies, social cohesion, democratic stability, and long term economic performance, among other phenomena. Moreover, reducing income inequality was included in the United Nations’ Sustainable Development Goals. However, less attention has been put on the link between differences in household incomes and other pressing sustainability challenges, such as those that depend on massive adoption of new technologies within network industry sectors: telecommunications, waste management, transport, energy and water. Does existent income inequality translate into adoption gaps within these sectors? Is inequality an obstacle for advancing the vision of an inter-connected and more sustainable world? This research explores these questions through seven stand-alone papers, which focus on adoption of broadband internet, municipal recycling and railway passenger transport. Part I of the thesis includes four papers based on publicly available data from traditional mainstream sources. Chapter 1 provides a systematic map of the peer-reviewed literature on the link between income inequality and adoption of the three selected network technologies. Chapter 2 looks at country-level panel data from OECD countries. Chapter 3 analyses cross-sectional data in a broader world-wide sample. Chapter 4 compares borough-level recycling and income distribution in two European cities: London (United Kingdom) and Barcelona (Spain). Part II provides an in-depth analysis of two South American metropolitan areas: Santiago (Chile) and Medellín (Colombia). This part includes three papers (chapters 5, 6 and 7), each one focusing on a specific sector, that employ mixed-methods based on fieldwork conducted in both cities. The main contributions of the thesis are new evidence on the negative effect of income inequality on network technology adoption, and a discussion of the role of formal and informal institutions in this relationship.

In memory of Exequiel Estay Tapia, who opened the doors of his house, offered me a cup of tea, and told me about the grassroots recyclers in Chile, Latin America, and the world.

For those who will keep struggling.

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Glossary of Terms

Term	Definition
Global South	Countries outside Europe, Canada, the United States, Japan, Australia and New Zealand.
Income Distribution	Proportion of the gross national income that is shared by different groups within a country, region or territory.
Income Inequality	Degree of difference in shares between different income groups.
Institutionalist Political Economy	Study of institutions based on an understanding of them as interlinked with power balances and distributional outputs, as well as in historical specificity.
Institutions	Written and unwritten rules that define the functioning of markets, exchanges and social interactions.
Latin America	Countries in the American continent that are located South of the Río Grande, and were Spanish or Portuguese colonies.
Network Industries	Industries that operate public utilities, or services that depend on infrastructure networks.
Political Settlements	Set of interdependent institutions, balances of power and distribution of benefits.
Sustainable Technology	A specific technology, old or new, that if adopted entails a significant advance toward an already-defined understanding of sustainable development.
Technology Adoption	Introduction of a previously inexistent product or service into consumption by users.
The rich	Usually the top ten or one percent of the population in terms of income distribution.

List of Acronyms

Acronym	Definition
2SLS	*Two Stages Least Squares*
ADSL	*Asymmetric Digital Subscriber Line*
BR between groups regression	*Between Groups Regression*
BRM	*Beta Regression Model*
CLP	*Chilean Peso*
COP	*Colombian Peso*
COP2525th	*Conference of The Parties, United Nations Framework Convention on Climate Change*
EKC	*Environmental Kuznets Curve*
EPM	*Empresas Públicas de Medellín*
ETs	*Environmental Technologies*
EU	*European Union*
FE	*Fixed Effects*
GDP	*Gross Domestic Product*
GDPpc	*Gross Domestic Product Per Capita*
HBS household budget surveys	*Household Budget Surveys*
HTE	*Household Transport Expenditure*
ICTs	*Information and Communication Technologies*
IMF	*International Monetary Fund*
INEQ	*Inequality*
IT10	*Income Share of the Top 10 per cent of the population*
IVs	*Instrumental Variables*
LAs	*Local Authorities*
LFA local fiscal autonomy	*Local Fiscal Autonomy*
MAs metropolitan areas	*Metropolitan Areas*
MWM	*Municipal Waste Management*
NA national accounts	*National Accounts*
NGOs	*Non Governmental Organisations*
NIE	*New Institutional Economics*
NTA	*Network technology adoption*
OECD	*Organisation for Cooperation and Economic Development*
OIE	*Old Institutional Economics*
OLS	*Ordinary Least Squares*
PAYT	*Pay as You Throw*
PPP	*Private Public Partnership*
R&D	*Research and Development*
RE	*Random Effects*
SCRs	*Separate Collection Rates*
SDGs	*Sustainable Development Goals*
SFR	*Service Financing Regime*
SIMBA	*Sistema d'Indicadors Metropolitans de Barcelona*
SMEs	*Small Medium Enterprises*
UK	*United Kingdom*
US	*United States*
VAT	*Value Added Tax*
VIF	*Variance Inflation Factor*
WDI	*World Development Indicators*

There are two pieces of bread.
You eat two. I eat none.
Average consumption: one bread per person.

Nicanor Parra, Chilean anti-poet.

Life is demand and supply, or supply and demand, that's what it all boils down to, but that's no way to live. A third leg is needed to keep the table from collapsing into the garbage pit of history, which in turn is permanently collapsing into the garbage pit of the void. So take note. This is the equation: supply + demand + magic.

Roberto Bolaño, 2666

General Introduction

During October 2019, widespread protests in Latin America, the most income-unequal region of the world, illustrated the tensions between two existential challenges of our time: inequality and the Climate Crisis.

During the first half of the month, a general uprising in Ecuador was sparked by a tax increase on fossil fuels and an agreement with the International Monetary Fund that involved applying austerity measures in the country. The face of the protesters was the Confederation of Indigenous Nationalities of Ecuador, rising their traditional pikes towards the sky while marching to Quito. Ironically, taxes on fossil fuels are part of 'what seems right' to do about the Climate Crisis. In 2018, the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel was awarded to William Nordhaus, one of the biggest advocates of carbon taxes. 2019 was also a year of intense global public debate about Global Warming and Climate Action. But in Ecuador – as it also happened in France –, attempts to implement taxes on fossil fuels were rejected by the people.

By the second half of the month, another unexpected news, this time coming from Chile, was going to mix inequality and the Climate Crisis via social unrest. The 2019 United Nations Climate Change Conference, also known as COP25, was planned to occur during December in Santiago, Chile. However, on the 30th of October, the Chilean President Sebastian Piñera announced that his government was cancelling the event. The two weeks before this announcement saw what probably was the most massive protests in Chilean history. A country-wide uprising started with an increase of 3 cents of a dollar in the Santiago Metro fare. But, as later was written in canvasses all along the country, 'it was not about 3 cents, it was about 30 years'. Secondary students called for massive fare evasions in the metro stations. The government answered by ordering police forces to custody main stations, and by closing them at the peak hour, during the evening of Friday the 18th. The result was instantaneous riots, and eight stations were set on fire. The new answer from authorities was to send the military to the streets, and to impose a curfew for the first time since the dictatorship led by Augusto Pinochet (1973-1990).

The riots in Chile rapidly turned into a massive movement that defied the presence of the military, and demanded not just the suspension of the Metro fare rise in Santiago, but to increase the minimum wage, the end of the privatised pension system, decent public health, nationalisation of privatised water rights, and a new constitution. According to – probably underestimated – police accounts, 4,2 million people marched after the two first weeks of protests, in a country where the president was elected in a second ballot by 3,8 million voters. In one month, as denounced by Amnesty International and Human Rights Watch, reiterated Human Rights violations were perpetrated by police and army forces deployed by Piñera. Truth and justice regarding these abuses became also part of the main demands from the people on the streets.

Such is the social complexity involved in any serious talk about these two existential challenges of our time: inequality and the Climate Crisis. It would not be fair to say that the indigenous peoples in Ecuador are against environmental action. Their struggles to preserve natural ecosystems and defy extractive industries has led to set unprecedented legal environmental protections (Wolkmer and Venancio, 2017). But the mix of increased fossil fuel taxes, austerity, and deregulation agreed with the International Monetary Fund was seen as a danger for almost two decades of achievements in redistribution and

advance of social rights. The paradox in Chile is more baffling: *Santiaguinos* directed their rage against the public transport system that is the basis for their daily mobility, and which is the most viable low-carbon passenger transport alternative in one of the most polluted cities in Latin America.

I began this research a couple of years before the start of this Latin American October. Yet, the protests, my subject of study and the results presented here share the same underlying question: is income inequality a barrier for Sustainable Development?

Although the general sentiment around the world has been far from optimist over the almost four years that this research took to be completed, there is one notion of progress that has not disappeared. That notion has to do with an inevitable continuous process of worldwide technology adoption. In particular, as an urban planner, a vision that I wanted to interrogate was that of an interconnected world. Recent slogans, such as the 'Smart Cities' (Wiig, 2015) and the 'Internet of Things' (Atzori et al, 2010), have been ways to promote this vision. To these slogans, more pessimistic voices have opposed notions of a splintering urbanism, a social connective apartheid, which is a result of a finance-led process of urbanisation, infrastructure convergence and digitalisation (Graham and Marvin, 2002). Yet, notable discussions of our time, such as those sparked by data protection breaches and manipulation of the masses using Facebook during the Brexit vote in the UK, and the 2016 Presidential Elections in the US, are somehow based on the assumption that big data continuously flows through an invisible and ubiquitous network of interconnected infrastructure.

My research questions have to do with this network of interconnected infrastructure, and the link between inequality and Sustainable Development: do existent inequalities translate into new network inequalities? Does inequality affect network technology adoption that is required for Climate Action? To what extent does poverty, access to money, and income concentration determine adoption of the network technologies that are both part of Climate Action and of that vision of an interconnected world? Who gets to be connected and who ends up being left behind by this vision?

This thesis attempts to answer these questions through the following seven papers. Each chapter is a stand-alone paper that should be readable without reference to the others, but a common thread unites all the texts. The first part, composed of four papers, presents a critical review of the evidence, covering different countries and settings around the world. The chapters in this part use publicly available sources such as the World Bank and the Organisation for Economic Cooperation and Development (OECD). The second part, formed of three papers, uses existent household surveys and primary qualitative data collection to develop a more in-depth perspective using two specific cases: the metropolitan areas of Santiago in Chile and Medellin in Colombia. Through the seven papers, the analysis is able to incorporate both the global and regional country-level perspective, and what happens within metropolitan areas.

Given the limited amount of time and resources, I decided to concentrate on analysing three specific network industry sectors that conform the material basis of the 'interconnected world': waste management, transport and telecommunications. More specifically, through the seven papers, the focus is put on the link between income inequality and adoption of recycling, rail passenger transport and broadband internet. These network technologies are, in the case of waste and transport, fundamental part of

Climate Action discourses. Recycling and rail passenger transport are part of existent Climate Action plans. For instance, Climate Neutral Europe 2050 (European Commission, 2018) aims to increase capacity of rail networks in order to provide an alternative to the use of private motorised vehicles. The same plan proposes to reinforce material recovery of waste in the form of recycling. These actions aim to advance towards the circular economy, which involves 'the adoption of closing-the-loop production patterns within an economic system (…) to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society' (Ghisellini et al., 2016:11). At a global level, the Sustainable Development Goals (SDGs) highlight similar measures (United Nations, 2019). For instance, target 11.2 points to 'By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons'. Conversely, target 12.4 defines 'By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse'.

Broadband internet is key for the digitalisation of all the other network industry sectors (Rifkin, 2014). Although broadband is not directly linked to Climate Action, information and communication technologies (ICTs) are increasingly the basis for the functioning of other sectors that have a fundamental environmental impact. Ideas such as the 'Smart Cities' or the 'Internet of Things' rely heavily on having 'connected homes', and convergence between different network industry sectors. Conversely, target 9.C of the SDGs points to 'significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020'.

Before explaining the structure of the thesis, it is worth mentioning two overarching narratives that emerged from this research. On the one hand, an analysis of income inequality as a factor of technology adoption requires to integrate two dimensions: aggregated income distribution and individual income generation. The two are interconnected, and this research ends up discussing both. On the other hand, it became rapidly clear that the dominant demand-based view of technology adoption is not enough to explain the links to income inequality. Income inequality is not only related to how much money consumers have in their pockets, but is also a proxy of deeply rooted power balances that define the rules of the game. That is why every step of this research ended up being a constant interrogation of the problem of institutions as mediators between income inequality and network technology adoption.

As a result of accounting for these two narratives, the two main contributions that I am able to make are robust empirical results on the effects of income inequality over the analysed technologies, and new theoretical perspectives on the institutional factors that shape this effect. These two contributions can be synthetized in one concept: the presence, in all sectors, of institutionally produced network disadvantage. By network disadvantage I mean supply-side barriers to adoption by users, regardless of their ability and willingness to pay. By institutionally produced, I refer to supply-side constraints that are enforced beyond any physical or technological restriction to expand and operate networks, but rather depend on formal and informal institutions that are sustained by balances of power between groups. On the basis of the findings from this research, especially from Chapters 2, 3, 5, 6 and 7, it is possible to claim that institutionally

produced network disadvantage affects mostly those in the 40 bottom per cent of the income distribution.

A by-product of the different methodologies and theoretical debates included in this thesis is support for a novel perspective within development economics. During most of the 20th century, the main subjects of the problem of underdevelopment have been the poor. However, more recent contributions by economists such as Jose Gabriel Palma (2011), Thomas Piketty (2014) and Branko Milanovic (2010) on income and wealth concentration by the rich have substantially changed the lens to look at development issues. The necessary effect of looking at income distribution and institutions as explanatory factors of any development-related variable – in this case, network technology adoption – is that the problem is not only the poor, but also the rich. Institutions emerge as part of a relational phenomena, in which society needs to be looked at as a whole, without falling to the temptation of thinking that one specific group deserves to be the face of underdevelopment.

Chapter 1 provides a theoretical framework and a systematic map of the peer-reviewed literature on the link between income inequality ad network technology adoption, focusing on the cases of internet, recycling and passenger transport. On the one hand, a theoretical framework is developed in order to analyse the link between income inequality and network technology adoption. This framework includes linking network industry sectors and development, explaining technology adoption within these sectors, and drawing possible connections to income inequality. On the other hand, after a parametric search using the Scopus search engine, a hundred papers are analysed and discussed. Gaps in the research literature are identified, and theoretical links between income and network technology adoption are highlighted.

Chapter 2 uses publicly available country-level data from OECD countries to propose an econometric panel data model to look at adoption of recycling, railway passenger transport and broadband internet. A novelty of this analysis is that, along with the often used Gini coefficient, I compare the use of income shares of different groups in each country. Instrumental variables are also included as a way to account for possible endogeneity and reverse causality issues raised by the literature review in Chapter 1.

Chapter 3 provides a world-wide analysis of one sector: transport. However, while Chapter 2 used measures of direct adoption of railway passenger transport, Chapter 3 goes back to another variable that is significantly present in the transport literature covered in Chapter 1: household transport expenditure. Results from transport in Chapter 2 contradict what the literature expects, and rises doubts about the rival nature of private motorised vehicles and public transport services. This analysis, based on diverse econometric models and instrumental variables applied to cross-sectional data, allows to complement and reinforce findings on transport from Chapter 2. Both in Chapters 2 and 3, a strong case for supply-side links between income inequality and adoption of public versus private transport is made.

Chapter 4 aims to provide a first exploratory approach to the effects of income inequality at a metropolitan scale. Almost purely based on quantitative data that is publicly available at borough level, it compares two widely studied European OECD cities with similar income distributions and recycling achievements: London in the UK and Barcelona in Spain. Econometric models are complemented by qualitative data from field visits.

Chapter 4 allows to understand that formal institutional factors, such as tax revenue and the way waste management services are financed, generate that those that participate in recycling are different in each case, according to their income. Institutional factors determine whether the most affluent communities are those more strongly involved in recycling, or if sustainable waste management is an effort that involves all. A strong case is made to defy the dominant idea in recycling studies, according to which income and separate collection rates are linked strictly through demand-based mechanisms.

Chapter 5 is the first paper from Part II. In it, a mixed methods approach is used to compare adoption of household broadband internet in Medellin and Santiago. On the one hand, a logit binary outcome regression model is used on household data from both cities. On the other hand, semi-structured interviews are used to illustrate local and informal institutions that seem to be playing a role in how differently the link between income and adoption works. In Chapter 5, just as in the following 6 and 7, the theoretical discussion goes beyond what was covered by the systematic map of peer reviewed literature in Chapter 1. That means that specific theories within studies for each sector are discussed.

Chapter 6 focuses on recycling in Medellin and Santiago. In this case, data availability constraints made it impossible to perform econometric analysis. However, an effort is made to provide a detailed understanding of aggregate recycling figures in both cities. Thanks to the possibility of having more space to develop a qualitative account of each case, institutional factors are explained as originated from long-term state building processes, in both cases as a result of violent national conflicts. In particular, recent constitutional processes, with constitutions written in 1980 in Chile and 1991 in Colombia, are key to understand how waste management regimes operate in each city.

Finally, Chapter 7 looks at public transport. Both cities have in common to structure their public transport systems on the basis of a trunk and feeder network that mixes metro lines with buses, all integrated through a unified fare. Just as in the case of Chapter 5, it is possible to use household data to include logit binary outcome models, which are complemented by qualitative analysis from semi-structured interviews. The presence of different informal institutions is discussed, and new elements are proposed as an addition to existent attempts to integrate institutional factors into transport economics.

At the time of the submission of this thesis, Chapters 3, 4, 5 and 6 had been published, and Chapter 2 was under review after submitting a first major revision. To the anonymous peer reviewers, I owe a relevant part of the most interesting sector-specific discussions, and many learnings on how to better organise my ideas. Particularly Part II, which for me is the most theoretically appealing part of the thesis, has been an intense intellectual journey. I decided to organise chapters from Part II in the same order as I wrote them, to somehow reflect the conceptual steps made through the writing process. The main contributions from the overall doctoral research project are synthesised in the conclusions.

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Part I

1 The relationship between income and network inequality: a review.

Abstract

Income inequality has been increasingly discussed within development economics. Scholars have highlighted the role of distribution of income among households as a fundamental factor to understand consumption, health, adoption of technologies, social cohesion, democratic stability, and long term economic performance, among other phenomena. Moreover, the Sustainable Development Goals included reducing income inequality as part of its multiple proposed dimensions of global sustainability. However, less attention has been put on the link between differences in household incomes and other pressing sustainability challenges, such as those that depend on massive adoption of new technologies within network industry sectors: telecommunications, waste management, transport, energy and water. Does existent income inequality translate into adoption gaps within these sectors? This research provides a systematic map of the peer-reviewed literature on the link between income inequality and network technology adoption, focusing on the cases of internet, recycling and passenger transport. Gaps in the research literature are identified, and possible theoretical links between income and adoption are provided.

1.1 Introduction

Although mentioned separately, both issues of inequality and network infrastructure are relevant part of the global vision proposed by the United Nation's Sustainable Development Goals (SDGs). On the one hand, a target within 'Goal 10: Reduced Inequalities' is 'By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average' (United Nations, 2019). This target responds to recent seminal studies that have observed how most changes in overall income distribution are due to concentration by the top earners and deprivation of the bottom 40 per cent of the population (Palma, 2011, 2014). On the other hand, a substantial part of the seventeen SDGs, and their respective targets, require changes and innovations within infrastructure networks. At least five goals actively involve network industries (i.e. transport, telecommunications, energy, water, waste management): '6: Clean Water and Sanitation', '7: Affordable Clean Energy', '9: Industry, innovation and infrastructure', '11: Sustainable Cities and Communities', and '12: Responsible Consumption and Production'.

In economics, access to and distribution of income are usually seen as conditions for technology adoption at the consumer level, and as a constraint to fiscal capacities to fund infrastructure. Thus, interesting questions emerge if these challenges in inequality and network infrastructure are combined. Some of these questions are: does income inequality produce network inequalities? Is inequality an obstacle for sustainable change within network industries? To what extent does income generation determine adoption of sustainable network technologies by households?

This chapter provides a framework for the study of the relationship between income inequality and adoption of technologies within network industries – what I call 'network technology adoption' (NTA). It does so by generating a systematic map of peer-reviewed literature (Grant and Booth, 2009). The focus here is put on three sectors: telecommunications, waste management and transport (see Section 1.3.1 for the justification of this choice). On the basis of this review, it is possible to establish what aspects of the income-adoption link have been consistently analysed, as well as gaps in the research literature that can inform future studies. At the end of this paper, I summarise a number of theoretical links between income inequality and NTA that can be extracted from existent scholarship, and provide questions for further research.

1.2 Framework

1.2.1 Network Industry Sectors and Development

The SDGs are one of the most recent steps in a long-standing effort to define global visions for human progress. It is worth noting that until the end of the 2000 decade, the mainstream economic views on both income inequality and infrastructure development came from the same origin: the international influence of the United States in the setting of a global development agenda after World War II, in the context of the Cold War. While acceptance of increasing income inequality as a 'natural' part of the path to economic development was promoted by Simon Kuznets (1955) in the 1950s – in order to promote free markets, as highlighted by Piketty (2014) –, infrastructure investment was crucial for the role of the Bretton Woods institutions proposed by John Maynard Keynes and Henry

Morgenthau in 1944 (Goldman, 2014). Particularly after the 1970 decade, support for privatisation and liberalisation of network industries, and the acceptance of income inequality as a given, were parts of the same mainstream development economics discourse.

The global development agenda on network infrastructure has fundamentally been set by the influence of the World Bank and the International Monetary Fund (IMF) (Goldman, 2014). Structural readjustment policies, promoted by these institutions, usually were associated with grants and loans that targeted infrastructure investment. During the last four decades, documents circulating within the World Bank show a continuous argumentation effort for supporting privatisation and liberalisation in all the network industry sectors, regardless of the decade or the country being intervened (see for instance Bobylev & Cukrowski, 2002 for Rusia; Rossotto et al, 2003 for the Middle East and North African countries; The World Bank, 2003 for Lebanon; The World Bank, 2011 for Ghana; The World Bank, 2013 for Ethiopia). A similar agenda can be found in documents by the IMF, which focus on transport, energy and telecommunications. The main agenda for the IMF has been how to facilitate the involvement of the private sector in infrastructure investment (Cerra et al, 2016; Komatsuzaki, 2016; Seneviratne and Sun, 2013; Ter-Minassian, 2008).

Moreover, privatisation, globalisation, and an increasing participation of transnational financial capital, brought a new challenge for infrastructure development: convergence between sectors. As highlighted by Graham and Marvin (1994) first signs of convergence were observed in the 1990s after privatisation of European network industries. These authors use the idea of the 'convergence of urban infrastructure' for describing 'cross-investment and convergence between previously separate infrastructure networks' (Graham & Marvin 1994:239). According to this idea, the market that was opened by privatisations fundamentally attracted a group of investors which are in search for a diversified profitable investment portfolio. Private 'distribution network operators' configure an environment in which companies seek for coordination and economies of scale (Foxon et al, 2015). 'Given their existing networks, knowledge and rights, the lucrative marketplaces in this area are very attractive to investors in search of diversified profits' (Graham and Marvin, 1994:239).

This idea is consistent with the treatment given to infrastructure by those working to promote involvement of the financial sector. For them, infrastructure is defined as a mixed investment portfolio that includes roads, urban infrastructure, major irrigation, waterways, electricity, telecom, ports, airports, urban electricity, and railways (Virmani, 2004). While trying to advocate for Public-Private Partnership (PPP) for investment, the Organisation for Economic Cooperation and Development (OECD) acknowledged this raising interaction between formerly separated networks and services, announcing that 'the various infrastructure systems themselves are interacting ever more closely with one another, engendering interdependencies and complementarities, as well as heightened vulnerability, and thereby posing new policy challenges such as interoperability and reliability' (Stevens and Schieb, 2007:20). Thus, convergence involves a close interaction between network industries and financial capital, as well as the inter-dependence of different network technologies – the best example is the increasing dependence on electricity and data networks by other sectors.

It is worth noting how the abovementioned narrative of privatisation and liberalisation has become more nouanced in recent years, due to the relevance played by China. The irruption of the globally dominant Chinese state-led finance of infrastructure challenges the idea of a lack of agency by governments. Furthermore, via the Asian Infrastructure Investment Bank, China has integrated its own agenda with the one of the Bretton Woods Institutions (Wilson, 2019). Parties that were totally separated during the Cold War are able now to compromise and share a global perspective on infrasturcutre. In addition, the liberal narrative on infrastructure development, specially strong in the telecommunications sector, also becomes more nuanced when authoritarian rule seems to be a strong factor behind adoption of new technologies that are associated to new visions such as the Internet of Things (Kshetri, 2017).

It is in the context of this complexity where new pressures related to the Climate Crisis and social inequalities emerge. On the one hand, network industries are critical for the use of resources that must be taken in account in order to confront new environmental catastrophes and thermodynamic challenges. For instance, the notion of 'Urban Metabolism' (Golubiewski, 2012) has been used to conceptualise resource use in urban environments. Coming from this perspective, Newman (1999) explains that:

> 'Like all ecosystems, the city is a system, having inputs of energy and materials, the main environmental problems (and economic costs) are related to the growth of these inputs and managing the increased outputs. By looking at the city as a whole and by analyzing the pathways along which energy and materials including pollutants move, it is possible to begin to conceive of management systems and technologies which allow for the reintegration of natural processes, increasing the efficiency of resource use, the recycling of wastes as valuable materials and the conservation of (and even production of) energy' (Newman, 1999:220).

As it is evident, energy, transport, telecommunication, water and waste management networks – the network industry sectors – are critical for the possibilities of controlling the resource use of an increasingly urban world. In summary, convergence is not only a given by privatisation and financialisation, but also a key for Climate Action.

On the other hand, the economy becomes more and more dependent on network infrastructure, as the world population continues its urbanisation, metropolitan areas grow larger and more populated, and urban service sectors base their business-models on telecommunications, energy and transport. Issues of connectedness and disconnectedness gain social and political relevance. In transport, 'forced car ownership' (Mattioli, 2017), 'transport disadvantage' (Walks, 2018) and 'immobility' (Esson et al, 2016) emerge as ideas that reflect pressing concerns about equity in the sector. In telecommunications, literature and policies use the concept of 'digital divide' (Van Deursen and van Dijk, 2019). The notion of 'energy poverty' is now in the centre of debates around electricity, gas and heating networks, both in developed and developing countries (Sovacool, 2012; Dubois and Meier, 2016). Contestation of privatisation of water utilities has led to new 'water wars' all around the world (McDonald and Swyngedouw, 2019). In waste management, a social divide grows between informal scavenging activities and formal up-to-date recycling programs that seem to target the rich (Gregson and Crang, 2015; Millington and Lawhon, 2018).

Calls for Climate Action require shifting how network industries are conceived, produced, governed, operated and updated. However, innovation to confront the Climate

Crisis will necessarily face the challenge of social and political pressures regarding equity and social justice within network industry sectors. These pressures add novel elements that should be considered to understand NTA. If the innovation literature long ago considered ability to pay as a driver of technology adoption, and therefore income distribution was sometimes discussed, there are new reasons to increase attention to inequality even further. Doing so when researching NTA, allows us to combine distributional and social-justice concerns, with the need for making network industries adapt and evolve.

1.2.2 Technology adoption within network industries

The history of network industries is intrinsically linked to the 'natural monopoly' as an economic concept. The origin of this link is the Industrial Revolution. Mosca (2008) explains that it is a 'typical case of economic thought shaped by reality', since 'the public utilities and networks determined the theory' (Mosca, 2008:346), especially during the 19th century. In this context, John Stuart Mill provided a first modern definition of what natural monopolies are: 'those which are created by circumstances, and not by law' (Mill, 1848:II.15.9 cited in Mosca, 2008:323). Since this beginning, network industries such as supply of gas and water were considered natural monopolies. Following Mill in the United Kingdom, Léon Walras stated in France that transport networks such as canals, railways and roads 'make up a natural monopoly' (Walras, [1875] 1936:232 cited in Mosca, 2008:324).

Taking in consideration the evolution of the concept of natural monopoly, Mosca (2008) defines it as 'a market structure in which there are barriers to entry created by a technology characterized by economies of scale (i.e. declining average costs) over the whole range of market demand. Such scale economies, due to the presence of high fixed start-up costs and low or zero variable costs, are considered to be the source of a market failure that requires government intervention' (Mosca, 2008:321). From a more mainstream perspective, Joskow (2007) states that 'the historical evolution of the natural monopoly doctrine reflects both a normative interest in identifying situations in which a single firm is necessary to achieve all economies of scale (…) as well as a positive interest in identifying the attributes of costs and demand that lead to market conditions that are "unsuitable for competition" to prevail and the associated normative performance implications for prices, costs and other attributes of social welfare' (Joskow 2007:1239).

In terms of the technological core of network industries, after an initial period of breakthrough innovation in the 19th century, during most of the 20th century, network industry sectors – with the exception of telecommunications after the 1990s –, were seen as virtually 'technologically mature' (Lo Schiavo et al, 2013), or at least saw a slow peace of innovation within their core business model. Furthermore, in her review of the history of the natural monopoly as an economic concept, Mosca claims that after 1890 'all of the concrete situations in which natural monopolies occur have already been pointed out, and nothing original was added in this respect by later economists' (Mosca, 2008:327). New divergent positions emerged after the 1970s, associated to the debate between public or private ownership of public utilities (Chang and Singh, 1993). Most debates had to do with economies of scale, large sunk costs, and dominant policy views assuming that, even when pure competition was not possible, market forces were the best drivers of general welfare, and therefore they had to be introduced to the administration of natural

monopolies. The terms of the discussion were, however, re-editions of the original arguments by classical economists from more than one century ago (Mosca, 2008).

One of the limitations of mainstream economic approaches to natural monopolies is that they tend to focus exclusively on government failure and justification for private participation (Chang and Singh, 1993) and on ways of attracting private capital to avoid enlarging government debt (Cerra et al, 2016). This has led to an almost exclusive focus on static efficiency during expansion and operation of networks that are based on relatively stable technologies. In contrast, there is a lack of well-developed theories to account for a more dynamic, open-ended and innovative view on infrastructure. Joskow (2007) mentions a pressing need for incorporating dynamic efficiencies into the economic theory about network industries: 'It is clear that the social costs of delaying product and process innovations can be very significant. Both theoretical and empirical research has probably focused too much on static welfare effects associated with the impacts of regulation on prices and costs in the short run and too little research has focused on the effects of regulation on the adoption and diffusion of product and process innovations' (Joskow, 2007:1329).

The dominant notion of innovation and technology adoption in economics comes from the work by Joseph Schumpeter (2011[1934], 2013[1942]) and his idea of 'creative destruction' as the engine of capitalist development. This idea assumes that innovation occurs due to incentives to create a temporal monopoly through innovative practice (Fagerberg et al, 2005; Hatipoglu, 2012). For entrepreneurs, the reason to innovate is the profitability of the monopoly resulting from innovations: this profitability holds while one firm is the only one able to provide the novelty. These moments of innovation and temporal monopolies are the basis for the innovative impulse among entrepreneurs, and a fundamental factor determining profits in competitive markets. Based on this demand-driven innovation process, the Bass model (see Figure 1) aggregates individual adoption in forms of diffusion curves (Cowan and Daim, 2011). This model and its adoption curves are the origin of popular notions of consumer segmentation between innovators, early adopters, early majorities, late majorities and laggards (Lee et al, 2013).

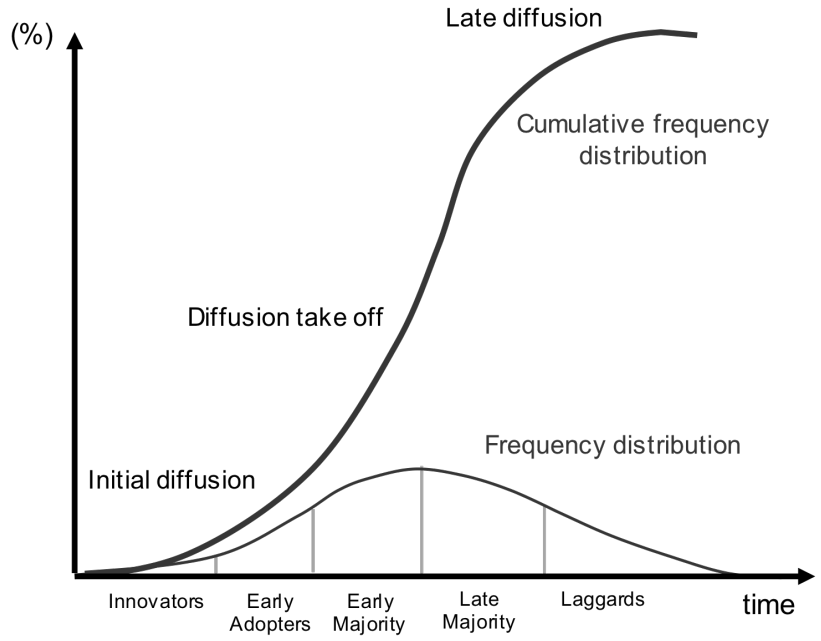

Figure 1. Bass model of technology adoption and diffusion.

The limitation for applying this analytical framework to innovation within network industries is that competition in the market is usually not how most network industry sectors work. If a monopoly is already granted, as it is the case of natural monopolies, this basic Schumpeterian demand-based innovative impulse for producing a temporal monopoly can not be the explanation for innovation.

It could be claimed that the exception to the absence of competition in the market among network industry sectors is telecommunications after the 1990s, particularly during adoption waves of mobile telephony and internet. According to the World Bank, the 'first-generation Information and Communication Technology (ICT) policies' involved 'market competition, private participation, and light-touch regulation' (The World Bank 2016:25). This has led research on the sector to treat ICT adoption as a demand-driven phenomena (Hyytinen and Toivanen, 2011; Gulati and Yates, 2012; Van Deursen and van Dijk, 2019). By assuming a universal presence of private global actors, market competition, and liberalised exchange between supply and demand, the paradox of the absence of the Schumpeterian innovative impulse is disregarded, and the focus keeps being put on the demand.

However, even the World Bank itself has questioned the current effectiveness of 'first-generation' (ICT) policies. In a recent World Development Report, it is said that these policies 'led to near-universal access and affordability of mobile telephony, but have so far been less successful in spreading internet services. Much of the explanation lies in continued policy failures such as regulatory capture, troubled privatizations, inefficient spectrum management, excessive taxation of the sector, and monopoly control of international gateways' (The World Bank, 2016:25). In other words, the natural monopoly condition of the telecommunications sector is back on the table. The supply-side complexity of the incentive for technology adoption in network industries is thus applicable to all the sectors, including telecommunications.

But, what does Network Technology Adoption (NTA) mean? As already mentioned, by this I refer to technology adoption within network industry sectors. However, the concept requires further specification to help approaching an empirical analysis. In economic terms, by adoption in network industries I refer to the consumption, at a household or individual level, of a distinct network service that is based on the introduction of a specific technology. While this definition allows to compare technology diffusion within network industries with the broad debate about adoption and diffusion (see for instance Fagerberg et al, 2005; Cowan and Daim, 2011; Lee et al, 2013), sector-based literature on access, adoption and appropriation has provided more complex models to understand this consumption phenomenon.

The literature on the 'digital divide', for instance, distinguishes 'three levels' in a multifaceted model of Internet appropriation and access (Helsper & Reisdorf, 2017; Van Deursen and van Dijk, 2019), which include material access, personal capacities and outcomes of technology use. Moreover, an analogous notion is present in mobility studies. Three main layers have to be observed in order to understand the capacity of movement (Ohnmacht et al, 2009). The first one is access, which refers to what mobilities are possible according to place, time and other contextual constraints. Networks and territorial dynamics are, of course, central for access, which is constrained by options and conditions. Options are the means available, while conditions refer to accessibility due to

costs, logistics or other constraints. The second layer is competence, which includes skills and abilities that can be physical abilities, skills related to rules and regulations, and organisational skills. Finally, the third layer is appropriation, which is related to how individuals, groups, networks or institutions interpret and act on the basis of perceived or real access and skills.

All these levels are interlinked in any technology adoption process by users. Furthermore, although NTA is a phenomenon that can be observed by data on the demand side, such as modal share, or intensity of use, it is always shaped by options and conditions in the supply side, such as stock of infrastructure, regulations, and prices. Adoption, regardless of the point of observation in the service production and consumption chain, is necessarily a two-sided phenomenon. However, the Schumpeterian approach to innovation, as well as the more classical approach to the 'invisible hand' of the market, are based on set views of what the supply side is. Put it simple, at the basis of this approach is an assumed view of what the nature, incentives and impulses of entrepreneurs are. These entrepreneurs are expected to generate economic development by aggregation through market interactions. More than excluding supply, demand-based approaches assume a properly functioning market for production, populated by these kind of entrepreneurs. In contrast, within network industries, those supply-side variables strongly depend on non-market interactions. Complex supply chains, as well as personal equipment required for using networks, might actually involve a role of competitive markets in NTA. However, the natural monopoly will still define, to different degrees, the functioning of any network industry sector, and therefore supply-side phenomena will significantly determine how NTA takes place.

1.2.3 Network technology adoption and income inequality

Thus, why does income inequality matter for NTA? From what is discussed in the two previous subsections, income inequality can be expected to influence NTA because of two types of phenomenon: demand-side and supply-side.

On the demand side, income inequality can be associated to a number of factors that could condition adoption, such as ability and willingness to pay, aggregate demand for innovative products, user preferences, and definitions of the value of time.

Firstly, as mentioned above, even if they involve natural monopolies over infrastructure, network industry sectors might involve the use of personal equipment that is purchased in related markets. NTA might strongly depend on equipment in hands of the end-user. Examples are private vehicles and fuel in transport, smartphones and computers in the telecommunication sector, household storage of recyclable materials in waste management, number of bathrooms or existence of gardens and pools in the case of water, and electric appliances in the case of energy. All these factors might depend on ability to pay and could strongly affect NTA.

Secondly, especially given that income, education and social status are strongly inter-related, income might be a proxy of consumer preferences that can be related to status-seeking, or that are popular among people above a certain level of educational attainment.

Thirdly, income distribution might affect perception of the opportunity cost of time. Perception of the value of time can affect NTA because adoption of some technologies

can be time-consuming in terms of learning how to use it – such as technology –, during use itself – such as waste separation –, or to restrain usage time – such as saving water or energy consumption. Furthermore, all these end-user equipment, consumer preferences and time-valuing do not only affect NTA in terms of use of a given technology, but also in terms of how they condition rival alternatives. For instance, purchase of private vehicles might not change how a trip on a train is experienced, but will certainly alter the rival alternative to that trip.

Yet, income inequality might also have to do with supply-side phenomena affecting NTA. The demand-driven approach considers market interactions, by which income distribution is a variable that aggregates or isolates potential users, whatever the cause is. However, the demand-driven approach does not consider that income distribution in a society might not only shape consumer behaviour, but also be closely related to how governmental decisions are taken, and how institutions that define options and conditions are shaped. There are at least three examples of literature attempting to bridge income distribution and institutions: welfare state regimes, theories about the median voter, and emergent literature on income concentration.

Firstly, in the Global North context, the Welfare State regimes approach (Esping-Anderson 1990), integrates income distribution, institutions and public policies within a country. Social-democratic countries are supposedly more egalitarian, while liberal ones are less egalitarian, and conservative regimes are somewhere in the middle. For instance, Schaffrin & Reibling (2015) use these welfare state regimes to model differences in how poorer and richer households adopt energy technologies. They use Denmark, Austria and the UK as examples of the social-democratic, conservative and liberal regimes, respectively. Differences between regimes are expected to have impacts on how natural monopolies work, especially when they are related to provision of basic services.

Secondly, institutional impacts of income inequality that are produced by the share of 'those in the middle' are usually associated to the 'median voter' in democracies (Alesina et al, 1999; Acemoglu and Robinson, 2006; Neckerman and Torche, 2007). The basic idea is that the presence of a large middle segment implies that politicians have the incentive to respond to the demands of the 'median' citizen, and therefore to provide better public goods. In this sense, public goods and universal services will more likely be produced and maintained when there is a larger group of voters in the middle of the distribution, with shared levels of income and thus also common interests. The opposite effect is expected to happen if there are more 'distanced' groups whose benefits are somehow in conflict. In such case, politicians will have the incentive to choose to favour one of the groups over the other.

Finally, new literature has emerged in recent years regarding how income concentration affects the way in which institutions, democratic accountability, and long-term investment decisions operate (Milanovic, 2010; Piketty, 2014; Palma, 2011, 2014; Stiglitz, 2012). Palma (2014, 2011), for instance, claims that differences in long-term economic performance between countries are related to what the rich do with their share. Conversely, other authors such as Stiglitz (2012) and Milanovic (2010) claim that income concentration along with financialisation of the economy will most likely distort major investment decisions, leading to market failure. These distortions will affect regulations, ownership of natural monopolies, large-scale investment, and the institutional environment in which NTA takes place.

1.3 Material and Methods

1.3.1 Selection of sectors

With the aim of systematically exploring what the existent literature can say about the link between income inequality and network industries, three sectors were selected. These sectors are telecommunications, waste management and passenger transport. The specific network technologies that are explored are household broadband internet, municipal separate waste collection for recycling, and rail passenger transport, respectively. The criterion was to include technologies that are associated to Climate Action, that involve convergence between sectors – meaning growing functional inter-dependence –, and that are organised through a variety of institutional arrangements that involve diverse modes of monopoly and competition.

Recycling and rail passenger transport are part of existent Climate Action plans. For instance, Climate Neutral Europe 2050 (European Commission, 2018) aims to increase capacity of rail networks in order to provide an alternative to the use of private motorised vehicles. The same plan proposes to reinforce material recovery of waste in the form of recycling, in order to contribute to the circular economy. At a global level, the SDGs point to similar measures (United Nations, 2019). For instance, target 11.2 points to 'By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons'. Conversely, target 12.4 defines 'By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse'.

Although broadband internet is not directly linked to Climate Action, it is included in this study because ICTs are increasingly the basis for the functioning of other sectors that have a fundamental environmental impact. Ideas such as the 'Smart Cities' (Wiig, 2015) or the 'Internet of Things' (Atzori et al, 2010) rely heavily on having 'connected homes', and convergence between different network industry sectors. Conversely, target 9.C of the SDGs points to 'significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020'.

Moreover, while ICTs are increasingly crucial for other sectors, municipal recycling and rail passenger transport also involve convergences with other network industry sectors. For instance, municipal recycling requires to be logistically integrated to transport systems, both in terms of collection routes and some times using street space for storage. Similarly, rail passenger transport requires integration with the electric grid in order to operate.

Finally, these three sectors and technologies represent a variety of institutional arrangements. As already mentioned, the telecommunications sector operates as a globalized and liberalized market. Rail passenger transport is usually in hands of operators that cover an entire country or region, with much higher sunk costs and entry barriers than the telecommunications sector. Recycling is usually in hands of municipal governments, some times involving local public enterprises, or some times contracting

out to national or global operators. Furthermore, all these sectors have different revenue models that might influence the way household income and adoption interact: while recycling tends to be funded by local taxes or central government grants, rail passenger transport tends to involve a mix of state subsidies and ticket charging, and internet is increasingly pre-paid, with a rare presence of subsidies. All these are institutional variations within natural monopolies: comprehending how they work is valuable for the study of the link between NTA and income.

1.3.2 Methodology and data

This paper provides a systematic map of peer-reviewed literature on the link between income inequality and NTA in the above specified sectors. In their categorisation of fourteen different types of literature reviews, Grant and Booth (2009) explain that a systematic map, also called mapping review, maps out and 'categorise existing literature from which to commission further reviews and/or primary research by identifying gaps in research literature'. The 'completeness of searching' is 'determined by time/scope constraints', there is no 'formal quality assessment' of the empirical evidence, synthesis 'may be graphical and tabular', and the analysis 'characterizes quantity and quality of literature, perhaps by study design and other key features', and 'may identify need for primary or secondary research' (Grant and Booth, 2009:94).

Accordingly, a parametric inquiry was generated using the Scopus search engine on the 5th of September 2019. The search included all disciplines, publication years, and articles written in English or providing an English abstract, with open access or access via journal subscriptions. The terms introduced in the category 'Article title, Abstract, Keywords' were a combination of '"income inequality" OR "income distribution"', on the one hand, plus 'AND' followed by "internet OR broadband"', 'recycling' or 'transport', on the other. The broad term 'transport' was used in order to have enough papers to analyse, since more specific ones such as 'rail' or 'public transport' provided a small number of results. The search generated 83 results for internet, 51 for recycling and 170 for transport. All titles and abstracts of these 304 papers were reviewed, discarding those which matched the words but their focus did not have to do with the topic.

The papers that were included in the final dataset were only those that associated income distribution or inequality with one of the sectors, regardless of the direction of the relationship. Many papers only referred just to income or to one of the sectors, and therefore were discarded. For instance, the term 'revenue recycling' produced the inclusion of a number of papers that analysed income distribution and taxation, but had nothing to do with waste management. In the transport sector, papers that did not mentioned land passenger services – for instance, literature on freight, ports or airports – were discarded. After these filters, 26 papers remained for internet, 16 for recycling, and 60 for transport. From these 102 papers, 100 were available for download and therefore were the basis for the analysis.

These 100 papers were read and categories were created from the qualitative analysis of the texts. These categories are grouped in 'approach', 'scope', 'methodology' and 'results'. In terms of approach, categories included whether the papers were purely theoretical or included empirical verification, whether income was observed in terms of 'income generation' or 'distribution of' income, how they measured income, definition of the main dependent and independent variables, and the treatment they gave to issues

of endogeneity and reverse causality. In terms of scope, categories included the countries or regions that were considered, if they reviewed specific cases within regions of countries, the observed unit of analysis, sample sizes, and timeframes. In addition, institution and city of affiliation of the first author, provided by the Scopus metadata, were grouped by country. In terms of methodology, 12 types were established, and, in the case of those studies that involved empirical quantitative inferential statistic analyses, additional specification categories were the type of regression used, and covariates or controls added in models. Finally, in terms of results, for the 51 papers that account for significance and sign of the income-adoption relationship, a detailed analysis was provided (see Section 1.4.5).

Results are presented in the next section in an integrated narrative that focuses on four different issues, preceded by a general overview. The issues are approach to income, approach to adoption, methodologies, and empirical evidence. Results are presented using tables, charts and maps.

1.4 Results

1.4.1 Overview

A first look at the analysed literature provides a series of overall characteristics in terms of evolution over time, as well as geographical origin of authors and cases. On the one hand, as shown in Figures 2 and 3, the first papers were published in 1991: they start by only covering transport. The first income-inequality-related study about recycling was published in 1997, while the first one about internet appeared in 2003. Within the analysed papers, whereas transport is the most studied sector by 2019, internet follows and recycling is the least covered. An interesting change occurs in transport during 2009 and 2010, when the volume of publications related to income distribution and inequality increases. One could interpret this as a sign of impacts of the 2008/2009 financial crisis on transport – something that is not shown in the other sectors.

In terms of territorial coverage of data and cases, 98 papers can be classified (Figure 4). The biggest group covers world-wide samples, counting 24 papers – never covering all countries, as it is usual in any field due to data availability –, followed by Europe and Asia, with 17 and 16 respectively. Studies covering US or Canada are equal in number to those covering Latin America and the Caribbean, while Africa follows close and the least covered region is Oceania, with all cases coming from Australia – as opposed to Melanesia, Micronesia or Polynesia. To summarise, 44 out of 80 papers that do not cover world-wide samples look at Europe, Australia, the US and Canada. In terms of sectors, the overall distribution is more or less replicated when it comes to transport, with a higher importance of Europe over world-wide samples, less presence of South America and more of Africa. In recycling, it is Asia that leads, followed by Europe and Latin America. In the case of Internet, 12 out of 25 papers cover world-wide samples, from which there are no studies focusing exclusively on European sets of countries.

Furthermore, Figure 6 shows a world map with country of affiliation of first authors. Scholarship on the link between the three studied sectors and income inequality has

almost exclusively been produced in the Global North. First authors from Latin America, Africa and Asia mostly come from a few specific cases, such as Brazil, South Africa, India, China, Japan, and Korea. In summary, both authors and cases tend to focus on the world's biggest economies. Countries included in world-wide samples also tend to be limited to OECD members, probably due to data availability constraints. The literature, therefore, must be interpreted under these contexts of data, scope, production and dissemination.

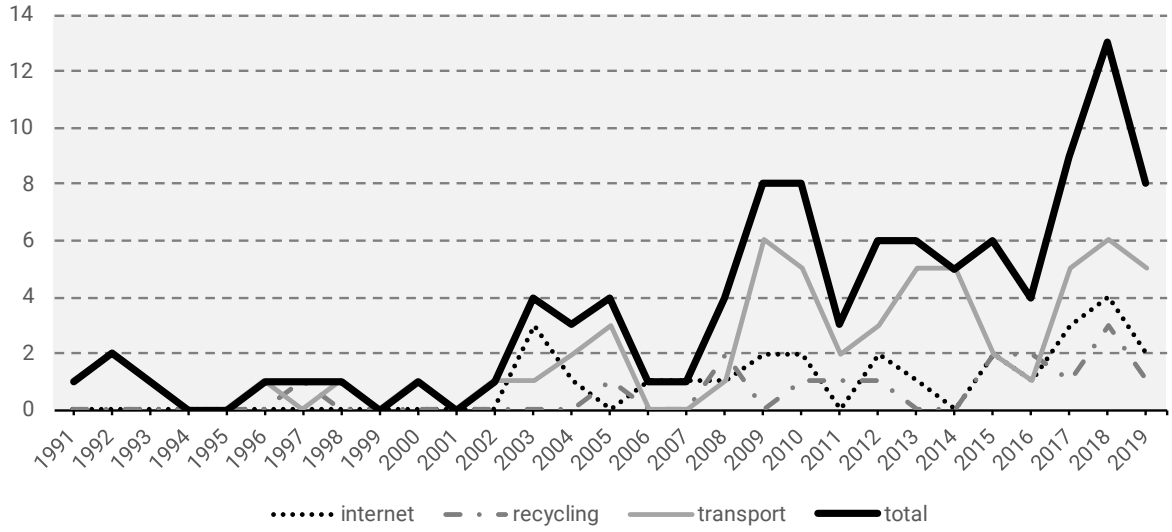

Figure 2. Papers per year and sector.

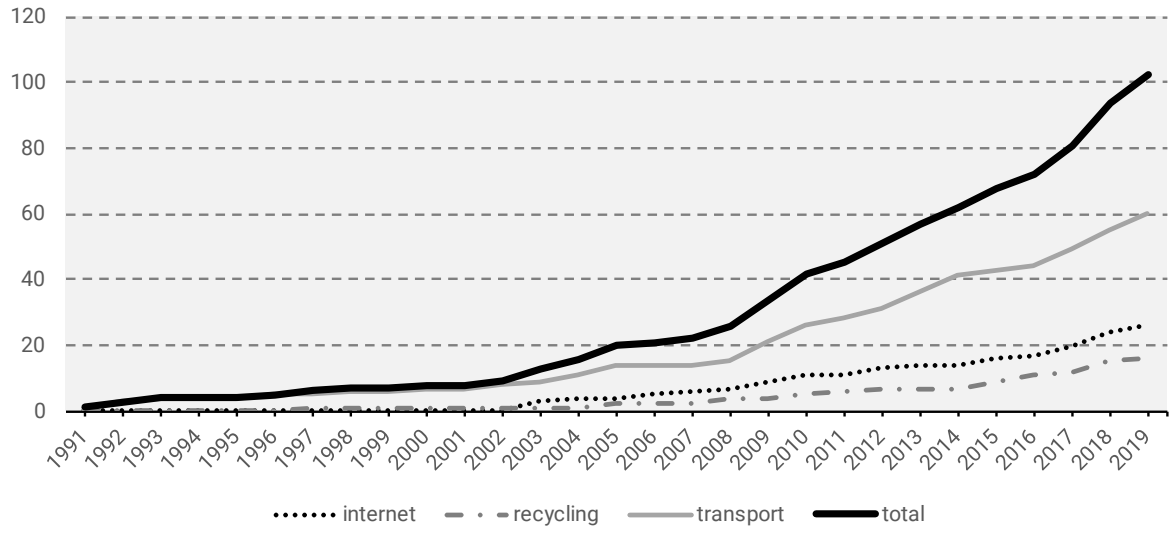

Figure 3. Cumulative count of papers per year and sector.

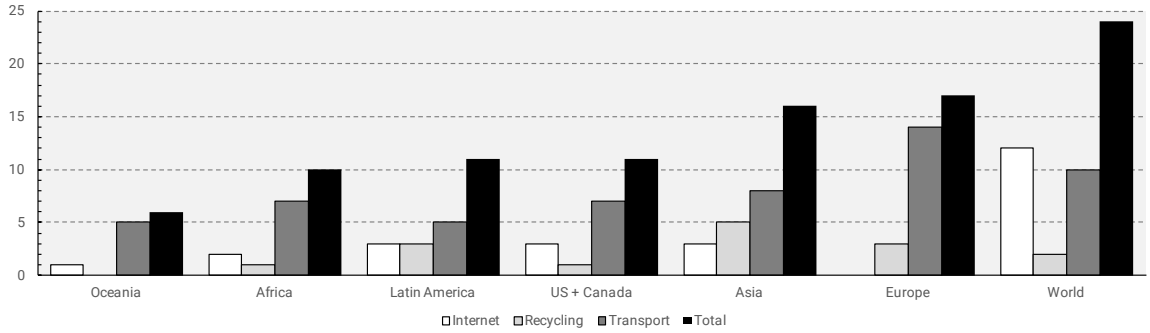

Figure 4. Papers by territorial coverage of cases and samples.

1.4.2 Approach to income: generation versus distribution

For 100 of the papers, I was able to classify their approach to income. As seen in Figure 5, overall, 53 of them focus on income generation, 43 focus on income distribution, and 4 discuss both. Regarding specific sectors, distribution is slightly prevalent in internet studies, while generation is marginally more frequent in transport. In the case of recycling, however, the literature is strongly skewed towards generation instead of distribution: whereas 13 cover the former, there are only 3 papers studying the latter. It is recycling therefore that can explain the overall balance towards generation instead of distribution.

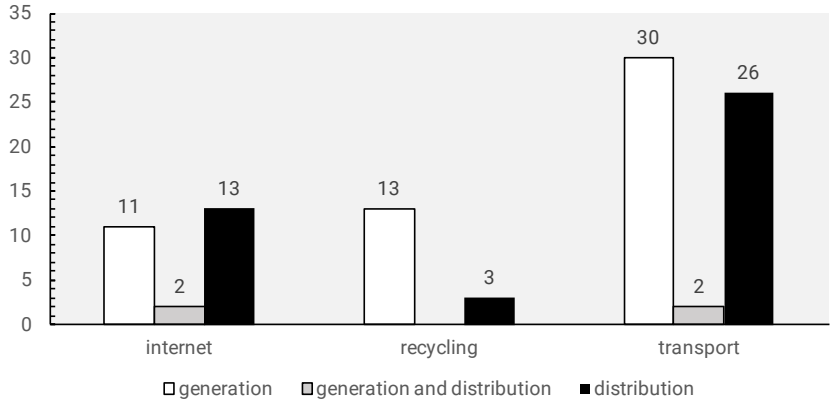

Figure 5. Attention to income generation or distribution of income by sector.

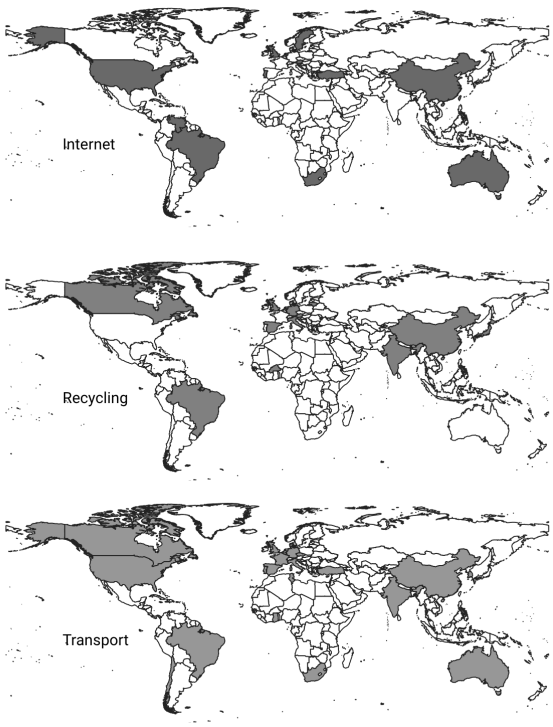

Figure 6. World Maps of country of affiliation of the first author, by sector.

Table 1. Measures used in papers that look at income-related independent variables.

Income or income-related variable	Internet	Recycling	Transport	Total
Income generation				
Household income	1	4	14	19
GNI or GDP per capita	0	1	3	4
Income distribution				
Gini index or Lorenz ratio	8	2	4	14
Income groups	6	0	4	10
Gini index + income groups	1	0	1	2
Gini + Atkinson + Palma	1	0	0	1
Gini + Palma + income groups	0	0	1	1
Wage vs profit rate	0	1	0	1
Urban vs rural incomes	1	0	0	1
Other				
Policies	0	2	0	2
Racial diversity	0	0	1	1
Experience of violence	0	1	0	1
Occurrence of crisis	0	0	1	1
Total	18	11	29	58

The causal link between income and NTA is explored in both directions. From 94 papers that can be classified, 58 use an income-related variable as an independent variable, while 36 of them use it as the dependent variable. As it can be seen in Tables 1 and 2, measures of household income and the Gini index are the two most used variables, along with different groupings of households or individuals according to their income level. In several cases, the use of the Gini index to observe income inequality is complemented by other income distribution measures. A more recently-created indicator, the Palma ratio (Palma, 2014), is only used in two papers that include income distribution as an

independent variable to explain adoption in the internet and transport sectors, respectively (Asongu et al, 2019). There are also some variables that are loosely linked to income, such as increased inequality due to the occurrence of an economic crisis (Bakhat et al, 2017), racial diversity in the South African context (Geyer and Quin, 2019), or likelihood of experiencing violence (Richardson et al, 2015).

Table 2. Measures used in papers that look at income-related dependent variables

Income or income-related variable	Internet	Recycling	Transport	Total
Income generation				
Household income	3	1	3	7
GNI or GDP per capita	0	1	4	5
Employment outcome	0	0	1	1
Hourly earnings	1	0	0	1
Per capita income	1	0	0	1
Income distribution				
Gini index	2	1	4	7
Income groups	0	0	4	4
Gini index +Theil	1	0	1	2
Atkinson	0	0	1	1
Theil	0	0	1	1
Urban vs rural	0	0	1	1
Other				
Poverty rate	0	0	2	2
Disadvantage	0	0	1	1
Extended family basic needs	0	1	0	1
Total	8	5	23	36

1.4.3 Approach to adoption

The definition of adoption varies across sectors, as summarised in Tables 3 and 4. First, the highest level of convergence in the variable used can be found among the papers on internet. In this sector, the most used variable, regardless of the direction of the link being observed, is some measure of users per thousand people or percentage of population with access to internet, followed by measures of internet use among individuals. When internet is studied as the dependent variable, there are also papers that discuss service prices (Weiss et al, 2015; Choudrie et al, 2015). The latter is the only supply-side variable observed within internet studies, while all the rest are demand-side. There are a series of other more specific variables used to observe links to income in the sector, such as measures of capacities for using internet, and type of contents accessed.

Second, in the case of recycling, the variables used can be divided into two groups according to their focus on demand or supply. On the one hand, demand-sided dependent variables are recycling rates, waste generation, and a diverse pool of measures of elasticity or willingness to adopt recycling. On the other hand, supply-oriented dependent variables are formalisation policies (Sharma et al, 1997), interventions by NGOs among communities that work on recycling (Andrianisa et al, 2018), or inclusion of a specific community in the productive process of recycling (Da Exaltacao Coutrim, 2010).

Table 3. Variables used in papers looking at adoption as dependent variable.

Internet	**18**
Users per m people or % with access	7
Use of internet by person	4
Mobile broadband price	2
Users per m people or % with access, quality of service	1
Composite scale of online reading activities	1
Inclusiveness by education levels	1
Internet searches	1
Various	1
Recycling	**11**
Recycling rate	3
Waste generation	2
Willingness to participate	1
Willingness to accept compensation	1
Participation in productive activity	1
Elasticity of recycling rate	1
Price of recyclable waste	1
Various	1
Transport	**30**
Share of trips	5
Household expenditure	4
Passenger kilometers or trips	3
Elasticity of travel demand	2
Vehicle stock	2
Elasticity of fuel demand	2
Per capita fuel demand	2
Emission test failures	1
Transport planning	1
Transport fuel use	1
Stock of public services	1
Fuel prices	1
Participation in voluntary programme	1
Perception about public transport	1
Traffic fatalities	1
Various	2
Total	**59**

Table 4. Variables used in papers looking at adoption as independent variable.

Internet	**7**
Users per m people or % with access	4
Access by individuals, activity online	2
Indexes of skills	1
Recycling	**3**
Ngo intervention	1
Policies	1
Participation in productive activity	1
Transport	**22**
Total or per capita units of physical infrastructure	7
Investment	3
Measure of accessibility	2
Policies	2
Tax rate	2
Vehicle electrification	1
Motorisation rate	1
Commuting expenses	1
Transport subsidies	1
Road pricing	1
Passenger kilometers or trips	1
Total	**32**

Finally, the heterogeneity of definitions of adoption is notably higher in the transport sector. When analysed as outcome, 28 out of 30 papers use variables that focus on the demand-side. The most frequently used ones are share of trips, household transport expenditure, passenger kilometres or trips, and elasticity of both travel and fuel demand. Only a few supply-side indicators can be found as dependent variables, such as transport planning and stock of public infrastructure. In contrast, when looking to transport-related

indicators to account for independent variables, measures tend to be much more supply-oriented: the ones that are repeated among papers are total or per capita units of physical infrastructure, investment, measures of accessibility, policies, and tax rates. Other less used measures are transport subsidies and road pricing, in the supply-side, and vehicle electrification, motorisation rate, commuting expenses and passenger kilometres or trips in the demand-side.

1.4.4 Methodologies

As shown in Figure 7, approaches within the literature are strongly empirical rather than theoretical. Theoretical studies are only 2 out of 26 in the case of internet, and 1 out of 16 in the case of recycling. There are more of these sort of studies in the transport sector, in which 10 out of 58 papers focus on theoretical modelling. Theoretical works looking at the link between internet and income-related variables take the form of literature-based discussions that use some descriptive statistics (James, 2008; Bauer, 2018). In the case of recycling, the one paper that provides a purely theoretical approach is based on a Sraffian model to try to predict prices of waste or 'secondary materials' as a function of variables that include a wage vs profit rate (Hosoda, 2012). The pool of theoretical works in the transport sector is heterogeneous, including diverse simulation models, narrative literature discussions, and commentaries.

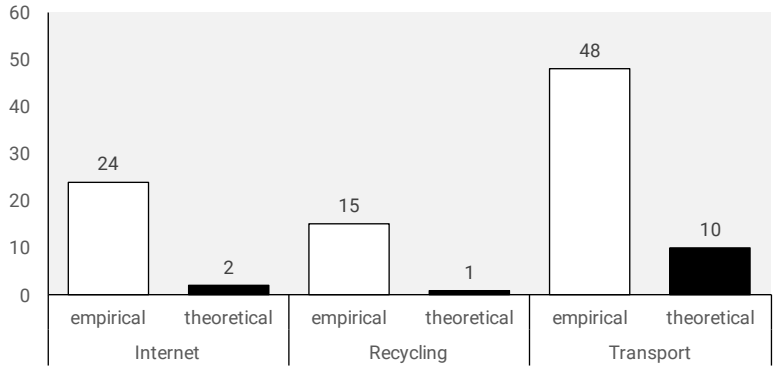

Figure 7. Empirical versus theoretical approaches by sector.

More specifically, types of methodologies can be clearly identified in 92 of the papers. Table 5 groups the classified papers among 12 types. As it can be seen in the table, 83 papers use quantitative methods, while only 9 are qualitative in nature. Only one qualitative paper provides a review, van den Bergh (2008), covering empirical literature on sustainable consumption and environmental regulation of household behaviour. The most used quantitative statistical models are linear and binary outcome regression models without spatial autocorrelation. As shown in Figure 8, the unit of analysis varies, being countries, households and individuals the most analysed: these three categories cover 67 out of 92 classifiable papers. The rest looks at sub-city areas, sub-national regions, types or groups within a country, and cities. The only paper that discusses different scales as units of analysis is the review by van den Bergh (2008).

Finally, in terms of modelling strategies, as shown in Figure 9, only a few studies take in account issues of endogeneity. The most recurrent strategy is the use of instrumental variables: among papers that use them, 8 focus on the transport sector (Liddle, 2009; Anbarci et al, 2009; Hu, 2017; Reis, 2014; Santos et al, 2017; Bakhat et al, 2017; Mishra and Agarwal, 2019; and also the published version of Chapter 3 in this thesis), 5 on

internet (Chang and Just, 2009; Celbis and de Crombrugghe, 2018; Alam et al, 2018; Asongu et al, 2019; Liu, 2017), and 2 on recycling (Kagawa, 2005; Hosoda, 2012).

Table 5. Methodologies used.

Types of methodologies	number of papers
Quantitative	
Descriptive statistics	22
Linear regression models on cross-sectional samples or pooled data (without spacial autocorrelation)	27
Binary outcome regression models	10
Panel regression models (FE, RE)	5
Regression models with spatial autocorrelation	3
Multi-level regression models	1
Count and hurdle models	1
Computable General Equilibrium models	3
Simulations	3
Other models (Engel functions, discriminant analysis, contingent valuation method, input-output, factor analysis, hierarchical cluster analysis, inter-group matrices)	8
Qualitative	
Qualitative, anecdotal or commentaries	8
Review	1
Non applicable	10
Total	**102**

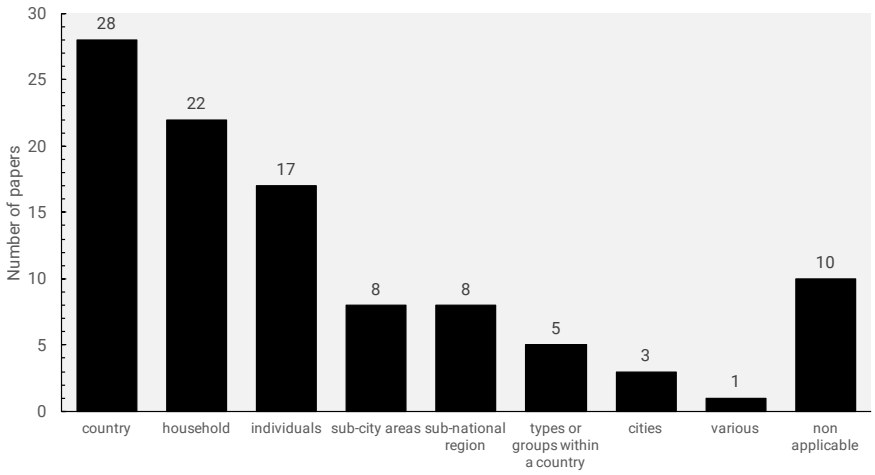

Figure 8. Unit of analysis.

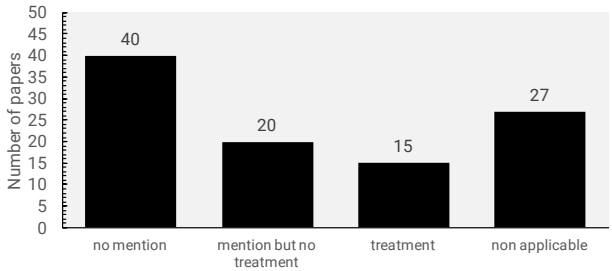

Figure 9. Approach to endogeneity issues.

1.4.5 Empirical evidence

The empirical literature can be divided according to the direction of the observed link, and by whether papers focus on income generation or on income distribution. When significance is analysed, as it happens in 51 papers, all results confirm significance, with the exception of three papers that point to significance as conditional to the use of certain control variables, or limited to a specific income group (Ciegis et al, 2017; Ma et al, 2019).

1.4.5.1 Income generation as a factor for adoption

First, when income generation is studied as independent variable, results tend to negatively link income to adoption of collective passenger transport modes, or positively to private modes and fuel demand. Crôtte et al (2009) associate a raise in minimum wages to higher private vehicle stock elasticity and also higher elasticity of travel demand within the metro network in Mexico City: in other words, with some additional income, metro users are keen to shift from trains to private vehicles. Lee et al (2018) find that vulnerable groups such as poor mothers show a higher share of trips made by active transportation modes in the state of California: they walk more and use more public transportation. Dahl (2012) finds that higher gross national income is linked to lower elasticity of gasoline demand, therefore richer countries will react less dramatically to increases of fuel prices for private transportation. Hájek and Siwek (2009) collect data from a survey in Zlin, Czech Republic, and find that the higher the income level, the lower perception of public transport as an alternative for commuting. Zhu et al (2018) find that the higher the household income, the lower the likelihood of using the metro for trips in Beijing. Diaz Olvera et al (2015) analyse Douala, Cameroon, and observe mobility inequalities measured as trips made per person according to income: access to motorised vehicles in the context of poor public transport is part of the explanation for higher mobility among high earners.

An interesting nuance in the 'linear' narrative regarding the link between income generation and public transportation has to do with forced car ownership. Mattioli et al, (2018) expect household income level to be positively linked to household transport expenditure and less vulnerability to fuel price rises in the United Kingdom. However, they also find that the poorest households spend disproportionate amounts on motoring, and that they are not able to reduce fuel expenditure when prices increase. Something similar can be found in the work by Zhao and Bai (2019:1), who find that 'less proximity to basic public services results in a forced car ownership for rural households' in China.

In the case of recycling, when it is analysed as dependent variable, income generation is seen as positively linked to separate collection rates or material recovery, with the additional presence of the 'environmental Kuznets curve' hypothesis, which predicts an inverted U curve for environmental harmfulness as income grows (Mazzanti, 2008). Otto et al (2016) use a survey collected in Chile to state that personal willingness to participate in recycling programmes increases with household income. In his Sraffian model, Hosoda (2012) finds that higher wages to profit rates generate higher prices of secondary materials, and therefore promote recycling, depending of technological choices.

Although the abovementioned are demand-side links, there are also mentions to supply-side ones. An indirect one comes from Mazzanti (2008), who explains that gross national

income per capita was positively linked to waste generation per capita in Europe between 1997 and 2001, due to lack of policy targets for waste prevention at source and recovery/recycling goals. This author attributes the lack of decoupling between income and waste generation to this absence of policies. Therefore, following an 'inverted U' hypothesis, he argues that, after a tipping point, if adequate policies are in place, waste generation should decrease and recycling to grow as income rises. Finally, a more direct supply-side link has to do with the likelihood of poor people to participate in informal recycling activities. Richardson et al (2015) study vulnerability to violence among people who use illicit drugs in Vancouver, and they find that they are more likely to participate in informal recycling and to be exposed to violence while doing so. Steuer et al (2018) analyse the case study of Beijing and state that adequate inclusive policies and institutional changes can both generate more income among informal recyclers and increase recycling rates in the city.

In the internet sector, all the analysed empirical literature points towards a positive link between income generation and adoption. This literature is entirely demand-based, without mentions to supply-side factors. Martin and Robinson (2007), for instance, find higher likelihood of internet use among individuals from higher income level households, while Hilbert (2010) finds similar results for household internet access in five Latin American countries. Gibson (2003) finds similar results at local area levels in New South Wales, Australia. Katz et al (2017) study parents and children in the United States and, again, conclude a positive link between household income generation and both access and quality of internet connection and use. Alam et al (2018) focus on mobile phone adoption, and find a strong positive link between household income and adoption in Bangladesh. Finally, Yang et al (2013) study internet use gaps among children from rural and urban schools in China, and they attribute existent gaps to differences in income generation among households.

1.4.5.2 The effect of technology adoption on income generation

The literature that explores the other direction in the relationship, that is to say, how does adoption affect income generation, is much more scarce. Whereas in the case of recycling there are no empirical papers analysing this link, in the case of internet there are two papers, both of which point to a significant and positive relationship. On the one hand, Kim (2003) studied the impact of unequal access to the internet on hourly earnings among workers in the United States, and found a positive link between internet access and information-seeking activity and utility maximisation. On the other hand, Celbis and de Crombrugghe (2018) studied regions in Turkey, and found that the number of ADSL lines per inhabitant is positively correlated to per capita income.

In the case of transport, the analysed literature is more abundant. When NTA is looked as independent variable, the common narrative is that supply-side measures such as infrastructure provision are linked to higher income. Caruana-Galizia and Martí-Henneberg (2013), and Caruana-Galizia (2013) analyse railway networks during the end of the 19th century and the beginning of the 20th in Europe and India, respectively, and find that network density is positively linked to regional gross domestic product per capita. Barton and Gibbons (2017) analyse concentration of bus and subway stations in census areas of New York city and find that concentration of stops is linked to higher median household income in a cross-sectional sample, and railway stations show a similar link in longitudinal analyses. Mayeres et al (2005) argue that a supply-side policy of

marginal social cost pricing of transport instead of average cost pricing in the transport sector, can generate higher shares of public transport, shifts of trips from peak to non-peak periods, to benefit the poor, and to increase overall social welfare. These authors state that the significance and size of the effect of adoption of different transport modes on household income can vary according to pricing, charging and taxing policies.

1.4.5.3 Income distribution as a factor for adoption

The empirical literature also analyses income inequality as a factor influencing adoption. However, studies are not equally abundant across sectors. While there are 9 studies covering internet and 6 covering transport, only one covers recycling. This lone paper in the waste management sector was written by Vieira and Matheus (2018) and analyses borough level data in Sao Paulo, finding that income inequality is positively linked to municipal solid waste generation per capita. The authors consider that higher income difference within a municipality means that, in order to have successful recycling policies that could reduce waste generation, a more diverse pool of policies must be put in place, according to the heterogeneity of sectors and income levels. They therefore expect less recycling in more unequal boroughs.

In the transport sector, the view is split between those studies that see income inequality as positively or negatively affecting adoption of public transport. In this case, however, the relationship is less directly studied, in the sense that most dependent variables have to do with private motorisation. All of these empirical studies observe demand-based variables of adoption in the transport sector. For instance, Haque (1991, 1992) published two papers analysing household transport expenditure in Australia, stating that higher income inequality generates lower overall expenditure due to less aggregate ability to pay for private vehicles. In this sense, higher inequality should also lead to more people forced to use public transport. In an analysis of subplaces within Cape Town, South Africa, Geyer and Quin (2019) find that higher racial diversity, which is correlated to higher income inequality, is positively linked to a higher share of trips made on public transportation.

The rest of the literature points to the opposite direction. Lenzen and Schaeffer (2004), for instance, analyse income distribution in Brazil and state that higher inequality leads to higher overall fuel consumption, which leads to expect income inequality to be associated to lower public transport ridership. Purwanto (2016) claims that income inequality leads to mobility inequality, in terms of trips and speed by users. This includes less mobility by users of public transportation. This author claims that 'policies such as subsidizing public transport tickets with regard to the different income or socio-professional groups should lead to reducing mobility inequality directly and also that of spatial segregation, such as the socio-spatial exclusion phenomenon, indirectly' (Purwanto, 2016:119). Thus, measures reducing income inequality should lead to higher use of public transport.

Works on the impacts of income inequality on internet adoption point to a negative effect. Tigre (2003) claimed that higher income inequality was correlated to lower penetration of internet among households in Brazil. On a study on Zimbabwe, Albania, Namibia and Venezuela, Udo et al (2006) claimed that income inequality was an obstacle to adoption of ICTs. Similar results were found by Fuchs (2009), Močnik and Širec (2010), and Gulati and Yates (2012), all using cross-sectional models to look at differences between world

samples of countries and density of internet connections. Using a different indicator, Weiss et al (2015) and Choudrie et al (2015) both claim that higher inequality is positively linked to higher mobile broadband prices across countries, which means less affordability for users. Asongu et al (2019) establish inequality thresholds at which information and telecommunication technologies promote inclusive education: beyond that threshold, fixed broadband subscriptions will no longer positively affect inclusive education.

1.4.5.4 Adoption as a factor for income distribution

Finally, the literature that explores possible effects of adoption on income distribution is the scarcest group within the analysed dataset. Again, there is only one paper on recycling. In this case, Sharma et al (1997) use the case of Mumbai to run a simulation showing that formalising informal recycling, taking the productive activity out from informal workers, generates higher income inequality. In the case of internet, there are two papers, that point to opposite links between adoption and income inequality. On the one hand, Santos et al (2017) use a panel of country level data to state that adoption of ICT has a positive effect on income inequality. On the other hand, Liu (2017) uses cross-sectional data to state that internet diffusion reduces income inequality.

Transport, however, offers a bigger group of studies. Most of them analyse supply-side variables. The only demand-side analysis is Santos et al (2017), which finds that passenger kilometres travelled at country level are associated to higher income inequality. The rest are supply-side oriented. For instance, Reaños and Sommerfeld (2018) analyses data on households from Germany and finds that, depending on the type of tax applied on fuel, the effects can be diverse on the income distribution. Furthermore, three papers focus on stock of infrastructure, finding negative effects on income inequality. Li and DaCosta (2013) analyse urban and rural areas in China, and find that the length of transportation routes by railways in operation reduces inequality. D'Onofrio and Giordani (2019) analyses provinces in Italy and find that transport infrastructure endowments have a negative impact on income inequality. Mishra and Agarwal (2019) analyse Asian countries and find that transport infrastructure reduces rural-urban income disparity.

1.5 Discussion and conclusions

1.5.1 From income to network inequalities: a causal link with diverse signs

On the basis of the results from the systematic map of the peer-reviewed literature, especially from the empirical evidence, it is possible to set a series of theoretical links in order to guide hypotheses for further empirical research. When applied to recycling, broadband and rail passenger transport, 9 different links can be hypothesised according to the sector, the direction of the link, and whether the income variable is related to generation or distribution. These theoretical links are summarised in Figure 10.

Yet, what can be said about the initial questions mentioned at the beginning of this chapter? does income inequality produce network inequalities? Is inequality an obstacle for sustainable change within network industries? To what extent does income generation determine adoption of sustainable network technologies by households? Although thoroughly answering these questions would still require further research, we are now able to start drawing responses on the basis of what has been stablished by the scientific scholarship.

The existent literature indeed provides a basis to expect both income generation and income inequality to affect NTA. Evidence varies across the studied sectors and technologies. In the case of broadband internet, for instance, the literature points to a common conclusion: while income generation is expected to produce higher adoption among households, income inequality is expected to negatively affect aggregate adoption. In the case of recycling, in contrast, evidence is mixed, and research concentrates on income generation instead of inequality. Finally, although the transport sector provides abundant literature that confirms the significance of these links to adoption, the sign of the relationship varies.

In terms of theory, the approach to empirical analyses is dominated by the mainstream Schumpeterian demand-based view on innovation and technology adoption. However, whereas there are no mentions to supply-side factors in the broadband adoption literature, a different story can be found in the waste management and transport industries. Part of the literature on transport, for instance, acknowledges the fact that political and institutional factors fundamentally shape adoption decisions in the supply-side. These factors have to do with infrastructure provision, pricing and taxation. The waste management sector, however, introduces a different sort of supply-side discussion. Although adoption of recycling requires government policies in a similar way than transport, the waste management sector is clearly influenced by a strong existence of informal activities in the supply-side. Although informal recyclers are not completely absent from the Global North, informality is most central for studying recycling in the Global South.

Thus, on the basis of the existing peer-reviewed literature, it is possible to expect a causal link between income distribution and NTA. The causal mechanism is related to the role of ability to pay in the adoption of broadband internet, recycling and public transport. However, how this mechanism operates is mediated by supply-side factors. According to the review, while income and adoption tend to be linearly and positively linked in liberalised environments such as the telecommunications sector, supply-side settings can make the sign vary when institutional factors become more relevant, as in the waste management and passenger transport sectors.

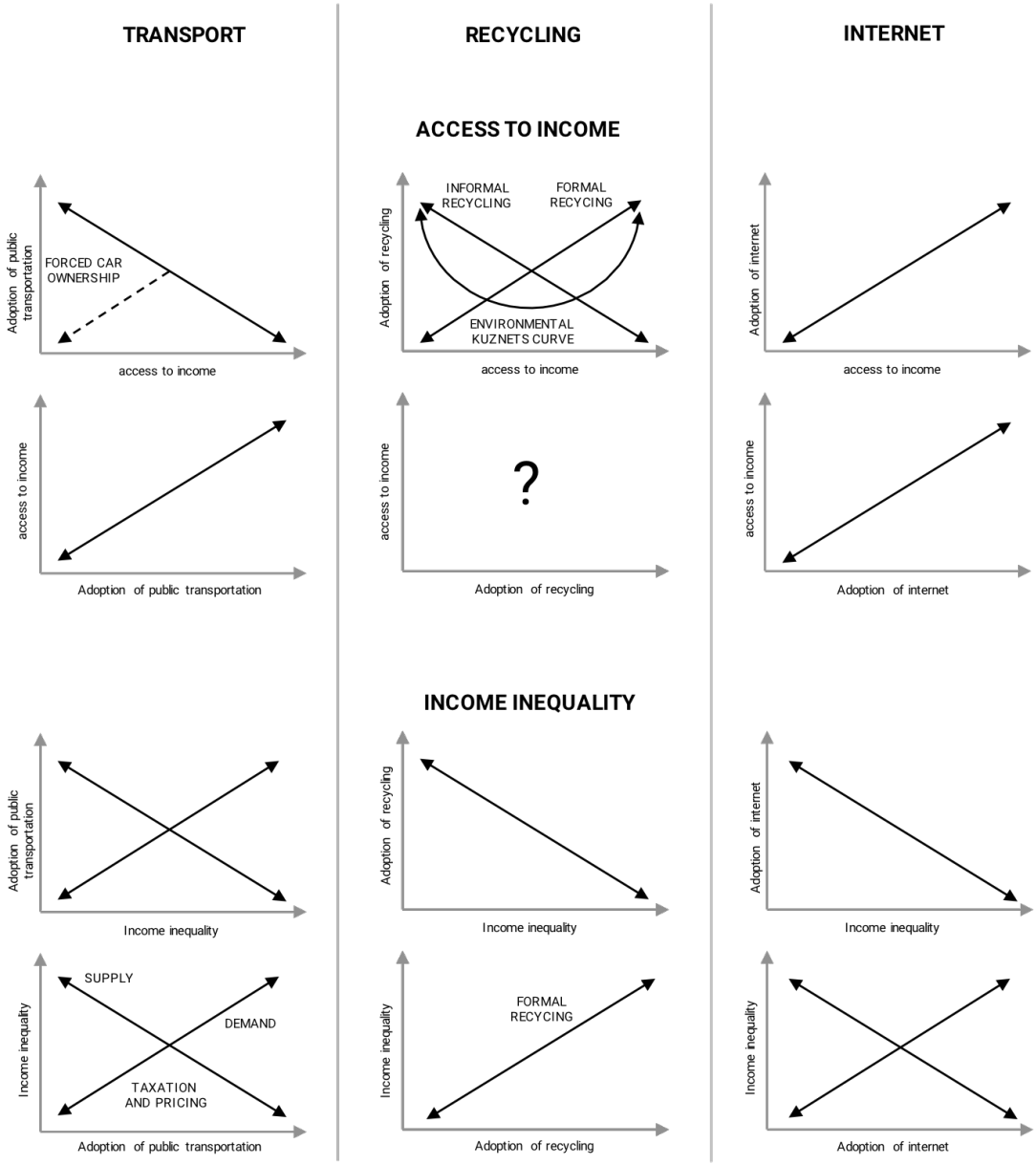

Figure 10. Summary of theoretical income-adoption links based on the empirical literature.

Moreover, something less explored is the reverse causality in the link between adoption and both income generation and income inequality. Whereas there is no evidence of an association between income and adoption of recycling by end-users in the waste management sector – some links are debated in terms of poor households working on income-generating informal recycling activities –, this link is documented in the cases of public transport – particularly rail passenger transport – and internet. This evidence has to be considered when looking at causality and endogeneity in the income-adoption link.

1.5.2 Gaps

Finally, some elements from the review can help to guide research in terms of gaps, possible biases and paradoxes. For instance, as discussed in Section 1.4.1, authors and cases are strongly concentrated in the Global North or, when looking at the Global South, to correspond to major economies such as China, India and Brazil. Consequently, it would be desirable to explore other cases from the South. Beyond this geographical bias, it must be noticed that, with a few exceptions, these countries from the Global North present

lower levels of income inequality compared to the Global South. It is plausible to expect the income-adoption link to work differently in a context of high inequality than in the most-studied and relatively less income-unequal Northern cases. The selection of case studies from highly-unequal South American countries, such as Colombia and Chile (as detailed in Chapters 5, 6 and 7) somehow account for this gap.

Another possible issue is publication bias. As mentioned in Section 1.4.5, all the 51 empirical studies that are analysed find the income-adoption link to be significant, although three papers condition significance to the use of certain controls or to the analysis of specific samples. Although the risk of this bias is always present in the very basis of any research process, an interesting partial mitigation to this risk can come from exploring more than one sector. As shown in Chapter 2, I find results on significance of income inequality to be different depending on the sector, and also on the way income distribution is measured.

Chapter 2 is also useful to tackle three additional gaps. One is the scarce treatment of endogeneity issues in quantitative inferential analyses. In the regression analysis of OECD countries, presented in Chapter 2, the use of instrumental variables allows to discuss interesting reverse causality issues depending on the sectors. On the other hand, it was not possible to find integrated or comparative analyses across network industry sectors in the reviewed empirical literature. Chapter 2 also provides some elements in regard to this gap, since it explores recycling, rail passenger transport and broadband internet using the same sample and model. A third gap is the sole use of the Gini coefficient in most empirical analyses. In this sense, Chapter 2 complements the Gini with the Palma ratio and attention to income shares of different groups.

Finally, many questions arise about the role of institutions (North, 1990; Khan, 1995; Chang, 2002) in the economics of network industries in general, and in the income-adoption link in particular. This review allowed, first, to acknowledge the dominant demand-based view of technology adoption in the three analysed sectors. However, it also detected some evidence of the mediator role of supply-side factors. This evidence comes mostly from the transport and waste management sectors, in the form of policies, taxation, prices and informality in service provision. Such list points clearly to institutions as supply-side elements that need to be incorporated in order to advance in the comprehension of the link between income distribution and network technology adoption.

Questions that remain unanswered are: are there other key institutional factors beyond policies, taxation, prices and informality? Is the issue of informality limited to network technology adoption in the waste management sector? Is the telecommunications sector free of these institutional factors, due to the universal diffusion of liberalisation policies? The following chapters try to shed some light on these issues.

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2 Income inequality as an obstacle for network technology adoption[1]

Abstract

A growing body of literature considers the problem of income distribution as a factor that might slow down or limit adoption of new technologies by consumers. However, less attention has been paid to network technology adoption, especially of old environmental technologies within public utilities that are relevant for Climate Action. In sectors such as energy, transport and waste, mass adoption of technologies that have long ago been available can be the answer for Sustainable Development. In this chapter I analyse the extent to which income inequality can affect adoption of municipal recycling, railway passenger transport and broadband internet. Using available panel data from OECD countries between 1996 and 2013, results show that the adoption rate is higher in countries with more egalitarian income distributions. In the case of recycling, there are no previous studies available linking income distribution and separate collection rates. In the case of transport, the observed association contradicts what could be expected by using theories from the existing literature. The link is found to be exogenous for recycling and railway passenger transport, although results are less robust for broadband internet. The chapter also looks at the relevance that the income share by specific groups has for each sector, and includes a theoretical discussion on possible explanations that can come from both consumer behaviour and institutional political economy.

[1] At the moment of submitting this thesis, a modified version of this paper was under review after one round of major revisions in the Journal of Cleaner Production, co-authored by N. Valenzuela-Levi and M. Abreu, titled 'More unequal, less green? Evidence on the link between income inequality and mature environmental technology adoption in the OECD's waste and transport sectors'. The contribution of each author was declared as follows. *Nicolás Valenzuela-Levi*: Conceptualization, Methodology, Data curation, Writing-Original draft preparation, Visualization, Formal analysis, Funding acquisition. *Maria Abreu*: Supervision, Writing- Reviewing and Editing.

2.1 Introduction

The Sustainable Development Goals (SDGs) are an effort to set the basis for a common world development (United Nations, 2019). Adopted by all the members of the United Nations in 2015, it includes 17 goals in a diverse range of social, economic and environmental issues. Yet, such an effort does not occur in a vacuum. An increasingly complex social context is coloured by growing attention to socio-economic inequalities, especially after the 2009 financial crisis (Milanovic, 2011; Palma, 2011, 2014; Stiglitz, 2012; Piketty, 2014; Pikett and Wilkinson, 2015). The question about transformative change and these fundamental societal problems has sparked growing debates about the role of innovation policies in socio-technical systems and sustainable transitions (Schot and Kanger, 2018; Schot and Steinmueller, 2018; Giuliani, 2018).

Renewed emphasis on addressing income distribution rather than simply poverty alleviation has brought an old debate about social justice back to centre stage of development. However, when it comes to the SDGs, income inequality does not only matter in terms of social justice, but also in terms of capacity for change. A question to be added is whether existent inequalities might affect possibilities for sustainable development. For instance, a relevant part of the targets set in the SDGs depend on adopting environmental technologies (ETs) and information and communication technologies (ICTs). When it comes to technology adoption in general, a growing body of post-financial-crisis literature has considered income inequality as a significant determinant (Tselios, 2011; Hyytinen & Toivanen, 2011; Hatipoglu, 2012; Bernardino and Araujo, 2013; Castaño et al, 2015). More specifically, studies that have focused on the case of ETs, have found evidence that income inequalities could negatively affect adoption processes (Magnani, 2000; Vona and Patriarca, 2011; Andrich et al, 2013). Conversely, evidence from ICT studies finds inequality to be a significant obstacle for technology diffusion (Tigre, 2003; Udo et al, 2006; Fuchs, 2009; Močnik and Širec, 2010; Gulati and Yates, 2012; Weiss et al, 2015; Choudrie et al, 2015; Asongu et al, 2019).

Nonetheless, something that might be counterintuitive is that ET adoption is not only relevant in the context of new technologies, but also in respect to older ones. Take for example district heating, a technology prevalent in the early 1900s, and later revived in 1970s during large-scale social housing developments in many high-income countries. Adoption of district heating has been recently identified as a potential blueprint for efficient energy distribution (Bolton and Hannon, 2016; Burlinson et al, 2018). Similarly, recent policy agendas, such as Climate Neutral Europe 2050 launched in late 2018 by the European Commission, place the adoption of mature technologies at the centre of their strategy. The European plan notes that a strong increase in capacity of – many times more than 150 years-old – rail networks will be required to reach carbon emission goals (European Commission, 2018). The plan also relies heavily on older technologies that can be integrated into a circular economy, for instance, reinforcing material recovery of waste in the form of recycling, which has now been part of the European policy agenda for at least 40 years (Gaballah and Kanari, 2001).

Just like the example of Climate Neutral Europe 2050 illustrates, while societies accept the notion of human-made Climate Change, network infrastructures such as rail (Turnheim and Geels, 2019) and waste management (Bugge et al, 2019) become absolutely critical for any attempt to govern the much needed change. In other words, 'infrastructure has become perhaps the political question of the Anthropocene'

(Wakefield, 2018:1). However, the cases of district heating, rail transport or recycling services in European countries show that although infrastructures might be long ago available, it is also crucial to understand how people adopt these particular mature ETs, replacing existing less sustainable rival alternatives.

This study focuses on the transport and recycling industries within OECD countries, as key examples of these mature environmental technologies that are crucial to govern the Anthropocene. It applies the same econometric model to these different industries, along with household broadband internet from the telecommunications sector. While broadband adoption corresponds to the most typical notion of 'new technologies' that replace 'old' ones, in the cases of both transport and recycling, adoption is related to a 'big shift' (Draper, 2013). In transport, modal shift in passenger kilometres from private motorised vehicles to railways is seen as a way of achieving more efficient passenger transport thanks to economies of scale and the use of electric power instead of fossil fuels (European Commission, 2018). In waste management, in-origin separation of waste by households is the basis for a shift from tons of materials being disposed in landfills to recovering them via composting and recycling (Abbott et al., 2011).

Interestingly, in the case of both transport and recycling, scholars have long ago considered income generation as a key factor at a micro-level (see Section 2.2.2). Yet, when it comes to aggregate levels of adoption, studies in transport and recycling tend to neglect the effect of income distribution within each country. While in the case of the former only a few studies consider inequality and they do it focusing on private motorised transport instead of rail (Section 2.2.2.1), I was unable to find studies analysing the link between income distribution and recycling (Section 2.2.2.2). Our aim is, therefore, to interrogate the role that can be played by income inequality in the process of adoption of mature ETs among OECD countries. In contrast, as already mentioned, the literature on the impacts of income inequality on ICT adoption is much developed and converges in establishing that the inequality-adoption link is significant and negative (Tigre, 2003; Udo et al, 2006; Fuchs, 2009; Močnik and Širec, 2010; Gulati and Yates, 2012; Weiss et al, 2015; Choudrie et al, 2015; Asongu et al, 2019).

In addition to exploring this link for three network industry sectors, I attempt to shade light on what happens beyond aggregate measures of income distribution, as it is the case of popular indicators such as the Gini coefficient. More than just the general income distribution, attention is paid to the income shares of specific groups within each country (Section 2.2.3).

In this article I test hypotheses for the link between income inequality and adoption of mature ETs and ICTs on the basis of existent theories and empirical evidence from the literature on transport and recycling, as well as previous approaches to adoption of 'new' environmental technologies (Section 2.2.4). Through the use of a Random Effects regression model and instrumental variables (Section 2.3) on panel data from OECD countries (Section 2.4), I am able to find that income inequality is significantly, negatively and exogenously linked to adoption of both rail passenger transport and recycling (Section 2.5). In the case of rail transport, our findings contradict what would be expected by using theoretical approaches from existent studies in the transport sector. In the case of recycling, material recovery as an alternative to landfill disposal seems to follow similar dynamics to what has been observed regarding adoption of 'new' environmental

technologies. The results are less robust for household broadband, but point towards confirming the conclusions from previous studies.

Furthermore, I find that adoption of mature environmental technology indeed seems to be sensitive to changes in the income shared by specific groups, depending on the sector. While railway passenger transport is sensitive to changes in shares of the bottom 40 per cent and the top 10 per cent, municipal recycling is more significantly sensitive to what happens in the top half of the bottom 40 per cent, and not affected at all by the share of the rich. Household broadband internet, in turn, seems to be more sensitive to the shares of the middle of the income distribution spectrum. I provide a discussion section to interpret and analyse the relevance of these results (Section 2.6). A fundamental question that should be clarified by further research on the link between income inequality and adoption of mature ETs is whether income distribution is reflecting the influences of changes in consumer behaviour on the demand-side, or being a proxy of institutional factors in the supply-side. Nonetheless, the evidence reinforces the need for considering income distribution when analysing adoption of ETs and ICTs.

2.2 Literature and background

2.2.1 Inequality and environmental technology adoption

The most influential idea linking aggregate levels of income and environmental consequences of human activity is based on the Environmental Kuznets Curve hypothesis. In their seminal work about the environmental impacts of the North American Free Trade Agreement, Grossman and Krueger (1991) were the first authors to propose that environmental degradation followed an inverted U shape relationship following economic development. The original Kuznets Curve theory, developed by Kuznets (1955) – and strongly criticised in recent times (Palma, 2011; Piketty, 2014) –, argues that there is a non-linear relationship between inequality and economic growth, with inequality first rising, and then falling, as an economy develops. Likewise, the Environmental Kuznets Curve theory argues that there is an inverted U relationship between economic growth and environmental degradation, with the level of pollution and other negative environmental outcomes first increasing with economic development (as more pollutants are emitted during the industrialisation process), and then decreasing as environmentally friendly technologies are introduced as a result of pressure from an increasingly environmentally aware and wealthy population.

However, while considering differences in aggregate and levels of economic development, this idea does not consider how income is distributed within the observed society. More or less in parallel to the work by Grossman and Krueger, some ecological economists warned that income inequality might generate market failures leading to higher environmental degradation. This position was first stated by Boyce (1994), who concentrates on 'asymmetries in the power-weighted social decision rule' derived from high income and wealth inequality. Boyce states that inequality leads to distortions of valuations of the costs and benefits of environmentally degrading activities. For instance, the 'efficient level' of environmental degradation in cases like air pollution, 'is higher when those who breathe the dirty air are poor than when they are rich, for the simple reason that the poor's ability and willingness to pay to avoid it is lower' (Boyce, 1994:174).

Although Boyce's propositions were theoretical and focused on environmental degradation in general, Magnani (2000) was later able to integrate the two approaches based on aggregate income and distribution, and focused her empirical work on environment-related R&D expenditure as a proxy of ET adoption. After looking at data from OECD countries, Magnani criticised the assumptions behind the Environmental Kuznets Curve hypothesis. Her main point is that it is not the mean national income but its distribution what will produce a virtuous path of sustainable growth. According to her, and arguing similarly to Boyce (1994), inequality produces a 'gap between the country's ability to pay for environmental protection and a country's willingness to pay' (Magnani, 2000:431). Her empirical results then supported the idea of income inequality negatively affecting adoption of environmental technologies.

A similar path has been followed by more recent studies, benefiting from increasingly available data both on income distribution and environmental variables. Cushing et al (2015) review evidence on the link between income inequality and diverse forms of environmental degradation that can affect health. They found that evidence on a negative impact of inequality is stronger for air and water than for other more dispersed pollutants that might have a less immediate but more longer-term health impacts. Wolde-Rufael and Idowu (2017) claim that a reduction in income inequality could be beneficial for environmental protection and diminishing CO_2 emissions, but its relevance depends on the specific characteristics of each country. Kashwan (2017) analyses the impact of income distribution on the establishment of protected areas. However, it does so departing from analyses centred on economic interests, and focusing on 'political choice'. Kashwan finds that the 'democratic dividend' – the idea that stronger democracies do environmentally better – diminishes as inequality increases, and that the effects of inequality vary depending on the strength of democracy. Finally, Grunewald et al (2017) use a wider and more extended panel dataset compared to other analyses that try to test the Environmental Kuznets Curve hypothesis, and find that the link between inequality and carbon emissions operate differently according to levels of gross national income. In rich countries, however, higher income inequality increases per capita carbon emissions.

Nonetheless, while the literature cited above has convincingly argued in favour of considering distribution as a relevant factor along aggregate income when looking at environmental degradation, after Magnani (2000), the specific issue of ET adoption has been less studied.

A few exceptions have emerged, however, after the 2009 financial crisis. For instance, Andrich et al. (2013) analyse different scenarios for adoption of electric vehicles in the state of Western Australia, and argue that income inequality is an obstacle to their uptake and therefore to sustainable energy use. However, the most cited recent work linking income inequality and ET adoption is the contribution by Vona and Patriarca (2011). These authors find a negative effect of income inequality on a wide range of innovation and technology adoption variables among OECD countries, including public R&D devoted to the control and the care of the environment, per-capita turnover of eco-industries, and the quota of priority patent applications in selected environmental domains. They find a significant negative link between income inequality and these outcome variables, but add, as a caveat, that the closer the technology is to the beginning of its life cycle, the less important the effect of inequality appears to be (Vona and Patriarca, 2011).

Consequently, what I can extract from existent work on inequality and adoption of 'new' environmental technologies, comes from Magnani (2000), Vona and Patriarca (2011) and Andrich et al (2013). All these authors argue in favour of a negative impact of income inequality on environmental technology adoption. In the case of Magnani (2000), inequality is expected to produce a gap between willingness to pay and ability to pay for investments on environmental technology research. In the case of Vona and Patriarca (2011), having wider segments of the population with ability-to-pay for new technologies will generate more demand for green innovation. In the case of Andrich et al (2013), although low-median income groups are the ones that can gain the most from electric vehicles and energy savings, they will lack investment resources for adopting new technologies, and therefore differential paths of transport technology use and energy consumption will lead to new inequalities: inequality is both a cause and consequence of unsustainable energy use.

I was not able to find specific studies linking income inequality and adoption of mature ETs. However, the already mentioned recent work by Burlinson et al (2018) highlights the importance of consumer preferences in adoption of district heating. After analysing results from a quasi-experimental survey applied in the United Kingdom, these authors conclude that problems related to decision-making will likely dissuade consumers from adopting district heating, and they point out that these problems will be more acute among low-income users. Following Burlinson et al and the previous mentioned studies on new environmental technology adaption, I should expect income distribution to be a factor influencing the demand for mature environmental technologies and their less sustainable alternatives. Following literature on new environmental technologies, I should expect inequality to negatively affect adoption. However, this is how far I can go based on the existing literature on environmental technology. In what follows, I review sector-specific literature on transport and recycling to further inform my hypotheses.

2.2.2 The role of income inequality in each sector

2.2.2.1 Transport

The idea of aggregate adoption of rail transport by passengers – in technology adoption language – is named by the transport literature as 'modal shift'. In general, rail is understood as a subset of public transport modes. Transport economics has long ago studied modal shift to public transport by focusing on factors influencing travel demand. These studies are based on the idea that a series of transport modes are available according to ability to pay and preferences. Behavioural psychology has set some of the foundations for micro-level assumptions that sustain theoretical and empirical approaches to the problem. For instance, Collins and Chambers (2005) have provided experimental support for the notion that private vehicles are usually competing with public transport, and that socio-economic factors matter because once supply-variables such as public transport accessibility and fares are defined, costs and available income are crucial for modal choice. In the same line, in his review of the literature on demand determinants for public transport, Polat (2012) points to higher income elasticity of travel demand among low-income groups, which could make one to expect income distribution to affect primarily modal shift among those groups.

Although issues of transport affordability and social exclusion have been increasingly discussed (see for instance the work convened by Mattioli et al, 2018), it is rare to find

studies that specifically include income inequality as a factor influencing modal shift to public transport. The exception is Albalate and Bel (2010), who use data on European cities to look at factors influencing public transport demand and supply. These authors test the hypothesis that higher income inequality might foster both demand and supply of public transport, but they only are able to accept the latter.

What Albalate and Bel find in relation to the role of income inequality is aligned with what is accepted in most studies that include inequality as a factor affecting demand for private motorised vehicles. Demand for public transport is seen as a rival of demand for purchase and use of private vehicles, and therefore inequality should have the opposite effect on each one. Although such studies are scarce, they all point to the same direction: higher income inequality will negatively affect the demand for purchase and use of private vehicles (Haque 1992; Storchmann, 2005; Lescaroux, 2010). The only exception is suggested by Storchmann (2005) who claims that this sign of the relation might be true for rich countries but actually in poorer countries, where adoption of private vehicles is lower, income concentration might foster aggregate demand by increasing ability to pay for private vehicles among the elites. In rich countries, however –as it is the case of the OECD–, the link should be negative.

2.2.2.2 Recycling

As mentioned above, I have not been able to find studies linking income distribution and adoption of recycling. However, what is usually present in the literature is income generation as a determinant of household level adoption of recycling, and median income level within a local authority jurisdiction as a factor determining aggregate levels of separate collection rates. Furthermore, adoption in the recycling sector can be understood, first, from the perspective of a municipal government, in other words, whether a local authority has adopted recycling as part of its waste management services. In this sense, existence of municipal services is a long time reality in most of the OECD countries analysed in this study.

Once recycling is adopted by municipalities, however, adoption can be analysed using aggregate levels of separate collection rates, or in other words, the proportion of the waste that is produced in a determined area that is collected for recycling. This can be measured using volume or weight, being the latter the most commonly available account. Separate collection reflects adoption of recycling among households because aggregate separate collection rates will depend on household's engagement with municipal recycling programs via waste separation in origin (Miafodzyeva and Brandt, 2013). This means both the extent to which a household adopts different forms of recycling in their daily life – programs usually involve a set of dry and wet options for separate collection –, and the probability of households adopting recycling at all.

Although income inequality has not been explored as a factor determining these two dimensions of household level adoption, scholars do provide theoretical associations to income generation that could similarly apply to distribution. For instance, on the one hand, higher income may be positively linked to the probability of adoption of recycling by a household because of educational levels that might allow higher environmental awareness (Chen, 2010), higher ability to pay for recycling services (Abbott et al., 2011), or availability of storage space for waste separation in origin – lower income households often live in smaller dwellings and share space among a higher number of occupants

(Miafodzyeva and Brandt, 2013). On the other hand, once adopted, higher income may influence the extent of that adoption within a household because more affluent groups consume goods with higher recyclable content (Callan and Thomas, 2006).

Although income is usually expected to be positively associated to recycling, there are also some scholars that mention possible negative links. For instance, due to higher opportunity cost of time for high income households, they could devote fewer time to waste separation (Abbott et al., 2011), and their larger consumption volumes might rise overall waste production and diminish the final proportion that is collected for recycling (Sidique et al., 2010).

Considering the theoretical support for a disaggregated household-level link between income and adoption of recycling, I am able to use the same rationale to expect a negative link between income inequality and separate collection rates. Just as discussed by the literature on inequality and adoption of 'new' environmental technologies (Magnani, 2000; Vona and Patriarca, 2011; Andrich et al, 2013), the link to adoption would occur, in the case of recycling, because a more egalitarian income distribution enlarges the portion of the population with enough income to increase the extent of their adoption or their probability of adopting recycling at all.

2.2.2.3 Broadband

As already mentioned, the literature on the effects of income inequality on adoption of ICTs is much more abundant than in the other sectors. All works on the impacts of income inequality on internet adoption point to a negative effect. Tigre (2003) claimed that higher income inequality was correlated to lower penetration of internet among households in Brazil. On a study on Zimbabwe, Albania, Namibia and Venezuela, Udo et al (2006) claimed that income inequality was an obstacle to adoption of ICTs. Similar results were found by Fuchs (2009), Močnik and Širec (2010), and Gulati and Yates (2012), all using cross-sectional models to look at differences between world samples of countries and density of internet connections. Using a different indicator, Weiss et al (2015) and Choudrie et al (2015) both claim that higher inequality is positively linked to higher mobile broadband prices across countries, which means less affordability for users. Asongu et al (2019) establish inequality thresholds at which information and telecommunication technologies promotes inclusive education: beyond that threshold, fixed broadband subscriptions will no longer positively affect inclusive education.

2.2.3 Measuring income inequality

The literature that covers the link between income inequality and technological innovation typically uses the Gini coefficient. As explained in Figure 11, the Gini is calculated as the area conformed between the real distribution curve and a 'perfect distribution', divided by the area under the real curve. Given this calculation, a more egalitarian distribution will have a Gini close to 0, and a distribution in which a few concentrate most of the income will have a Gini closer to 1.

However, a recent and growing body of literature on inequality has focused on new ways of measuring changes in the income distribution. Piketty (2014), for instance, has focused on the income and wealth of the top 1 per cent of the distribution, signalling that concentration by this group tells much about the current nature of capital accumulation.

Moreover, Palma (2011, 2014) has highlighted problems with the Gini coefficient, in particular, its inability to capture changes in the tails of the distribution, and especially in the top 10 per cent and bottom 40 per cent of the population. Given the way of calculating the Gini coefficient explained before, the coefficient will be much more sensitive to changes in the middle than in the tails, therefore neglecting the relevance of the tails detected by Palma. Consequently, the 'Palma ratio' – ratio obtained by dividing the share of the top 10 per cent for the 40 bottom per cent – has increasingly been adopted in mainstream economics to complement the Gini (Palma, 2011; Cobham et al, 2015).

The issue of focusing on the general distribution or on income shares of specific groups is not only a recent debate among inequality scholars, but was also acknowledged almost two decades ago by the ecological economists who aimed to understand the link between income inequality and environmental technology adoption. Magnani (2000), for example, warned that measures like the Gini have the disadvantage, 'in common with any aggregate measure of inequality, that it may change of the same amount and in the same direction following very different changes in income distribution' (Magnani, 2000:438). We engage with this discussion when accounting for adoption of mature environmental technologies, using new inequality indicators as the Palma ratio, as well as looking to the income share of specific groups.

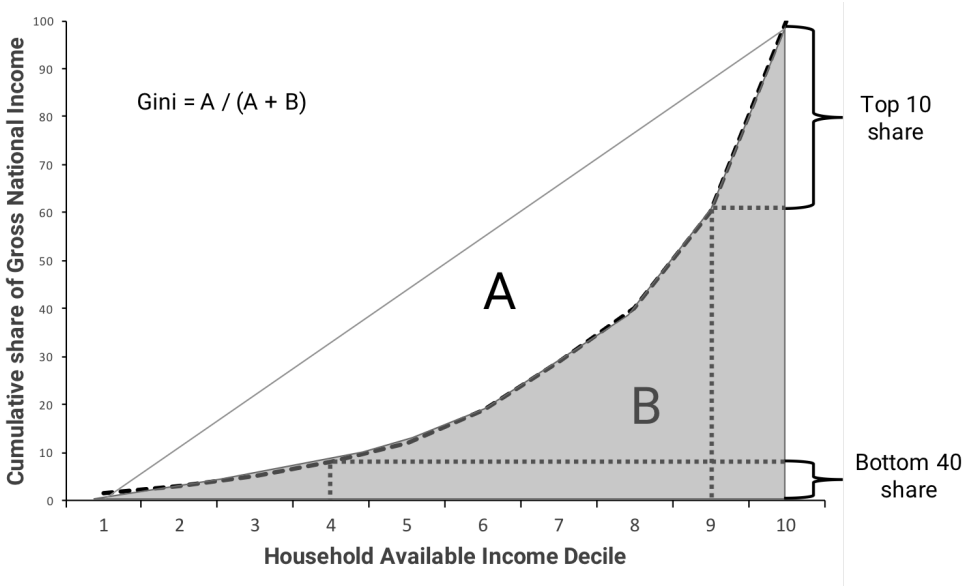

Figure 11. Calculation of different income distribution measures explained from a Lorenz curve.

2.2.4 Hypotheses

The proposed theoretical approach is summarised in Figure 12. On the one hand, the literature reviewed from the transport sector clearly establishes a link between individual income generation and overall income distribution. The former is observed in the context of the latter, and they are mutually dependent as different scales of the same phenomenon. The same applies for adoption at the societal and individual level. In the case of recycling, I conform my hypothesis by theorising on the basis of extrapolating findings from the literature on the individual level into what can be expected at the societal level. Additionally, one could speculate about feedback loops from adoption to income distribution and access, which points to the need of considering reverse causality and endogeneity issues in any empirical modelling strategy.

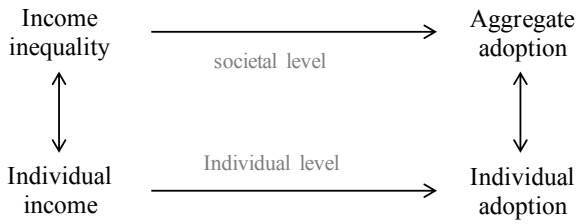

Figure 12. Theoretical links between income and adoption at individual and societal level.

Thus, on the basis of the literature reviewed so far, I test two hypotheses the case of each network technology: recycling, rail passenger transport and broadband. Firstly, on the basis of Section 2.2.2, the first hypothesis is:

H_1: income inequality causes lower network technology adoption.

Secondly, based on Section 2.2.3., I account for the criticism on the use of the Gini and the call to took at specific changes in income shares of different groups both in income distribution studies, and in specific literature that looks at adoption of technology adoption:

H_2: instead of the overall income distribution, network technology adoption is influenced by income shares of specific groups.

2.3 Model

The Random Effects (RE) regression equation is:

$$\ln(Adoption)_{it} = \beta_1 \ln(Inequality)_{it} + \beta_2 \ln(GDP\ per\ capita)_{it} + \beta_3 \ln(Ageing)_{it} + \beta_4 \ln(Absolute\ Latitude)_i + \beta_5 \ln(Supply\ Characteriser)_{it} + \beta_6 (Financial\ Crisis\ Dummy)_t + \varepsilon_{it}$$

Where

- $\ln(Adoption)_{it}$ is the natural log of the percentage of adoption of Railway Passenger Transport or Recycling for each country *i* in each year *t*.
- β_k(*k*=1…6) is the coefficient for the natural log of the independent and control variables;
- ε_{it} is the composite error term.

The modelling strategy aims to take advantage of the availability of panel data for OECD countries, both in the case of income distribution and adoption of the studied mature environmental technologies. A Random Effects (RE) model is used to account for the variance between and within countries. In order to do so, the dependent variables include the main factors that can be found in the literature when modelling the income-adoption relationship. The first is, of course, income distribution, but I also include GDP per capita and Ageing of the population (percentage of the population aged 65 or more), since both are usually incorporated in models within the transport, waste management and internet literature. I use log transformation on all the variables, since most of them are fractional data, or using this transformation is part of the usual convention (as in the case of GDP per capita). Variance Inflation Factor (VIF) was also calculated for pooled data in order to ensure the absence of multicollinearity.

The included income inequality measures are the Palma ratio, share of the top 10 per cent (percentiles 91 to 100), middle 50 (percentiles 41 to 90), bottom 10 (percentiles 1 to 10), bottom 20 (percentiles 1 to 20) and second-bottom 20 (percentiles 21 to 40). All the inequality measures are calculated using available household income, as specified by the metadata from the World Development Indicators (World Bank, 2019).

GDP per capita is expected to determine modal share as it should increase total travel demand and the extent to which travel is made by private motorised vehicles (Bris et al, 2017; Ahmad & Puppim de Olivera, 2016; Skálová & Stávková, 2013; Diaz Olvera et al, 2008; Nolan, 2003). In a similar way, GDP per capita is expected to positively affect waste generation (Slavik and Pavel, 2013) and the aggregate level of wealth should also impact the recyclable content of consumed goods (Sidique et al, 2010; Lakhan, 2014). The same can be said about GDP or aggregate income and broadband internet adoption (Močnik and Širec, 2010; Gulati and Yates, 2012).

*A*ge structure of the population is also included in models as *Ageing*. In transport, percentage of the population that is 65 years or older is expected to have impacts on overall modal share because older people have a higher need for motorized travel and, and greater demand for private and more flexible means such as cars (Aigner-Walder & Döring, 2012). In waste management, older people are expected to recycle more because their alternative cost of time should be lower than other groups (Sidique et al, 2010; Starr and Nicolson, 2015). Age is usually expected to negatively affect the digital divide (Hyytinen & Toivanen, 2011)

A control variable is added to account for individual characteristics in terms of the supply of infrastructure and network services in each country. This takes the form of a '*Supply Characteriser*' for each sector. In the case of railway passenger transport, I use total railroad kilometres per capita. In the case of recycling, I use total tons of waste recycled per capita by municipalities. Considering that we are already controlling for GDP per capita, which is a strong proxy of waste generation, this variable accounts for how much of the total waste is actually being collected by formal services, of which municipal recycling is part of. In the case of the telecommunications sector, I use mobile telephone subscriptions per 100 people. Given the widespread diffusion of mobile telephoning, and considering that broadband providers are often the same companies, this indicator can be used as a proxy of how active and spread the telecommunications sector is.

Finally, since the analysed period covers almost two decades (1996 to 2013), I include a country-invariant dummy to account for the 2009 Financial Crisis. This implies that values are 0 between 1996 and 2008, and 1 between 2009 and 2013. In this way, I account for variations in income distribution, GDP per capita or supply-side austerity measures that could be specific for the second period, in order to be able to draw conclusions for the whole sample.

After estimation, I run a Fixed Effects (FE) regression with a similar specification, in order to apply Hausman tests to define if RE is efficient, or, in other words, whether the included variables can sufficiently account for individual country characteristics.

In order to test H_2 and compare the effect of general income distribution measures such as the Gini coefficient with the income shares of specific groups, results for the same RE

model are compared using different income inequality measures in Table 10, accounting for correlation coefficients, standard errors, overall R^2 and p-values for significance level.

Table 6. Summary Statistics.

Variable		Mean	Std. Dev.	Min	Max	Observations
Recycling	overall	29.715	17.821	0.000	65.234	N = 258
	between		17.180	1.095	60.195	n = 25
	within		4.196	16.673	46.863	T-bar=10.32
Rail	overall	6.402	4.671	0.017	30.873	N = 250
	between		6.604	0.122	30.873	n = 24
	within		0.767	2.881	10.896	T-ba=10.4167
Broadband	overall	46.105	24.024	0.229	97.474	N = 151
	between		18.146	15.539	95.154	n = 23
	within		16.850	8.330	80.265	T-bar=6.56522
Gini	overall	32.679	6.036	23.700	51.400	N = 263
	between		5.234	24.678	47.573	n = 25
	within		1.205	29.707	37.759	T-bar=10.52
Income Share of 10th decile	overall	25.725	4.257	20.100	41.000	N = 263
	between		3.595	20.567	37.641	n = 25
	within		1.035	23.283	30.397	T-bar=10.52
Income Share of 5th to 9th deciles	overall	53.952	1.701	47.200	56.700	N = 263
	between		1.376	48.869	55.918	n = 25
	within		0.645	50.589	55.577	T-bar=10.52
Income Share of 2nd quintile	overall	12.655	1.590	7.900	14.900	N = 263
	between		1.386	8.816	14.678	n = 25
	within		0.286	11.655	13.438	T-bar=10.52
Income Share of 1st quintile	overall	7.668	1.566	3.900	10.200	N = 263
	between		1.397	4.674	9.844	n = 25
	within		0.303	6.468	8.461	T-bar=10.52
Income Share of 1st decile	overall	2.952	0.735	1.400	4.300	N = 263
	between		0.662	1.740	3.989	n = 25
	within		0.170	2.325	3.532	T-bar=10.52
Palma ratio	overall	1.339	0.509	0.801	3.475	N = 263
	between		0.421	0.839	2.814	n = 25
	within		0.113	0.888	2.000	T-bar=10.52
GDP per capita	overall	35266.040	11668.710	13468.500	65083.260	N = 263
	between		11105.120	15555.970	62803.260	n = 25
	within		1882.409	29145.670	39838.720	T-bar=10.52
Population Over 65	overall	14.817	3.933	4.378	22.097	N = 263
	between		3.766	5.388	22.097	n = 25
	within		0.700	12.368	17.385	T-bar=10.52
Km of railway lines per capita	overall	11.006	4.711	0.361	19.692	N = 263
	between		4.344	2.136	17.735	n = 25
	within		1.215	0.508	14.743	T-bar=10.52
Tons per capita colected	overall	0.484	0.151	0.149	0.830	N = 263
	between		0.138	0.155	0.760	n = 25
	within		0.031	0.362	0.617	T-bar=10.52
Mobile subscriptions per 100 inhabitants	overall	96.359	35.237	1.097	172.122	N = 194
	between		24.334	42.628	142.529	n = 19
	within		22.510	11.978	142.960	T-bar=10.2105
Tax revenue as percentage of GDP	overall	19.539	6.022	8.156	35.093	N = 187
	between		6.099	8.932	32.802	n = 19
	within		1.038	16.059	23.542	T-bar=9.84211

N = number of observations, n = number of panels, T-bar = average number of years under observation

In order to ensure that income inequality has an exogenous impact on adoption, I run a Two Stages Least Squares (2SLS) regression with RE (Woolridge, 1997) in order to incorporate instrumental variables (IVs). These variables are the natural logarithms of a five year lagged Gini coefficient, and of total Tax Revenue as percentage of GDP. On the one hand, the overall income inequality from five years before each adoption measure can be expected to be free of influences of the current level of recycling, share of railway passenger transport and households with access to broadband internet. On the other hand, since Gini coefficients from the World Development Indicators are calculated on the bases of total available income, that is to say, after taxes and government spending, the Tax Revenue as percentage of GDP is expected to determine this income inequality measure separately from the market-based distribution of income that is usually regarded as a possible reverse causality from adoption.

Thanks to the use of these two instruments, the 2SLS model can be over-identified and account for weak instruments. Results include post estimation tests, including Sargan-Hansen´s test for overidentifying restrictions, Durbin-Wu-Hausman test of endogeneity, and F-statistics for the rule of thumb for weak instruments (Stock and Yogo, 2005).

2.4 Data

The panel dataset covers the years 1996 to 2013 for 25 OECD countries, for which there is data availability. These countries are Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The three dependent variables *Railway*, *Recycling* and *Broadband* are measured, respectively, as passenger kilometres of railway passenger transport as percentage of total passenger kilometres (the totals also include buses and private vehicles) , tons collected for inorganic recycling and composting as percentage of total tons of waste collected by municipal recycling services (other options are landfilling or incineration), and percentage of total households with access to broadband connection. These variables, as well as the *Supply Characterisers,* come from the OECD (2019) statistic portal. Transport data for Iceland was not available. Available data for mobile telephone subscriptions is only available for 19 countries, which reduces the sample for the regression.

Income distribution measures apart from the Palma ratio, GDP per capita, and percentage of the population aged 65 or more are available in the World Development Indicators database (World Bank, 2019). The Palma ratio – income share of the top 10 per cent divided by the share of the 40 bottom percent of the population –, as well as kilometres of railroads per capita, were calculated using the same database. Data for instrumental variables also comes fro the World Development Indicators. Table 6 shows summary statistics, and Figures 13, 14 and 15 provides an overview of the evolution of each dependent variable.

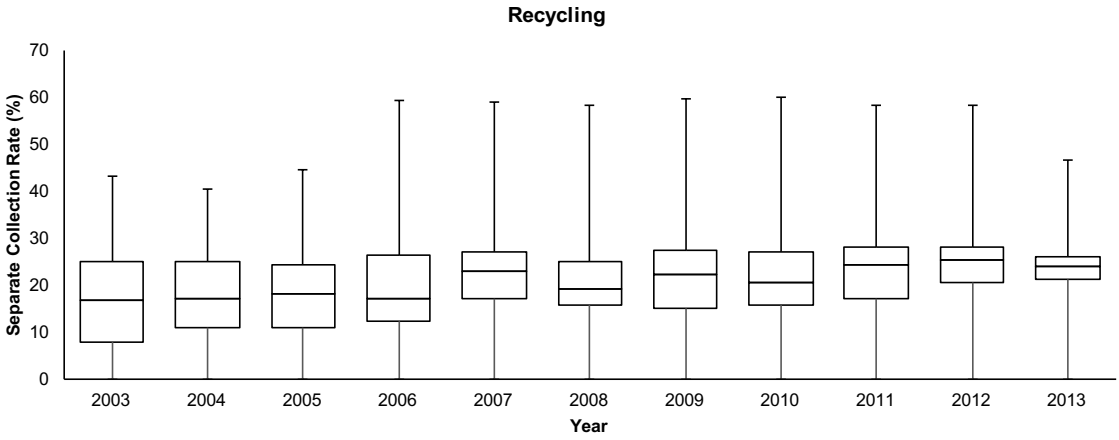

Figure 13. Box and whisker Plot of available OECD data on Recycling in the 2003-2013 period.

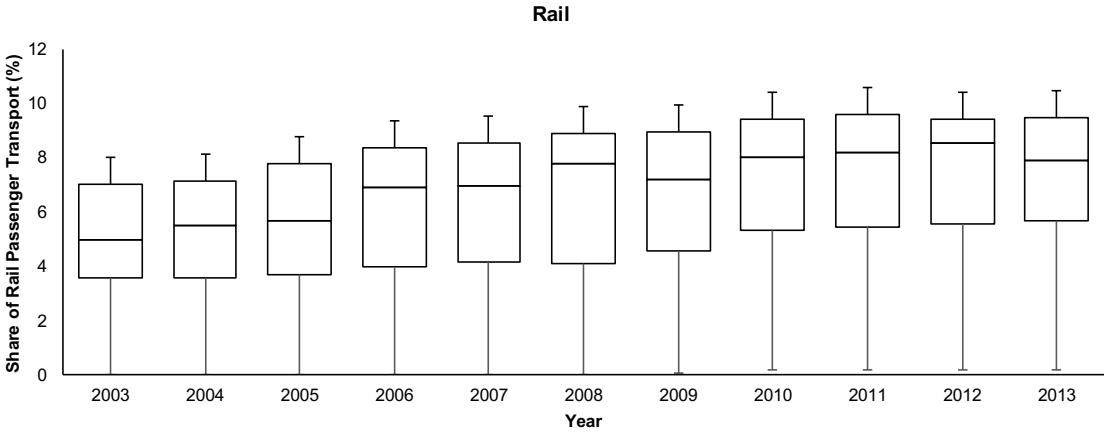

Figure 14. Box and whisker Plot of available OECD data on Transport in the 2003-2013 period.

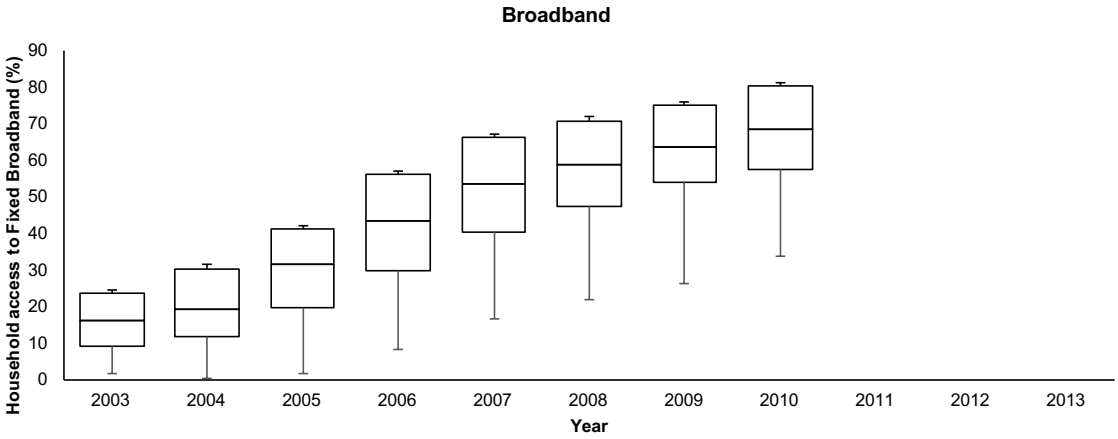

Figure 15. Box and whisker Plot of available OECD data on Broadband Internet in the 2003-2013 period.

2.5 Results

The main results from the panel regressions are summarised in Tables 7, 8, 9 and 10. R^2 reaches 0.69 for municipal recycling, 0.50 for railway passenger transport and 0.26 for broadband internet. P-values from Hausman test for fixed versus random effects models are higher than 0.05 in the cases of recycling and railway passenger transport, which means that the country-specific effects are uncorrelated with the independent variables, or, in other words, the RE model is appropriate to account for country-specific characteristics. This does not happen for household internet broadband, which means that, at least using the Gini coefficient, the individual-specific effects are correlated with the independent variables, and therefore the FE model is the most appropriate. As shown in Table 5, efficiency of the RE model is robust to all the income inequality measures that were tried apart from the Gini.

Moreover, income inequality measured by the Gini index is significantly and negatively linked to adoption in the RE model for recycling and railway passenger transport, and in the FE model for household broadband. Replacing the Gini by the Palma ratio and income share of different groups (Table 10) shows that the significance of the link, the goodness of fit of the model, and efficiency of the variables to account for country-individual characteristics varies according by sector according to the group being analysed. In the case of recycling, the only income inequality variable that is significant apart from the Gini is the share of the 2nd quintile. In the case of railway passenger tranpsort, income inequality is still significant regardless of the measure included, although the goodness-of fit, significance and size of the effect are at their peaks when using the 2nd quintile. The correlation coefficient, for instance, is almost the double for the 2nd quintile than for the 1st quintile. However, R^2 is slightly higher in the latter than in the former. In the case of RE regressions on internet broadband, the only significant income inequality measure is the share of deciles 5th to 9th – the 'middle' in words of Palma (2011, 2014), for which R^2 also reaches its peak. However, negative p-values show that assumptions for the Hausman tests are not met.

Table 7. Regression Results for Municipal Recycling.

	OLS			FE			RE		
ln Recycling	Coef.	Sig.	Std. Err.	Coef.	Sig.	Std. Err.	Coef.	Sig	Std. Err.
ln Gini	0.249		(0.298)	-1.172	**	(0.595)	-0.873	*	(0.496)
ln GDP pc	1.718	***	(0.145)	1.987	***	(0.384)	1.843	***	(0.290)
ln Ageing	1.141	***	(0.167)	1.014	*	(0.576)	0.823	**	(0.360)
ln Totals Waste pc	0.095		(0.121)	0.248		(0.347)	0.192		(0.257)
Financial Crisis dummy	0.183	**	(0.080)	0.117	*	(0.067)	0.141	**	(0.055)
Constant	-18.729	***	(2.041)	-16.120	***	(4.375)	-15.186	***	(3.597)
Observations	256			256			256		
Mean VIF (after OLS)	1.680								
Adjusted R^2	0.699								
R^2 within				0.290			0.288		
R^2 between				0.683			0.687		
R^2 overall				0.685			0.689		
Hausman test for fixed versus random effects model (p-value)				0.833					

*p-value ≤ 0.1; **p-value ≤ 0.05; ***p-value ≤ 0.01

Table 8. Regression Results for Railway Passenger Transport.

	OLS			FE			RE		
ln Rail	Coef.	Sig.	Std. Err.	Coef.	Sig.	Std. Err.	Coef.	Sig	Std. Err.
ln Gini	-4.352	***	(0.515)	-1.096	**	(0.470)	-1.315	***	(0.451)
ln GDP pc	-1.264	***	(0.225)	-1.477	***	(0.297)	-1.438	***	(0.274)
ln Ageing	2.513	***	(0.309)	2.717	***	(0.622)	2.924	***	(0.504)
ln Km lines pc	-0.030		(0.065)	0.003		(0.028)	0.004		(0.028)
Financial Crisis dummy	0.264	*	(0.136)	-0.004		(0.051)	-0.020		(0.046)
Constant	22.726	***	(2.991)	13.244	***	(3.253)	13.150	***	(3.136)
Observations	235			235			235		
Mean VIF (after OLS)	1.470								
Adjusted R^2	0.557								
R^2 within				0.189			0.187		
R^2 between				0.404			0.428		
R^2 overall				0.478			0.495		
Hausman test for fixed versus random effects model (p-value)				0.561					

*p-value ≤ 0.1; **p-value ≤ 0.05; ***p-value ≤ 0.01

Table 9. Regression Results for Household Broadband Internet.

	OLS			FE			RE		
ln Broadband	Coef.	Sig.	Std. Err.	Coef.	Sig.	Std. Err.	Coef.	Sig	Std. Err.
ln Gini	0.569		(0.515)	-1.928	**	(0.837)	-0.699		(0.807)
ln GDP pc	1.179	***	(0.207)	5.551	***	(0.961)	2.264	***	(0.448)
ln Ageing	-1.313	***	(0.378)	1.112		(2.237)	-0.789		(0.741)
ln mobile subscriptions	0.518	**	(0.253)	1.348	***	(0.412)	1.962	***	(0.330)
Financial Crisis dummy	0.692	***	(0.134)	0.466	***	(0.115)	0.447	***	(0.099)
Constant	-9.561	***	(3.381)	-57.332	***	(8.910)	-24.622	***	(5.751)
Observations	111			111			111		
Mean VIF (after OLS)	1.200								
Adjusted R^2	0.380								
R^2 within				0.760			0.704		
R^2 between				0.120			0.083		
R^2 overall				0.198			0.258		
Hausman test for fixed versus random effects model (p-value)				0.000					

*p-value ≤ 0.1; **p-value ≤ 0.05; ***p-value ≤ 0.01

Table 10. Key indicators after RE regressions for different income distribution measures.

		Gini	Income share by groups					Palma
			10th decile	5th to 9th decile	2nd quintile	1st quintile	1st decile	
	Overall R^2	0.689	0.698	0.701	0.685	0.697	0.690	0.694
	P>|z|	0.078	0.216	0.980	0.059	0.455	0.144	0.174
Recycling	Coefficient	-0.873	-0.609	0.043	1.436	0.322	0.456	-0.391
	Srd. Err.	0.496	0.492	1.725	0.762	0.432	0.312	0.288
	Hausman test (p-value)	0.833	0.923	0.918	0.848	0.947	0.878	0.920
	Overall R^2	0.495	0.470	0.427	0.535	0.548	0.523	0.513
	P>|z|	0.004	0.021	0.082	0.000	0.000	0.000	0.001
Rail	Coefficient	-1.315	-0.989	2.490	3.050	1.745	1.018	-0.888
	Srd. Err.	0.451	0.429	1.433	0.735	0.385	0.258	0.260
	Hausman test (p-value)	0.561	0.133	0.381	0.694	0.682	0.458	0.438
	Overall R^2	0.258	0.264	0.300	0.261	0.270	0.269	0.260
	P>|z|	0.386	0.185	0.061	0.617	0.917	0.826	0.334
Broadband	Coefficient	-0.699	-1.053	5.440	0.759	0.089	0.135	-0.485
	Srd. Err.	0.807	0.795	2.904	1.517	0.847	0.613	0.501
	Hausman test (p-value)	0.000	-8.200	-14.540	0.000	0.028	0.144	0.000

Note: All variables were transformed to natural logarithms

The use of instrumental variables – whose correlations with the income inequality measure used as main explanatory variable are shown in Tables 11, 12 and 13 – allows to confirm that the income-adoption link is exogenous for recycling and railway passenger transport, but not for household internet. Results from post estimation tests are summarised in Table 14. F-statistics show that instruments are weak for broadband internet, but strong for recycling and railway passenger transport. P-values above 0.05 in the Sargan-Hansen's test mean that 2SLS RE models are robust to over-identification. Results from the Wu-Hausman test allow to discard endogeneity in the link between income inequality and both adoption of recycling and railway passenger transport.

Table 11. Income Inequality measure and Instrumental Variables used for Recycling.

(obs=132)	ln Share of second quintile	ln Tax Revenue vs GDP	ln 5-year lagged Gini
ln Share of second quintile	1.000		
ln Tax Revenue vs GDP	-0.835	1.000	
ln 5-year lagged Gini	0.508	-0.452	1.000

Table 12. Income Inequality measure and Instrumental Variables used for Railway Passenger Transport.

(obs=132)	ln Share of first quintile	ln Tax Revenue vs GDP	ln 5-year lagged Gini
ln Share of first quintile	1.000		
ln Tax Revenue vs GDP	-0.794	1.000	
ln 5-year lagged Gini	0.422	-0.452	1.000

Table 13. Income Inequality measure and Instrumental Variables used for Household Broadband Internet.

(obs=132)	ln Share of 5-9 deciles	ln Tax Revenue vs GDP	ln 5-year lagged Gini
ln Share of 5-9 deciles	1.000		
ln Tax Revenue vs GDP	-0.605	1.000	
ln 5-year lagged Gini	0.474	-0.452	1.000

Table 14. Post estimation results after 2SLS with RE.

	Recycling (RE)	Rail (RE)	Broadband (RE)
Sargan-Hansen's test of overidentifying restrictions (p-value)	0.053	0.104	0.124
F-statistics (rule of thumb for weak instruments)	101.922	55.202	4.135
Durbin-Wu-Hausman test of endogeneity on pooled data (p-values)			
Durbin	0.189	0.760	0.082
Wu-Hausman	0.204	0.770	0.099
Wu-Hausman on Random Effects regression	0.068	0.313	0.896

2.6 Discussion

The results bring relevant contributions to the literature on the link between income distribution and network technology adoption, particularly in the case of environmental technologies. Firstly, I find evidence that income inequality is significantly, negatively and exogenously linked to adoption of municipal recycling between and within OECD countries. This is a major contribution considering that I was not able to find previous

studies looking at this relationship. Furthermore, the link works as expected by the theorisation based on studies on adoption of 'new' environmental technologies, as well as on the influence of individual income generation and recycling rates. The causal relationship between income and recycling that I extrapolate from existing theories can find empirical support in these findings.

Secondly, the results on railway passenger transport challenge the existent theorisation on the link between income distribution and modal choice in transport. As explained in section 2.2.2.1, the existant theories are based on the assumption that private motorised vehicles are the preferred modal choice when enough income is available. Higher share of income by the bottom 40 per cent, as shown by the results, should diminish and not increase the share of railway passenger transport, as more people would have the option to operate private vehicles to satisfy their travel demand. Consequently, I need to provide alternative theoretical explanations for income inequality acting in the opposite sign than expected.

One alternative explanation could be that, when available, railway passenger transport is preferred to private motorised vehicles by poorer households. This might be expected in countries with lower motorisation rates, but is not so obvious in OECD countries, in which a relevant part of the poor has access to private vehicles. In fact, recent studies have pointed towards transport disadvantage as an increasingly prevalent phenomenon by which the poor are forced to own and use cars in order to access to mobility (Curl et al, 2018; Walks, 2018). A complementary explanation could be that higher share of income by the poor is activating their demand and therefore railway passenger transport, as part of public transport systems, is sustaining additional trips that are supressed if the poor have less income generation. It could be that there is not modal shift going on, but simply an increase in the intensity of use of rails by those that were already using them under more restricted circumstances. If any of these two explanations is accepted, the theoretical assumptions behind existing studies on the link between income inequality and transport should be revised. The main issue to be questioned would be the assumption of private vehicles as a preferred choice when income is available.

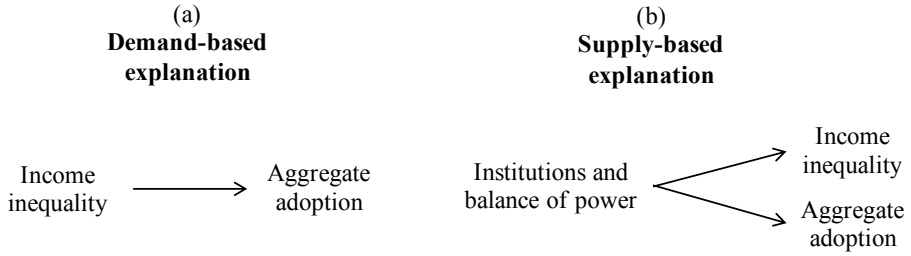

Figure 16. Demand-based and supply-based causal explanations for the link between income inequality and adoption of mature environmental technologies.

Nevertheless, another explanation could also be possible (Figure 16). My hypotheses, just as most of the reviewed literature, only focus on demand-based explanations for the significance of income inequality on mature technology adoption. However, it could be possible that income inequality is acting as a proxy of supply-side phenomena. In order to explore these possibilities, one would need to go beyond neoclassical economics and dive into the realm of institutional political economy (Chang, 2002) and a more interdisciplinary body of literature. For instance, welfare state regime approaches study the relationships between institutions, commodification and social stratification (Esping-

Andersen, 1990). More recently, political settlements theory (Khan, 2010) focuses on the interdependence between institutions, distribution of benefits and balance of power, which has been suggested as an appropriate framework for analysing the urban built environment (Goodfellow, 2017). Furthermore, social epidemiologists have extensively highlighted a negative causal link between inequality and health, arguing that larger income differences reinforce social distances, and therefore social class and status differences (Pickett & Wilkinson, 2015). More recently, mainstream economics has also turned towards the analysis of the "price of inequality", arguing that increased income inequality was a cause of the market failures linked to the 2009 financial crisis (Stiglitz, 2012). In all these views, inequality not only shapes markets due to the distribution of the ability to pay, but also shapes institutions by influencing the rules of the game or by being a proxy of power relations beyond consumer behaviour (see Neckerman & Torche 2007 for a thorough review of the literature on social effects of inequality).

Thus, income distribution could be understood as a proxy of the political settlement (Khan, 2010) that determines the degree of commodification of public services. These services include railways. In a more commodified regime, income distribution could worsen at the same time than a higher portion of costs of services are transferred to users, which could make transport less efficient and attractive. In contrast, a particular set of institutions could be at the same time causing a more egalitarian income distribution, and sustaining stronger public goods that include public transport and railway infrastructure. If the latter were correct, we could be in presence of a new explanation for the empirical results. Income inequality would not be reflecting a demand-side phenomenon, but rather acting as a proxy of supply-side conditions that favour adoption of railway passenger transport over other transport modes. Adoption of mature environmental technologies would be fostered by progressive institutions and balance of power that also redistribute income, and not just by changes in consumer behaviour in the demand-side. A question for further research could be how to bridge the institutional implications of income inequality and socio-technical regime theory, which has integrated institutional theory and innovation studies (Fuenfschilling and Truffer, 2014; Fuenfschilling and Binz, 2018).

Furthermore, regardless of speculations about supply and demand side explanations, accepting H_2 drives the attention toward the income share of specific groups and its influence on adoption. As detailed in Table 10, while R^2 does not show notable variations by changing the income inequality measure when analysing recycling, accepted significance levels – p-values equal or bellow 0.1 –only hold for the Gini coefficient and the second quintile (percentiles 21 to 40). Income inequality is not significantly linked to recycling when using the Palma ratio or the shares of other income groups.

Two theoretical explanations could arise. On the one hand, if the lower-middle income groups are already participating in recycling, an increase of their share might also be associated to the extent of their participation by means of adopting a wider range of recycling options – for instance, incorporating composting or other more specialised waste separation activities (see Chapter 4 for examples) – or by consuming goods with higher recycling content. On the other hand, it could also be possible that recycling is mostly a high and medium-income activity – part bourgeois and middle-class culture – and in places where the top part of the bottom 40 per cent increases their share, some new people are incorporated to the 'green club'. Nonetheless, it is important to notice that, although results for recycling follow the expected demand-based theoretical explanation, a supply-side alternative causal mechanism (as explained in Figure 16) could still be

playing a role. However, the difference between rail passenger transport and recycling is that the link to income distribution and the former holds for the shares of all income groups, while in the case of the latter is restricted to the 5th quintile. A demand-based explanation seems more appropriate.

Goodness-of-fit also provides some elements for discussion. The results for transport show a more notable increase of goodness-of-fit when shifting the income inequality measure, along with an increase of already high significance levels when using the Gini. The percentage of the variance that can explained by the model ranges from 43 to 55 depending on the measure used. In contrast to what is observed for recycling, in railway passenger transport, the share of the rich seems to matter. Higher income concentration is linked to lower adoption. Furthermore, the less significant measure, with the lowest goodness-of-fit, is the share of the middle 50 per cent (percentiles 41 to 90). The phenomena of transfers between the tails of the distribution, observed by Palma (2011, 2014) seems to be crucial in the case of transport, but not in recycling. This could also resonate with possible supply-side explanations, as the relevant phenomena could be not so much about modal shift by the rich, but actually taxation and the amount of resources that are channelled toward public services, which include railways. Regarding transport, I might have to further reflect on Palma's way to put it: "it's the share of the rich – and what they do with it –, stupid!" (Palma, 2011:120).

Finally, although results are not as robust for household broadband internet as in the case of the other sectors, there are some signs of a relevant role of inequality (as expected by the literature reviewed in Section 2.2.2.3). It is worth noting that the significance of the income share of the 'middle' in the RE model could support demand-based explanations according to ability to pay. The lack of robustness of the result is linked to the sample size – notably less countries and years than in the case of recycling and railway passenger transport – and to the fact that the telecommunication sector is institutionally different from the other two, and therefore some other relevant factors might be missing from the models. This interpretation is backed by the lower goodness-of-fit compared to the other two sectors.

2.7 Conclusions

In this chapter I was able to analyse and compare the link between income inequality and adoption of municipal recycling, railway passenger transport and household broadband internet in OECD countries. Panel data regressions provide evidence to support the negative effect that income distribution has on adoption of environmental technologies such as recycling and railway passenger transport. In these cases, adoption is lower when income inequality is higher, both between and within countries. These findings are relevant in the context of the existing literature, first because I was not able to find previous studies on the influence of income distribution on recycling, and because the results contradict the usual assumption of the primacy of private motorised vehicles as modal choice by users when more income is available.

Additionally, I show that more than general income distribution – as measured by traditional indicators like the Gini coefficient – what seems to matter for mature environmental technology adoption is the income share of specific groups. While recycling is more significantly linked to the share of the richest half of the bottom poorest

40 per cent, adoption of railway passenger transport depends on both income concentration by the rich and the share of other groups, particularly the poor. Both links are proven to be exogenous. By discussing these results, I theorise that neoclassical demand-based explanations are limited to explain possible supply-side institutional phenomena that could be determining both income redistribution and adoption of public services. Further research would be needed to explore the nature of these causal links. However, it is clear that income inequality matters.

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3 Why do more unequal countries spend more on private vehicles? Evidence and implications for the future of cities[2]

Abstract

Household transport expenditure (HTE) can account for issues of transport affordability and of how mobility interacts with other needs. Income inequality, on the other hand, is crucially linked to both transport demand and institutions that can shape transport regimes. However, existent literature has scarcely linked income inequality and HTE. This research provides evidence about this link. Income concentration by the richest 10 per cent of the population is found to be significantly, positively and exogenously correlated with HTE on purchase and use of private transport equipment. The proposed econometric models can explain close to half of the variance of this type of HTE among countries. Two theoretical explanations are proposed and debated. One is demand-based, and the other supply-based. I show that the latter is more conceptually sound and claim that income concentration by the elites is a proxy of a balance of power that is associated to private-oriented transport regimes. Such regimes promote private goods over public goods; in other words, car dependency, transport disadvantage and/or informal transport over strong public transport networks. A fundamental challenge for the future of cities is that more unequal societies are in danger of producing wider inequalities after adopting private-oriented smart transport technologies.

Keywords: Income inequality; Mobility; Transport consumption; Household expenditure; Institutional political economy; Smart city; Electric cars

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3.1 Introduction

As recently acknowledged by the United Nation's Sustainable Development Goals (United Nations 2017) and a growing body of literature (notably Palma 2011, 2014; Palma & Stiglitz 2016; Piketty 2014; Milanovic 2011), fighting income inequality is a central task for our societies. However, is inequality relevant to the discussion about the future of smart and sustainable cities? Some existent literature has stated that higher income inequality can be an obstacle for diffusion of innovations such as electric vehicles (Andrich et al 2013) and other environmental technologies (Vona & Patriarca 2011). This research provides evidence on the link between income inequality and household transport expenditure (HTE) on purchase, operation and maintenance of private vehicles, and discusses further possible impacts on the future of smart and sustainable cities.

Two types of causal mechanisms – one demand-based and other supply-based – are proposed as part of a conceptual framework (Section 3.3) that is empirically tested via econometric analysis. Beta Regression Models (BRM) and Ordinary Least Squares (OLS) are used, as well as Two Stage Least Squares (2SLS) regressions and Instrumental Variables (IV) to account for endogeneity. The link is shown to be positive, significant and exogenous. Additionally, models can explain almost half of the variance of HTE on operation and maintenance of private vehicles between countries.

After discussing the results (Section 3.7), the favoured theoretical interpretation comes from institutional political economy: more unequal countries are more likely to have private-oriented transport regimes, in which public goods such as public transport networks and regulation of the use of private vehicles are weak. Private-oriented transport regimes – as opposed to public-oriented ones – promote automobile dependency, as well as informal transport when public services are scarce. This is why HTE and inequality are linked: households from unequal societies tend to be more dependent on using private vehicles.

Moreover, the example of electric cars is used to illustrate consequences of the findings for smart transport technology adoption. Under private-oriented transport regimes, societies that are unequal today are likely to produce wider and/or new inequalities in the future.

This paper is structured as follows: Section 3.2 provides a literature review that helps to contextualise and justify the contribution of this research; Section 3.3 discusses a theoretical framework to understand the link between income inequality and HTE; Section 3.4 explains the econometric models; Section 3.5 describes the data; Section 3.6 explains the results; Section 3.7 discusses interpretation of results, as well as implications that the findings could have for smart transport technology adoption and the future of cities; Section 3.8 concludes.

3.2 Literature Review

3.2.1 Approach to the variables

The approach that the literature has for defining HTE tends to follow what is usually considered as 'transport expenditure' in Household Budget Surveys (HBS), and its disaggregated components. The same sort of definitions of HTE is used in this study, as

detailed in Table 15. There are three dimensions of this expenditure. A first one is the part of the household budget that is spent in purchasing vehicles. Second, these vehicles are operated and maintained. Third, households also pay for transport services when they do not own or are not using private vehicles.

Furthermore, when it comes to the analysis of factors influencing HTE, income distribution is rarely seen among explanatory variables. This occurs despite long-standing warnings such as 'per capita increase in demand for transport and communication item would be underestimated if the income distribution would not be considered' (Haque 1992:52). Moreover, relevance of the influence of personal or household level ability to pay is approached by means of the GDP, available income, or total consumption (Bris et al 2017; Ahmad & Puppim de Olivera 2016; Skálová & Stávková 2013; Diaz Olvera et al 2008; Nolan 2003; Nicholson & Lim 1987). However, although expenditure on food and non alcoholic beverages falls as GDP per capita grows (a phenomenon known as the Engel Law), Figure 17 shows that there is a wider dispersion when it comes to transport.

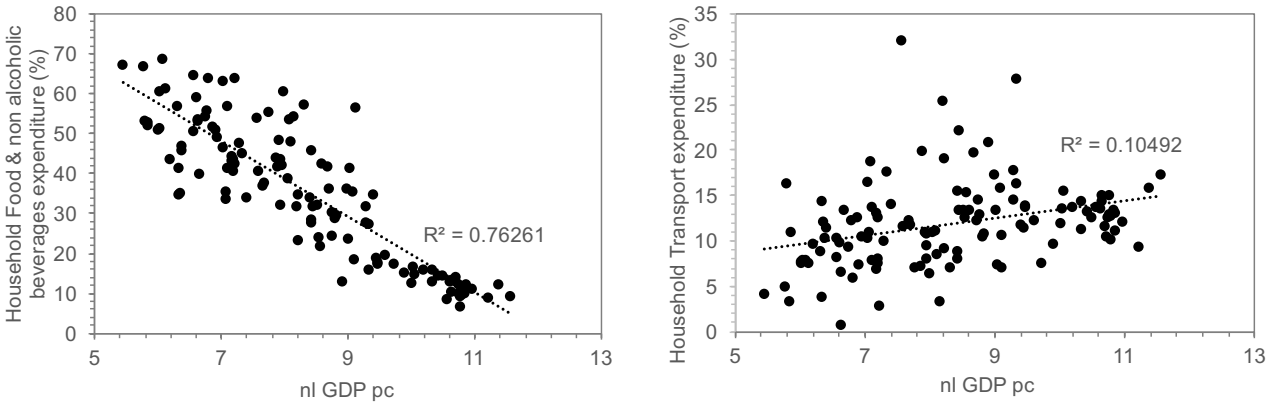

Figure 17. Cross-country differences in household expenditures and GDP per capita (2010).

Table 15. Categorisation of THE: disaggregated transport expenditure.

Type of expenditure	Details
Purchase of vehicles	Motor cars, motor cycles, bicycles, animal drawn vehicles.
Operation of personal transport equipment	Fuels and lubricants for personal transport equipment, maintenance and repair of personal transport equipment, other services in respect of personal transport equipment.
Transport services	Passenger transport by railway, passenger transport by road, passenger transport by air, passenger transport by sea and inland waterway, combined passenger transport, other purchase transport services.

Source: the author based on World Bank (2014)

Surprisingly, the few studies that have been found during the present research point to a negative correlation between income inequality and HTE (as discussed in Sections 3.6 and 3.7, the opposite sign of the correlation is found in regression results). On the one hand, Haque (1992) uses the Lorenz ratio or Gini index while using Engel elasticity models to predict household consumption on transport and communications. He claims that 'the percentage change in demand increases with the decrease of the Lorenz ratio' (Haque 1992:52). On the other hand, Lescaroux (2010) includes income dispersion as a variable for estimating car ownership from household budgets, also using an Engel's curve approach. In this case, he claims that a lower Gini index will imply a more

accelerated curve for transport expenditures such as purchase of vehicles, since, once a certain threshold of available income is passed, more egalitarian countries will have wider groups of consumers with the required ability to pay in comparison to more unequal countries.

Nonetheless, other variables are more often included. Some are only applicable so far at sub-national scales and usually on a small number of cities. That is the case of urban morphology (Ahmad & Puppim de Olivera 2016), access to specific transport infrastructures and services (Li et al 2015), and commuting distances (Li et al 2015; Mattingly & Morrissey 2014; Zolnik 2012; Day & Cervero 2010). Other variables are sometimes observable at a national level, although diverse data availability constraints might apply. Examples are: diesel prices, car ownership, access to ICTs (Bris et al 2017), household size and composition, age and occupation of head of household (Nicholson & Lim 1987), association to socio-cultural or ethnic groups (Ahmad & Puppim de Olivera 2016), housing expenditure (Li et al 2015; Mattingly & Morrissey 2014; Zolnik 2012), and distinction between rural and urban areas (Dargay 2002).

3.2.2 Scope of cross-national studies and sample size

The body of literature that tries to provide an international perspective on HTE started first comparing a small number of countries or cities. This type of perspective had its first contributors in the 1980s, with studies such as Roth & Zahavi (1981) on Bogota, Santiago, Singapore and Salvador, or Nicholson & Lim (1987) on New Zealand and Australia. More recent studies follow a similar scope, as Falavigna & Hernandez (2016) on two cities in Argentina and Uruguay, Berri et al (2014) on France, Denmark and Cyprus, and Skálová & Stávková (2013) on Poland, Slovakia, Hungary and Czech Republic. A particular contribution on a region that concentrates key development challenges is the work by Diaz Olvera et al (2013) on six cities from West and Central Africa, and Diaz Olvera et al (2008), which reviews practically all the available data from African cities, and focuses on three specific cases to compare discrepancies produced by different survey types.

Recent literature about HTE has acknowledged the scarcity of studies covering 'developing economies' (Ahmad & Puppim de Olivera 2016:106). Furthermore, research attempting to provide a global perspective on HTE tends to use small samples. Lescaroux (2010), for instance, looks at 64 countries, while Kauppila (2011) covers 25 OECD economies, and Bris et al (2017) 33 countries with a diverse degree of economic development. In contrast, this research contributes by using a worldwide sample with 123 countries, including 90 considered 'developing'. It was not possible to find such a broad sample within the existent literature.

3.2.3 Empirical and conceptual problems

Finally, some empirical and conceptual issues are mentioned by the literature. Two of them seem to be the most relevant ones. Firstly, transport costs are a phenomenon that not only involves a pecuniary dimension, but also time. Transport economics has worked long ago with time and money all together (Roth & Zahavi 1981). However, data including time is usually collected at a city level, is expensive to obtain, scarcely available, and difficult to compare.

Secondly, as discussed by Diaz Olvera et al (2008, 2013), walking is particularly important for poor and vulnerable citizens, and their activities often tend to take place near home due to travel difficulties. Under these contexts, HTE tends to underestimate the costs of transport for part of the population that does not even reach the minimum ability to pay for transport. However, acknowledging these issues, and although HTE is limited to pecuniary costs, it is still a valuable approach for a global perspective, since there are no other available alternatives to observe a more precise variable at such a large cross-country scale.

3.3 Conceptual Framework

The conceptual framework proposed attempts to account for two types of causal mechanisms that can theoretically influence the link between income inequality and HTE: one is demand-based and the other is supply-based.

The 'political settlement' approach by Khan (2010) is the basis for developing the conceptual framework behind this research. A political settlement is 'an interdependent combination of a structure of power and institutions at the level of a society that is mutually 'compatible' and also 'sustainable' in terms of economic and political viability' (Khan 2010: 20). In other words, a particular institutional arrangement will be sustainable only if the distribution of benefits that it produces is compatible with the existent balance of power. Therefore, income inequality is used here to account for the distribution allowed by a particular political settlement, which means that it can be a proxy of the balance of power between the rich, the middle-income groups and the poor (as notably discussed by Palma 2011, 2014; Palma & Stiglitz 2016).

Furthermore, recent research on political settlements, such as Goodfellow (2018), has illustrated how political settlements are useful to describe mutually dependent national and city-level dynamics. In the same line, the proposed conceptual framework assumes that part of the institutions that are defined by the political settlement include those that shape mobility regimes. Thus, national-level HTE can account for these multi-scalar dynamics that occur within countries, regions and cities.

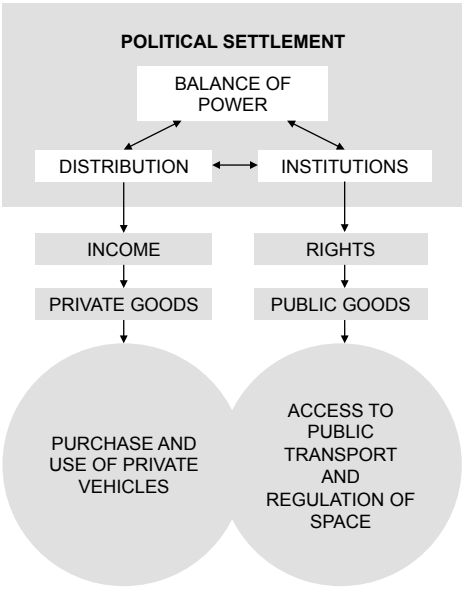

Figure 18. Proposed theoretical approach.

Source: the author

Figure 18 describes the proposed theoretical causal mechanisms by which income inequality can be linked to HTE. The left side of the diagram explains the demand-based link, whereas the right side explains the supply-based nexus.

On the one hand, one of the main benefits distributed according to the political settlement is income. Different income distributions lead to diverse patterns of purchase and use of private goods such as vehicles (Lescaroux 2010). This demand-based link is the conceptual basis for the existent studies that pay attention to the HTE-inequality nexus (Lescaroux 2010; Haque 1992). On the other hand, consumer behaviour will be influenced by both regulations of the use of different transport modes and availability of public transport as a rival to private vehicles. For instance, segregated lanes implemented in Bus Rapid Transit (BRT) corridors produce radical improvements of public transport (Lindau et al 2010); at the same time, they restrict the public space available to private vehicles. Another example is public transport fare reduction thanks to government subsidies (Bocarejo & Oviedo 2012).

These examples are closely linked to the balance of power in a society. Institutions involved in the political settlement entail definitions of social rights (Marshall 1950), which today include the right to public transport (Lipsitz 2004). This is how income distribution is embedded in multi-directional causal links to provision of public goods by governments (see Neckerman & Torche 2007 for a thorough review of research in this link). Investment, social spending and regulatory decisions by the latter are the basis of the supply-side nexus between balance of power and HTE. In summary, institutions that are part of a specific political settlement will include the transport regime within a country and/or a city. Depending on who is favoured by the political settlement, this regime will end up leaning towards a private or public orientation.

Finally, the bottom of the diagram shows the interaction between the demand and supply sides. This is how HTE is determined, since it is defined as the aggregate of expenditure on transport services plus purchase and use of personal transport equipment (Table 15). Transport decisions are influenced by rival alternatives derived from access to different mobility options, their respective time and money costs, and associated regulations of public space.

This is where the hypothesis for this research comes from. On the one hand, we know that within-country inequality at the beginning of the 21st century is strongly shaped by income concentration by the elites (as demonstrated for the top 10 per cent by Palma 2011, 2014 and the top 1 per cent by Piketty 2014). On the other hand, income shares reflect the balance of power between different groups within a society, since power, institutions and benefits must be mutually compatible in a political settlement (Goodfellow 2018; Khan 2010). Therefore, the hypothesis was formulated as follows:

> *H: higher power concentration by the elites, evidenced by income inequality, is linked to looser regulation of private vehicles and weaker public transport provision, leading to higher expenditure on purchase and use of cars*.

As it can be seen in Sections 3.6 and 3.7, this hypothesis is accepted.

3.4 Econometric Model

3.4.1 Model selection

The empirical approach to verify the abovementioned hypothesis implies using HTE as the outcome variable, and income inequality as the explanatory variable plus controls. Two modelling strategies are suitable given the fact that dependent and independent variables are fractional data (i.e. ratios, percentages, coefficients). The first one is running Ordinary Least Squares (OLS) regressions after logarithmic transformation (see, for instance, Hyytinen & Toivanen 2011). The second one avoids data transformation and allows non-linear relations by using beta fractional outcome regressions (BRM).

Let y_i denote HTE_{di} on a disaggregated expenditure d (on private vehicle purchases or operation/maintenance of private transport equipment) for country i and and x_i a k x 1 vector that includes all the explanatory and control variables described in sections 3.4.1 and 3.4.2. HTE_{di} can only assume values between 0 and 1 (0 and 100 if read as a percentage). The model should explain as much as possible of the expected value of y_i given x_i, $\mu_i \in (1,0)$ for every x_i. The OLS estimator of β in the linear model is problematic, as it may predict values outside the 0 to 1 range. The alternative is to use the Beta Regression Model (BRM) with similar specifications to the OLS (for more on the BRM, see Castellani et al 2012).
Results are also reported two OLS models, $y_i = x_i\ \beta + \mu_i$, and $\ln y_i = \ln x_i\ \beta + \mu_i$. Post-estimation tests are ran for diagnostic purposes: Variance Inflation Factor (VIF) calculation for multicollinearity, and Breusch-Pagan / Cook-Weisberg tests for heteroscedasticity.

3.4.2 Main variables

On the dependent variable side, the hypothesis defined in Section 3.3 requires to pay attention to two disaggregated elements of HTE, which are (1) purchase of private vehicles and (2) operation and maintenance of personal transport equipment. Table 1 provides a definition of these variables. HTE on transport services is not analysed, since it would require control variables that are not available for all the countries included in the sample (i.e transport fare prices, transport subsidies).

On the independent variable side, the research process included four different measures of inequality: Gini coefficient, Palma ratio, income share of the 10 per cent (IT10), and income share of the bottom 10 per cent. Due to space constraints, only results using IT10 are reported in detail. This measure has the best fit with the theoretical model and hypothesis defined in Section 3.3, and results show that it contributes to higher explanatory power compared to other indicators (see table 23).

3.4.3 Selection of control variables

Control variables needed to be found in order to account for relevant possible drivers of HTE at a national level. Those included in the model cover factors mentioned by the literature (see Section 3.2) that were available for a large sample of countries. These controls are associated to economic development, urbanisation patterns, geography, government, demographics and global private vehicle markets.

Firstly, GDP per capita (GDPpc) is expected to be the basis of the raise in transport expenditure as food and non-alcoholic beverages decreases its relative importance (see Figure 17). Controlling for *GDPpc* also allows comparisons between countries with a diverse range of economic development.

Secondly, urbanisation patterns are expected to affect HTE (Kauppila 2011), therefore percentages of total population living in both urban areas and in the country's main city are included. While the former explains rural versus urban demographic balances, the latter accounts for economies of scale and agglomeration.

Thirdly, the mean absolute latitude of every country is also incorporated to capture different climatic conditions associated to the distance to the equator. Temperature and weather should be a relevant factor influencing transport-related decisions among households. In fourth place, government spending is also included since it is expected to affect transport costs (Metz 2011). Although this link should be looked at a much more detailed level, such as transport subsidies in specific cities (Bocarejo & Oviedo 2012), government spending at a national level accounts for the general environment in which transport consumption occurs.

In fifth place, percentage of population over 65 years old was considered since ageing is expected to have a relevant impact on HTE (Aigner-Walder & Döring 2012). Older people have a natural need for higher motorised transportation, which should be expressed by the data. Finally, two variables related to private vehicle markets are included. On the one hand, motorisation rate is added since acquisition and use of cars is usually regarded as relevant for the link between economic development, consumption and transport (Lescaroux 2010). On the other hand, the mean trade value per imported vehicle accounts for the market environment in which consumers take decisions regarding private vehicles.

Additionally, from a theoretical perspective, it would have been appropriate to include oil consumption per capita to account for fossil fuel dependency, since energy prices can impact household budgets and access to transport (Li et al 2015; Kauppila 2011). However, although data was available, the inclusion of this variable caused problems of multicollinearity (tested using Variance Inflation Factor), since it is strongly correlated to GDPpc (see figure 19). Data on other factors that might be relevant is not available or only exists at a sub-national level, which means that such variables were omitted. Examples are housing prices, availability of infrastructure for different modes, urban morphology, public space regulation, and multiple dimensions of local culture.

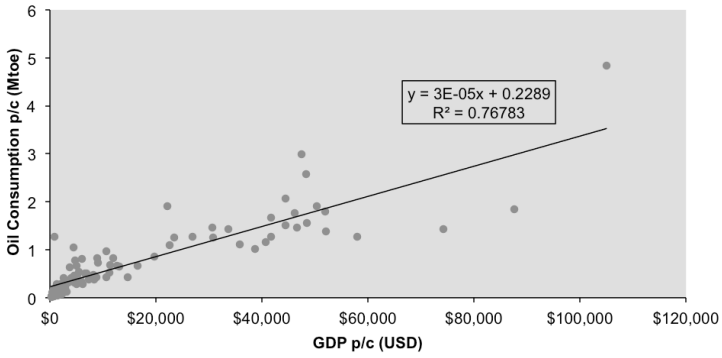

Figure 19. Correlation between GDP p/c and Oil Consumption p/c.

3.4.4 Endogeneity and instruments

It is reasonable to consider that HTE might have an impact on income distribution, since transport could affect income generation via impacts such as accessibility of jobs. For instance, Verikios & Zhang (2015) find evidence of small impacts of transport reforms in Australia on the country's income distribution. This would mean that the causal link discussed in Section 3 operates in the opposite direction. To explore this possibility, Instrumental Variables (IVs) in a Two Stages Least Squares (2SLS) model are incorporated and reported.

The first instrument is the lagged value of INEQ ($INEQ_{t-10}$) (see Cingano 2014 for a similar IV). Values for this IV correspond to one decade before the measurements of HTE and IT10. There are a number of studies that have focused on recent changes in the elasticity of transport during the 2000s, which means that it has recently become a basic need – for elasticity studies see Cortés & Pérez (2010). On the other hand, an increasing number of case studies are analysing the 2009 financial crisis and austerity policies as an episode of strong commodification of public services, including transport, with a simultaneous increase in income inequality (see Cascajo et al 2017). Considering the latter, HTE is assumed to have effects on income inequality after the mid 2000s, so that distributions a decade before can be used as an instrument to observe more recent effects.

The second instrument is *LWHEATSUGAR*, which is a measure of agricultural endowments based on the proportion of land suitable for wheat versus sugar cane. This instrument was found by development economists when looking for a variable that could explain income inequality before recent effects of market inequality and redistribution via taxes and transfers. It was proposed by Easterly (2007), who followed a proposition by the economic historians Engerman and Sokoloff (1994). The latter authors hypothesised that structural inequality in Latin America is higher than in the United States due to a mixture of geographic characteristics and a specific agrucultural business model that was sustained by a set of social and economic institutions. According to this hypothesis, in Latin America, the land endowments lent to commodities featuring economies of scale and the use of slave labor, especially in the case of sugar cane. In North America, in contrast, land endowments lent themselves to 'commodities grown on family farms (…) and thus promoted the growth of a large middle class' (Easterly, 2007:756), being wheat the best example of such kind of crop. The hypothesis was empirically verified by Easterly (2007) in a cross-sectional sample of countries. Accordingly, *LWHEATSUGAR* has been used as an instrument to account for endogeneity by researchers who aim to understand the effect of inequality on more contemporary phenomena, such as adoption of mobile telephoning (Hyytinen, and Toivanen, 2011).

The instrument is measured as: $LWHEATSUGAR_i$ = log[(1+arable land suitable for wheat)/(1+arable land suitable for sugar cane)] in country *i*. As it is developed theoretically and empirically by Easterly (2007), countries with more suitability for wheat than for sugarcane were those in which family farms had a bigger share of total land, and therefore implied a more egalitarian distribution for the century between 1858 and 1958. *LWHEATSUGAR* is significantly correlated with the values of current income inequality,

part of which can be explained by this structural historical long-term association. In contrast, changes in HTE are much more recent, and correspond to processes of urbanisation and technification of passenger transport that occurred mostly later during the 20th century. Therefore, there are no causal links to be expected between suitability for different crops and HTE, and any correlation might be due to the independent relation of each variable with income distribution. Thanks to the use of these two instruments, the 2SLS model can be over-identified and account for weak instruments, as discussed in Section 3.6.

Table 16. Distribution of countries by region.

Continent/region	Countries
Africa	Benin, Burkina Faso, Burundi, Cabo Verde, Cameroon, Chad, Congo Dem. Rep., Congo Rep., Cote d'Ivoire, Djibouti, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia.
Asia	Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iraq, Jordan, Yemen Rep., Lao, Maldives, Mongolia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Timor Leste, Turkey, Vietnam, Israel, Japan, Korea.
Eastern Europe	Albania, Bosnia and Herzegovina, Bulgaria, Macedonia, Montenegro, Romania, Serbia, Czech Republic, Hungary, Poland, Slovak Republic, Slovenia.
Europe	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.
Former USSR	Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Russian Federation, Tajikistan, Ukraine, Estonia.
Latin America and the Caribbean	Bolivia, Brazil, Colombia, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Chile, Costa Rica.
North America	Canada, United States.
Oceania	Fiji, Papua New Guinea, Australia, New Zealand.

3.5 Data

The study uses the World Bank's (2014) Global Consumption Database (GCD), which informs household expenditure from 90 developing countries. The GCD data is based on Household Budget Surveys (HBS). Following Kauppila (2011), HBS data is complemented with National Accounts (NA) data for additional countries. In this case, OECD (2017) data is used to add 33 countries whose data is reported in the OECD NA and were not included by the GCD. The final number of countries included in the dataset is, therefore, 123 (Table 16).

Some minor considerations need to be mentioned about reference values for ratios and time periods. National level ratios of a specific expenditure versus total household expenditure are used. The GCD reports original values in the table 'Consumption Shares 2010 by Country, Product/Service, Area and Consumption Segment (Percent)' (World Bank 2014). Although it reports rural/urban areas and different income groups separately, aggregated national data is used in order to make them comparable with the NA data from the OECD. In the case of the latter, the measure 'Current Prices' is used as the basis for calculating percentages, since it is the one that presents more observations. The percentages for each item in the OECD data were calculated using the item 'P31DC: Final consumption expenditure of households on the territory' as the total. The data from the OECD is extracted for 2010 since the GCD presents homologated values for that year. Three countries presented values equal to zero for HTE on operation/maintenance (Benin, Bhutan, Djibouti), therefore were dropped from the regression.

Most of the remaining variables come directly from the World Bank's (2017) World Development Indicators, or were calculated using figures from the same source. That is the case of GDPpc, income distribution measures (post-tax), urbanisation patterns, and demography. Absolute latitude was calculated from the original values by country found in Google Developers' canonical concepts (Google Developers 2012). Trade value per vehicle comes from the United Nations (2017) Comtrade Database. Oil consumption per capita was calculated using data from the International Energy Agency's Atlas of Energy (IEA 2015). However, as already mentioned, this variable was dropped from the model due to multicollinearity issues.

Motorisation rate by country was extracted from the International Organization of Motor Vehicle Manufacturers' (OICA 2014) dataset. The use of this variable presents some conflicts, as it lowers the number of observations since data is available for only 98 of the 123 countries. On the other hand, the database provides reports for 2013/2014 and not 2010. The variations between 2010 and 2014 might be minimum in most countries, but it is considerable in others such as China (ITF, 2017). The values are still used here, as they account for relevant differences between countries. However, results must be analysed with the caveat that motorisation rates are not useful to interpret results in exceptional cases like China.

All the remaining figures correspond to year 2010, with the exception of the measures of income distribution. In the case of the Gini index and Palma ratio, the values correspond to the mean between the years 2005 and 2015, in order to be able to reflect the long term situation during the decade in which consumption data was collected, and to have more observations. Regarding the instruments, the lagged measure of income inequality, $INEQ._1$, corresponds to the mean between 1995 and 2005. The data for *LWHEATSUGAR* comes from Easterly (2007). Descriptive statistics for all the variables are summarised in Table 17.

Table 17. Descriptive Statistics..

Variable	Obs	Mean	Std. Dev.	Min	Max
Ratio vehicle purchase vs total household consumption	118	0.048	0.026	0.003	0.151
Ratio vehicle operation and maintenance vs total household consumption	115	0.041	0.026	0.001	0.113
IT10	118	0.298	0.064	0.207	0.523
GDP pc	123	12,807.470	19,613.210	231.194	104,965.300
Ratio people in Cities 1 million vs total population	110	0.301	0.140	0.030	0.758
Ratio people in urban areas vs total population	123	0.547	0.222	0.106	0.976
Absolut Latitude	123	28.322	18.262	0.024	64.963
Ratio Gov. Spending vs GDP	117	0.169	0.094	0.051	0.969
Ratio people aged over 65 vs total population	123	0.084	0.058	0.023	0.229
Mean trade value per imported vehicle (USD)	109	217.847	478.726	0.150	3,607.583
Motorisation rate	98	268.335	251.639	1.597	848.733
lwheatsugar	97	0.122	0.205	-0.393	0.544
INEQ-1	107	0.314	0.071	0.206	0.548

3.6 Results

Results provide evidence of the significant, positive and exogenous link between IT10 and household expenditure on operation and maintenance of personal transport equipment. They also show a significant positive correlation between IT10 and household expenditure on purchase of vehicles.

In regard to the latter, as shown in table 18, a significant positive correlation between income inequality and HTE on vehicle purchase is seen in the OLS regression without data transformation and in the BRM. However, in the OLS, the adj. R^2 is barely above 0.22, and a p-value of less than 0.05 in the Breusch-Pagan / Cook-Weisberg test implies heteroscedasticity. The OLS after logarithmic transformation has almost no explanatory power, as also shown in Table 4. In the BRM, IT10 is significant (at the 0.005 level) and positively correlated. The control variables that are significantly correlated (at the 0.05 level) are urban population and absolute latitude. After controlling for key variables (GDPpc, urbanisation, concentration in big cities, government spending, people over 65 years old, value per imported vehicle and motorisation rate), IT10, percentage of urban population and distance from the equator are significantly linked to expenditure on private vehicle purchases. BRMs allow calculating marginal effects at certain values of the factor variable, therefore projecting conditional means that provide an easy interpretation of the link, as shown in Figure 20. Table 19 shows details of the significance of the correlation at each point. Figure 20 shows that the link is not entirely linear.

Table 18. Regression results for HTE on purchases .

	OLS regression without transformed variables			OLS regression after logarithmic transformation		Fractional outcome Beta regression (marginal effects)		
	Coef.		Std. Err.	Coef.	Std. Err.	dy/dx		Delta-Method Std. Err.
Inc. share of top 10%	0.204	***	(0.058)	0.606	(0.422)	0.152	***	(0.046)
GDP pc	0.000		(0.000)	0.081	(0.115)	0.000		(0.000)
% Cities 1 million	0.008		(0.021)	0.046	(0.113)	0.012		(0.018)
% urban	0.049	**	(0.019)	0.263	(0.250)	0.035	*	(0.017)
Absolut Latitude	0.001		(0.000)	-0.012	(0.070)	0.001	*	(0.000)
% Gov. Spending	-0.030		(0.060)	-0.080	(0.209)	-0.042		(0.055)
% aged over 65	-0.062		(0.104)	-0.203	(0.229)	-0.078		(0.095)
Value per imported car (USD)	0.000		(0.000)	-0.005	(0.043)	0.000		(0.000)
Motorisation rate	-0.000		(0.000)	0.032	(0.115)	-0.000		(0.000)
Constant	-0.044		(0.023)	-2.041	(1.755)			
Observations	83			83		83		
R^2	0.308			0.128				
Adj. R^2	0.223			0.021				
Breusch-Pagan / Cook-Weisberg p-value	0.000			0.020				

*** = p-value < 0.005; ** = p-value <0.01; * = p-value < 0.05

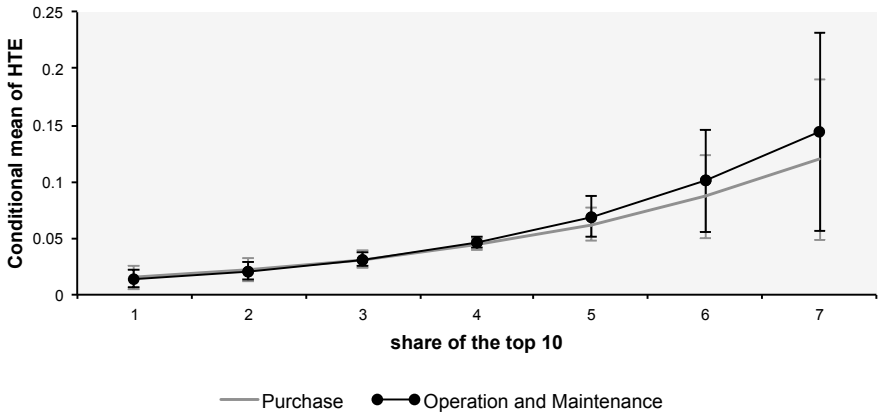

Figure 20. Income inequality and household transport expenditure (margins after Beta regression with 95% interval).

Table 19. Marginal effects of THE on purchases at specific values of income inequality after BRM.

at IT10 value	Margin	Delta-Method Std.Err.	P>z	[95% Conf.	Interval]
1	0.016	0.005	0.002	0.006	0.025
2	0.022	0.005	0.000	0.013	0.032
3	0.031	0.004	0.000	0.024	0.038
4	0.044	0.002	0.000	0.040	0.049
5	0.062	0.007	0.000	0.048	0.076
6	0.087	0.018	0.000	0.052	0.122
7	0.120	0.035	0.001	0.052	0.188

As already mentioned, the most robust results come from regressions for HTE on operation and maintenance of personal transport equipment. The three models show significant positive correlations for the same three variables: income inequality, government spending and proportion of population over 65 years old (see Table 20). The OLS after logarithmic transformation, however, presents problems of heteroscedasticity (table 20 shows the Breusch-Pagan / Cook-Weisberg test's p-value under 0.05). However, Table 21 shows that the linear regression after log transformation is not heteroscedastic anymore after excluding the OECD countries.

Table 20. Regression results for HTE on operation and maintenance

	OLS regression without transformed variables			OLS regression after logarithmic transformation			Fractional outcome Beta regression (marginal effects)		
	Coef.		Std. Err.	Coef.		Std. Err.	dy/dx		Delta-Method Std. Err.
Inc. share top 10%	0.157	**	(0.050)	1.321	**	(0.449)	0.175	***	(0.047)
GDP pc	0.000		(0.000)	0.099		(0.122)	0.000		(0.000)
% Cities 1 million	0.003		(0.018)	0.093		(0.122)	0.005		(0.017)
% urban	-0.010		(0.016)	-0.279		(0.267)	-0.006		(0.017)
Absolut Latitude	0.000		(0.000)	0.062		(0.074)	0.000		(0.000)
% Gov. Spending	0.120	*	(0.052)	0.489	**	(0.224)	0.106	*	(0.050)
% aged over 65	0.225	*	(0.089)	0.493	*	(0.244)	0.218	*	(0.086)
Value per imported car (USD)	0.000		(0.000)	0.029		(0.046)	0.000		(0.000)
Motorisation rate	0.000		(0.000)	0.041		(0.122)	0.000		(0.000)
Constant	-0.047	*	(0.020)	-6.063	**	(1.865)			
Observations	82			82			82		
R^2	0.520			0.506					
Adj. R^2	0.460			0.441					
Breusch-Pagan / Cook-Weisberg p-value	0.766			0.000					

*** = p-value < 0.005; ** = p-value <0.01; * = p-value < 0.05

Table 21. Regression results for OLS with logarithmic transformation, excluding OECD countries

	Including Motorisation rate			Excluding Motorisation rate		
Ratio income share of top 10% vs total income	1.621	*	(0.610)	1.439	*	(0.564)
GDP pc	-0.104		(0.236)	-0.037		(0.197)
Ratio people in Cities 1 million vs total population	0.126		(0.187)	0.166		(0.173)
Ratio people in urban areas vs total population	-0.206		(0.349)	-0.083		(0.308)
Absolut Latitude	0.072		(0.092)	0.061		(0.085)
Ratio Gov. Spending vs GDP	0.338		(0.292)	0.344		(0.269)
Ratio people aged over 65 vs total population	0.606		(0.326)	0.621	*	(0.290)
Mean trade value per imported vehicle (USD)	0.040		(0.074)	0.019		(0.072)
Motorisation rate	0.097		(0.162)			
Constant	-6.022	*	(2.493)	-6.065	**	(2.162)
Observations	57			63		
R^2	0.300			0.264		
Adj. R^2	0.166			0.154		
Breusch-Pagan / Cook-Weisberg p-value	0.095			0.060		

*** = p-value < 0.005; ** = p-value <0.01; * = p-value < 0.05

As seen in table 20, correlation coefficients and marginal effects present a quite similar size in the linear OLS and the BRM. Table 22 shows how p-values for the margins at each value of the factor variable never go below 0.001, as they do in the case of purchases (Table 19).

Table 22. Marginal effects of HTE on operation/maintenance at specific values of income inequality after BRM

at IT10 value	Margin	Delta-Method Std.Err.	P>z	[95% Conf.	Interval]
1	0.014	0.004	0.001	0.005	0.022
2	0.021	0.004	0.000	0.013	0.029
3	0.031	0.003	0.000	0.025	0.037
4	0.047	0.002	0.000	0.042	0.052
5	0.069	0.009	0.000	0.052	0.087
6	0.101	0.022	0.000	0.058	0.143
7	0.144	0.042	0.001	0.062	0.226

Although BRMs do not provide such an intuitive indicator of goodness-of-fit as R^2 in the case of OLS, it is possible to expect the non-linear model to provide a more precise fit, and that the Adj. R^2 of 0.460 from the OLS without data transformation is a reliable indicator that these variables can explain almost half the variance of household expenditure on operation and maintenance of private vehicles. Discarding heteroscedasticity, a remaining possible problem with the OLS regression without data transformation is that the model could theoretically predict negative values if the factor variables get close to 0, and numbers beyond the limit of 1 (or 100 if figures are used as a percentage) among the highest values. Nonetheless, figure 21 shows real and predicted values: there are no predicted values below 0 or above 1. Also Honduras, the country with the highest reported HTE in the GCD (World Bank 2014), is shown clearly as an outlier. Dropping Honduras produces an increase in the R^2, as shown in Figure 21.

The model shows that ten additional percentage points of IT10 are linked to 1.75 additional percentage points of household expenditure on operation/maintenance of private vehicles. Given the non-linearity observed (Figure 20), this increase is higher as income inequality gets to the maximum observed values.

In regard to endogeneity, the 2SLS regression was run using the IVs mentioned in section 3.4.4. The instruments pass tests for weak instruments and over-identifying restrictions, as shown in Table 23. Running the 2SLS regression pre and post logarithmic transformation checks robustness of these results. Given the heteroscedasticity problem after transformation discussed above, post estimation results are reported also for a sample excluding the countries added from OECD NA (which does not have the problem of heteroscedasticity). In the three reported settings, the link between income inequality and HTE on operation and maintenance of vehicles is exogenous.

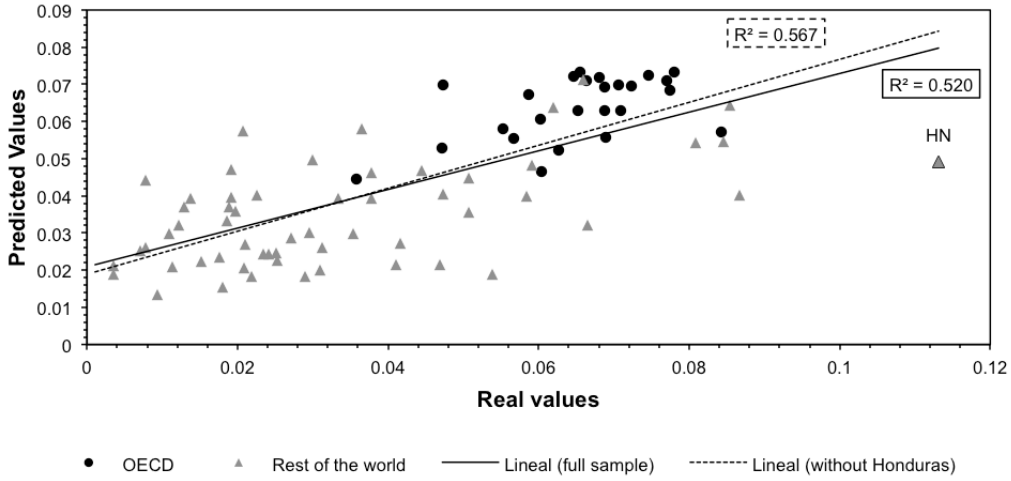

Figure 21. Goodness of fit OLS model without logarithmic transformation: real and predicted values for HTE on operation and maintenance of personal transport equipment.

Table 23. Test results after 2SLS with instrumental variables for endogeneity of the link between income inequality and HTE on operation and maintenance of private vehicles

Test	OLS model without data transformation	OLS model with logarithmic transformation	
Sample	Full sample	Full sample	No OECD
Hansen's test of restrictions (p-value)	0.881	0.928	0.600
F-statistics (rule of thumb for weak instruments)	28.493	87.824	89.283
Durbin test for endogeneity (p-value)	0.862	0.947	0.852
Wu-Hausman (p-value)	0.874	0.952	0.871
Observations	66	66	43

Summarising, evidence is found to support the proposed theoretical approach and hypothesis (Section 3.3). This evidence is stronger in the case of operation and maintenance than of purchase of vehicles. Endogeneity was ruled out for the former but not for the latter. The theoretical fit of IT10 as a measure of income inequality and as a proxy of the power of the elites is reinforced by empirical results from the models. For instance, Table 23 summarises R^2 of the OLS models and p-value of different income inequality measures. Using income share of the richest decile provides the highest mixture of predictive power and significance.

Table 24. Predictive power of models for operation and maintenance of vehicles using different measures of income inequality (OLS regression without logarithmic transformation)

	Gini	Palma	bottom 10 share	IT10
R^2	0.514	0.515	0.492	0.520
Adj R^2	0.450	0.452	0.428	0.460
p-value	0.002	0.002	0.023	0.002

Finally, it is worth mentioning that additional models were run including the square of income inequality measures and GDPpc. In the case of the former, a quadratic relation was discarded – neither the original variable nor the squared one resulted significant when added together in the regression for any one of the two dependent variables. On the other hand, the case of squared GDPpc was included to check any possibility of a Kuznets-style curve (Palma 2011, 2014; Picketty 2014), especially considering the relevance of this idea in inequality studies and ecological economics – as the 'environmental Kuznets curve' (Magnani 2000; Chen & Chen 2008). Results allow discarding this sort of quadratic correlation between GDPpc and HTE, at least in a cross-national setting at the beginning of the 21st century, as covered by this study.

3.7 Discussion

3.7.1 Is it the rich driving more or rather private-oriented transport regimes?

This section focuses on the implications of results for HTE on operation and maintenance of personal transport equipment, given the significance and exogenous nature of the link to IT10.

The fact that IT10 is the inequality measure that provides the best goodness-of-fit for HTE on operation (Table 23) means that the most relevant part of income distribution is the share of the rich. Therefore, it is not what happens in the middle, as it would have been the case if the Gini coefficient resulted more efficient. Neither is what happens in the bottom, as it would have been the case if the R^2 increased by using the income share of the poorest 10 per cent. IT10 is also better to predict HTE than the Palma ratio (share of the bottom 40 per cent in relation to IT10), meaning that it is more about concentration by the rich than deprivation of the poor.

Furthermore, this result can be more specifically interpreted, particularly since the proposed conceptual framework from Section 3.3 suggests two possible causal links (see Figure 18). One is a demand-based explanation: higher HTE on operation is produced due to higher available income among the rich. The other is supply-based: higher IT10 is a proxy of a political settlement that prioritises private goods over public goods, which includes to incentivise the use of private vehicles. Exogeneity, verified for the link between IT10 and operation of personal transport equipment, can be applied to both explanations. But, is it possible to validate one explanation over the other?

On the one hand, to validate the demand-based explanation, one must accept that higher ability-to-pay by the rich leads to more vehicles being operated, or more intensive use-

patterns by this group, all of which rises aggregated national-level HTE on operation. In this case, raises of HTE on operation within this minority should not only equal but also surpass the aggregate impact of drops of aggregated HTE due to lower income shares by the rest of the population.

On the other hand, the supply-based explanation is plausible under two scenarios. In both, IT10 works as a proxy of institutional variables that are difficult to measure. These scenarios are, firstly, weak public transport with no proliferation of informal transport – which would be the case of car-dependent rich countries –, and secondly, weak public transport with high levels of informal transport – which would be the case of most poor countries.

Given that existent institutions are only admitted in a political settlement when they are compatible with specific distribution of benefits and balance of power (Goodfellow 2018; Khan 2010), IT10 can account for benefits derived from those institutions – expressed in form of income. These institutions are the ones that define social rights and public goods such as provision of public transport and regulation of public space. The same institutional arrangement that benefits the rich could be also promoting car-dependency and private-oriented transport regimes. If this explanation were plausible, the correlation between IT10 and HTE on purchases and operation would be due to this supply-side causal link.

The relevance of informal transport in poor countries deserves additional discussion. It could be possible that some of the expenditure on purchase and operation of vehicles by households is, in fact, masquerading expenditure on vehicles for producing transport services. If they were not informal, costs would be entirely or partly absorbed by households in form of HTE on transport services (the third sub-item of HTE in Table 15). Existent research such as Diaz Olvera et al (2008, 2013) discusses both measurement issues and how important informality is for access to mobility within poor or 'developing' countries. Under these circumstances, a private-oriented transport regime and its subsequent weak public goods would also pose incentives for the growth of informal transport services that could be hidden behind a rise in HTE on purchases and operation of vehicles.

Opportunely, available data on household size can help one to validate the supply-based explanation and to disregard the demand-based one. As seen in Figure 22, only 6 out of 62 countries with available household size data (United Nations 2018) have less tan 0.1 vehicles per household: Ethiopia, Bangladesh, Mali, Burkina Faso, Uganda and Vietnam. Being these national averages, tenancy of vehicles probably grows much higher among the richest ten per cent of the population. Moreover, if there are ten vehicles available per every hundred households – as it is the case with 0.1 vehicles per household –, the rich will probably own most of these vehicles. Even with such low motorisation rates, rich households would already have access to vehicle ownership.

Nonetheless, the figure is greater in most of the countries: mean vehicle per household at country level within the 62 countries is 0.95, and the median is 0.90. It is likely that higher income concentration by the rich will lead them to spend more on purchases of vehicles (Cascajo et al 2017; Dargay 2001) for renewing their existent personal transport equipment, or for luxury consumption. However, these sorts of expenses on purchases are unlikely to substantially increase total distance travelled and HTE on operation and

maintenance by the rich. By way of explanation, it is improbable for increases of IT10 to have such an impact on HTE on operation that could lift national aggregated figures. It is implausible for additional purchases to incorporate more cars to operation by rich households: there is a practical limit for significantly increasing operation options that are already available for them. Most of those vehicles will be parked most of the time. On the contrary, HTE on operation of vehicles by the rich will probably decrease if replacement equipment is more energy-efficient (as seen in Nayum et al 2016).

Consequently, since the demand-side explanation can be discarded, the strongest interpretation is that a private-oriented transport regime favours private goods over public goods, which includes neglecting private transport and incentivising use of private vehicles and/or informality. In other words, more unequal countries, and particularly those in which the rich concentrate income, tend to be more car-dependant.

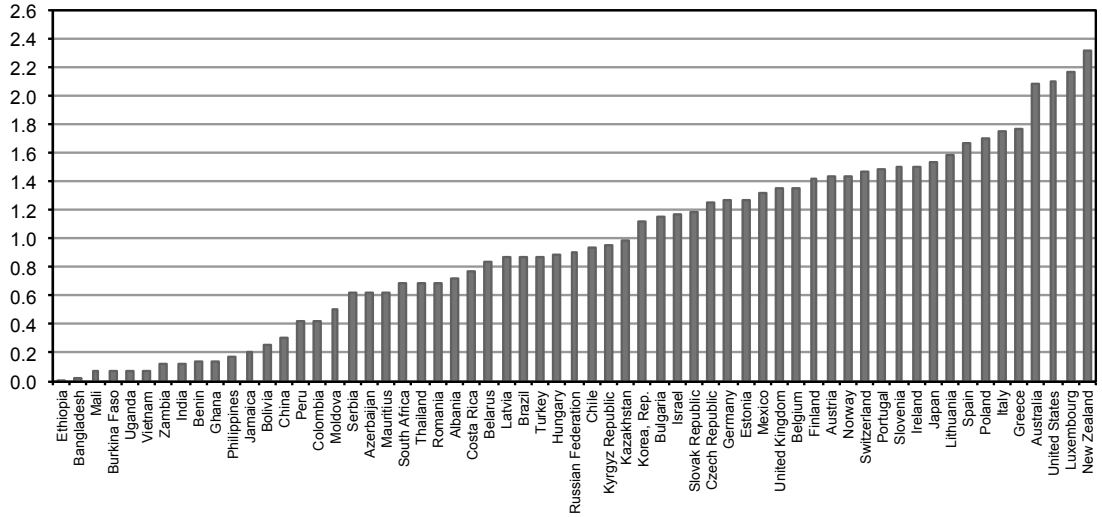

Figure 22. Vehicles per household in countries with available data on household size (n=62).

3.7.2 Impacts on adoption of smart transport technologies

Such a finding has fundamental consequences for the future of cities, and particularly for the adoption of smart transport technologies. The reason is that this nexus between income concentration and what can be called private-oriented mobility regimes implies that more unequal societies are precisely those most in risk of increasing inequalities and of producing new ones while adopting smart transportation technologies.

Existent research can illustrate this risk. Dargay (2001), for instance, proved that income elasticity of car ownership is not symmetric. Car ownership is more sensitive to rising than to falling income. This is in line with more recent studies, such as Curl et al (2018), which suggests that deprived urban communities experience a phenomenon of 'forced car ownership'. This notion was, born out of transport research on British rural areas, implies that poor households avoid spending on other necessities and/or reduce their travel activity to a bare minimum, in order to be able to have basic access to car-based mobility (Mattioli et al 2017).

Automobile dependence is, of course, linked to transport disadvantage, which means a 'situation in which local residents must practically rely on a car in order to get to most

important destinations' (Walks 2018:137). In poor countries with less access to cars, transport disadvantage means to depend on informal transport or to simply limit mobility to what can be reached by walking (Diaz Olvera et al 2008, 2013). The opposition between public-oriented and private-oriented transport regimes is evident: vulnerability, social exclusion and even higher debt are associated with automobile dependence (Walks 2018), while prioritising public transport benefits those with less income. Cascajo et al (2017), for instance, found that stronger public transport networks facilitated adaptation to the 2009 financial crisis in Spain. Moreover, a private-oriented transport regime, or austerity policies that can lead to one, do not only come with smaller and weaker public transport networks, but also can imply less subsidies and higher fares, with greater impact among the poor (Cascajo et al 2017; Li et al 2015).

What does all the above have to do with adoption of smart transport technologies? A good example to answer this question is electric vehicles. Andrich et al (2013) studied impacts of income inequality on adoption of this sort of vehicles, which are a significant feature of what is considered smart technology. These authors found that income inequality can be an obstacle to the uptake of electric vehicles, and also that subsequent disparity on energy use by different income groups leads to increased inequality. In their words, 'low-median income households have the most to gain from overall electric vehicle uptake, but these same households cannot afford to adopt these vehicles" (Andrich et al 2013:315).

Furthermore, qualitative studies in advanced economies – where adoption of electric vehicles is occurring at a higher pace – have shown that socio-economic characteristics linked to income are fundamental to understand willingness to adopt electric vehicles. According to a study from Norway, adopters of electric vehicles tend to evaluate convenience and performance attributes in a lesser extent than conventional vehicle buyers (Nayum et al 2016). Conversely, education level – which is linked to income – has been found to have a positive impact on attitudes for adoption of electric vehicles among Swedish buyers (Westin et al 2018). In the same line, willingness to pay is key to understand purchase intention of electric vehicles among users from Hong Kong (Ng et al 2018). The above-mentioned characteristics point to the same direction of Andrich et al (2013): an electric vehicle adoption process that will take place primarily among the rich and will amplify existing inequalities.

The key question is, therefore, about the future transport regime that adoption of smart technologies will help to build. Is smartness going to be private-oriented or public-oriented? If smart technologies follow a merely demand-based diffusion process (Hatipoglu 2012; Vona & Patriarca 2011), smart transport technologies that will flourish will be those individually purchasable, as opposed to natural monopolies such as public transport systems. Technology adoption within those monopolies requires effective policy and active government involvement (Mazzucato 2011). Under a private-oriented regime, as suggested by Andrich et al (2013), current inequalities will delay adoption of new technologies and produce new divides. The warning that emerges from this research is that, without active policies to break inertia, societies that are unequal now – which are likely to have private-oriented transport regimes –, will probably produce more socially unjust cities in the future. A better horizon for all requires public-oriented smart cities, achieved via public-oriented smart policies.

3.8 Conclusion

After controlling for other external factors that could explain HTE at a country level, more income unequal countries, particularly those characterised by income concentration by the elites, have higher levels of expenditure on purchase and use of private vehicles. The proposed theoretical explanation is that higher income concentration reflects a particular political settlement in which the power balance produces private-oriented transport regimes.

Further research on longitudinal data would be desirable to more thoroughly analyse this phenomenon. Furthermore, the bridge between transport and structural adjustment or austerity policies deserves a more detailed attention, following emergent studies such as Cascajo et al (2017). Nonetheless, the evidence from this study should be enough to include income distribution and transport regimes as factors when attempting to analyse and predict household transport expenditure.

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4 Do the rich recycle more? Understanding the link between income inequality and separate waste collection within metropolitan areas[3]

Abstract

There is a widespread concern about increasing inequalities within cities. However, it is not clear whether these inequalities translate or not into differences in pro-environmental activities such as recycling. In this chapter, Barcelona and London are compared to characterise the income-recycling nexus within cities. On the one hand, in Barcelona, although the income gap is smaller, separate collection rates reproduce income disparities between local authorities. On the other hand, in London, a bigger income gap is not translated into separate collection rates. Evidence is provided to hypothesise that this difference is linked to their service financing regime. The idea that the rich recycle more because of being more educated or having different consumption patterns should be re-examined under institutional lenses. If the rich recycle more, it might be just because of regressive distribution of municipal resources. It is urgent to consider distributional issues when designing metropolitan recycling policies. Otherwise, transitions to sustainable urban environments might be restricted to affluent areas within cities.

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4.1 Introduction

Promoting recycling and reducing income inequality are both part of the Sustainable Development Goals (United Nations, 2016), as well as central pieces of any transition towards equitable, sustainable, and liveable cities. In order to implement such a transition in the world's largest urban areas, attention needs to be paid to how social inequalities and environmental policies interact. Furthermore, resources and waste management decisions do not take place in a vacuum, but 'within the framework of historically contingent socio-political institutions (e.g. liberal democracy, consumer society, atheistic/humanistic/hedonistic values prevailing)', and 'under conditions of the contemporary political economy (e.g. highly financialised, globalised, and deindustrialising capitalistic market systems)' (Iacovidou et al, 2017:1283).

In an attempt to contribute to our understanding of part of that framework in which waste management is defined, this research explores the link between income inequality and municipal separate collection rates (SCRs) among local authorities (LAs) within metropolitan areas (MAs). In order to perform this exploration, an institutional political economy perspective (Chang, 2002) is employed to overcome the limits of usual studies, most of which tend to neglect institutional variables which might shape the income-recycling nexus. In particular, this chapter highlights the importance of the distributional aspect of the service-funding regime (SFR) that sustains municipal waste management (MWM); that is to say, the question is whether funding mechanisms and local fiscal autonomy (LFA) reproduce, ignore or correct income inequalities between LAs, particularly when it comes to SCRs.

As part of the neglect of institutional factors, most of the existent literature places income on the demand side of variables, seeing it as a predictor of consumer or voter behaviour. Scarce consideration is given to the fact that income distribution might be a proxy of institutional arrangements, political settlements and balance of power between different groups (Goodfellow, 2017). A possible explanation for a lack of discussion about the SFR might be that studies analysing determinants of SCRs at LA level tend to select samples of cases that belong to the same institutional framework. For instance, a vast majority of existent studies focus on LAs within one specific country (Hahladakis et al, 2018; Agovino et al, 2016; Carvalho & Cunha Marques, 2014; Slavik & Pavel, 2013; Gallardo et al, 2012; Abbott et al, 2011; Matsumoto, 2011; Lavee & Khatib, 2010; Chen, 2010; Chen & Chen, 2008; Peretz et al 2005), and some additional studies look at what happens within a specific region or state (for states under federal regimes see Starr & Nicolson, 2015; Lakhan, 2014; Sidique et al, 2010; Callan & Thomas, 2006; for a region see Passarini et al, 2011). In both national or regional/state scale studies, the analysis is usually limited to one specific institutional framework, therefore reducing the possibilities of observing differences associated to relevant contrasts in rules. The aim of this chapter is to fill the gap by using a mixed methods approach is used here to explore this gap by means of comparing two MAs from different European countries: Barcelona (Spain) and London (United Kingdom).

This work therefore provides an institutional supply-side approach to income as a factor determining recycling within cities. Evidence is provided of the relevance that institutional factors such as the SFR might have on this link. This research should contribute, first, to expand our understanding of the income-recycling nexus in cities, and second, to move beyond a focus on the demand side, also considering institutional supply-

side factors. The way in which existent income inequality can shape new divides – as could be the environmental ones – depends on policy and urban political economy.

4.2 Material and methods

4.2.1 Case study selection

This study compares two cases of MAs that operate mature recycling systems (Peretz et al, 2005), within the European Union: Barcelona and London. These cases are particularly interesting in the context of a discussion on accelerating the transition to equitable, sustainable, and liveable cities towards post-fossil carbon societies, since the two have been referenced as model cities in regard to different urban development paradigms. For instance, both have been regarded as global cities (Sassen, 2007), creative cities (Florida, 2005), and more recently, smart cities (Morandi et al, 2016).

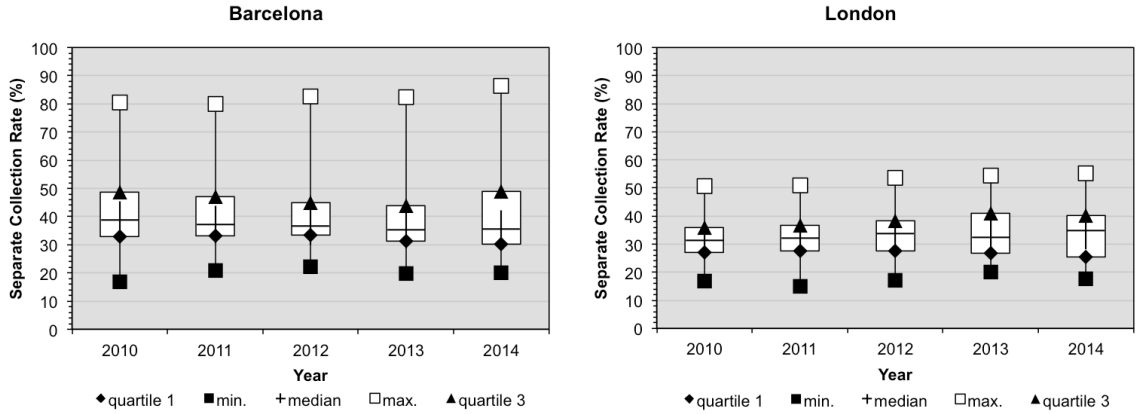

Figure 23. Separate Collection Rates at LA level in Barcelona and London

As MAs with mature recycling systems, the mean SCR at a LA level is stable above 30 per cent in both Barcelona and London (Figure 23), although the mean is slightly higher in the former than in the latter (Tables 24 and 25). Both cities have long ago implemented both compulsory municipal recycling and landfill tax, which are key policies for promoting recycling (for the European context see Antonioli & Massarutto, 2012; for Spain and Barcelona, see Chamizo-Gonzalez et al, 2016, Puig-Ventosa, 2008, and Rifé & Domènech, 2007; for the UK see Abbott et al, 2011, Martin & Scott, 2003, and Burnley, 2001). For instance, landfill tax was implemented for the first time in the UK in 1996 (Seely, 2009), while Catalonya implemented it in 2004 (Almasi & Milios, 2013).

However, whereas general recycling policies and waste-collection responsibilities of LAs are similar in both cases, municipal financing models differ, leading to contrasting levels of LFA. Autonomous revenue, that is to say, income generated by municipalities regardless of grants from other government levels, is a relevant measure to understand financial capacities at the local level. As it can be seen in Figure 24, autonomous revenue is far more relevant as part of municipal budgets in Barcelona than in London. During year 2014, for instance, while autonomous revenue represented a mean of 71.1 per cent in Barcelona's metropolitan municipalities, the equivalent figure was 27.4 per cent in the case of London boroughs. Weights of central versus local resources are the opposite in both cities. Additionally, although the relevance of locally generated income is lower,

divergence among LAs is higher in London than in Barcelona, as it can be seen when looking at the standard deviation for the 2010-2014 period: 12.2 in the latter and 8.4 in the former (Tables 24 and 25). While in Barcelona municipal budgets are more stably dependent on autonomous revenue, ranging between 42.3 and 89.6 per cent of total municipal budget during the period, in London divergence is wider, ranging from 1.8 to 66.6 per cent.

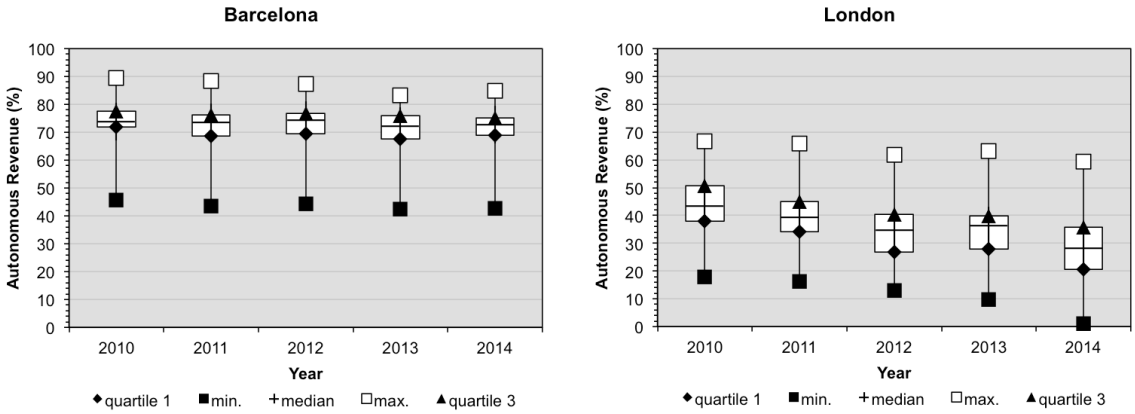

Figure 24. Autonomous revenue as percentage of total municipal budget.

Moreover, in regard to income distribution, Gini coefficient among households during year 2016 was 0.39 for Greater London and 0.33 for Barcelona (Barcelona Activa & Barcelona City Council, 2017). Although income inequality is higher in London, both cases rank close to the average within the OECD, which was 0.32. Both cities are quite egalitarian compared to other OECD MAs, such as New York – 0.42 – or Santiago de Chile – 0.48 (Barcelona Activa & Barcelona City Council, 2017). However, household income is geographically distributed differently in both cities. Barcelona, for instance, is not only slightly less unequal at a household level, but also differences in mean income between LAs are smaller than in London, and rich municipalities are not so spatially concentrated as in the UK's capital (Figure 25).

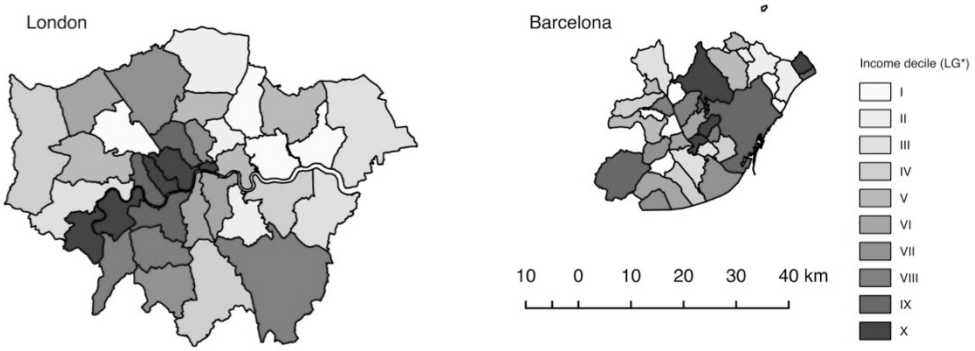

Figure 25. Geographical visualisation of mean income per LA (deciles).

4.2.2 Methodology

The research questions that guide the chosen methods are:

> *Do separate collection rates necessarily mirror the residents' income differences between LAs within a MA?*

and

Are service financing regimes linked to separate collection rates?

In order to answer these questions, the study adopts a mixed-methods exploratory approach. This implies that more than entirely defining causality issues, the objectives are:

- to describe and characterise different forms of the nexus between income and recycling between LAs within a MA, based on the two selected cases, and
- to find evidence that institutional supply-side factors such as the SFR might have a role in shaping this link.

In order to advance towards these objectives, a comparative analysis between the two cases is made on the basis of the three methods described below.

4.2.2.1 Descriptive analysis: comparing curves

In order to obtain a more general and intuitive approach to both income and recycling gaps at LA level within each city, a simple exercise is performed to draw curves representing these gaps. A ratio is calculated both for the SCR and mean residents' income per LA, using the formula *Ratio* = x_i / x_{min}, where x_i is the value per LA, and x_{min} is the minimum value per LA within the metropolitan area. LAs are ordered from the lowest to the highest mean income. The Results are shown in Section 4.4.1.

4.2.2.2 Econometric models: panel data regressions

Fixed (FE) and random effects (RE) regressions on panel data are used for both cases. Mean income and autonomous revenue are the explanatory variables. Autonomous revenue is the percentage of the municipal budget that comes from local sources instead of grants or transfers from the central or regional government. Residential density is used as control variable, as present in most of the models from the literature. Due to data availability constraints, other relevant explanatory variables that can be found in the literature are missing (i.e. age, education, collection frequency and technique, density of drop-off points and pricing scheme). However, the models do not attempt to predict SCRs, but to look specifically into the link between recycling and income differences at LA level. Logarithmic transformation of variables is included as a standard approach that allows working with fractional data.

The FE regression equation is:

$$\ln (REC)_{it} = \alpha_i + \beta_1 \ln(INC)_{it} + \beta_2 \ln(AUT)_{it} + \beta_3 \ln(DEN)_{it} + \mu_{it}$$

Where

- $\ln (REC)_{it}$ is the dependent variable (natural log of the SCR), where i = LA and t = time;

- $\ln(INC)_{it}$, $\ln(AUT)_{it}$, and $\ln(DEN)_{it}$ represent the independent variables, which are the natural logs of mean income, autonomous revenue, and density, respectively;
- β_k(k=1…3) is the coefficient for the independent variables;
- α_i(k=1…n) is the intercept for each entity (LA-specific intercepts);
- μ_{it} is the error term.

The RE regression equation is:

$$\ln(REC)_{it} = \beta_1 \ln(INC)_{it} + \beta_2 \ln(AUT)_{it} + \beta_3 \ln(DEN)_{it} + \varepsilon_{it}$$

Where

- $\ln(REC)_{it}$, $\ln(INC)_{it}$, $\ln(AUT)_{it}$, $\ln(DEN)_{it}$ r, as well as β_k(k=1…4) represent the same as in the FE model;
- $\varepsilon_{it}$is the composite error term.

In addition, squared mean income ($INC\text{^}2$) to account for the Environmental Kuznets Curve (EKC) structural relation (see Section 4.3.3.). In the case of the FE regression, the new equation is $\ln(REC)_{it} = \beta_1 \ln(INC)_{it} + \beta_2 INC\text{^}2_{it} + \beta_3 \ln(AUT)_{it} + \beta_4 \ln(DEN)_{it} + \alpha_i + u_{it}$. In the case of the RE regression, the new equation is $\ln(REC)_{it} = \beta_1 \ln(INC)_{it} + \beta_2 INC\text{^}2_{it} + \beta_3 \ln(AUT)_{it} + \beta_4 \ln(DEN)_{it} + \varepsilon_{it}$.

Hausman tests for fixed versus random effects models are run and reported for all the regressions. Results can be found in Section 4.4.2. Along with FE and RE regression results, reports also include Ordinary Least Squares (OLS) regressions on pooled data, and Between Groups Regressions (BR) for the panel data. Reported R^2 is 'adjusted' for OLS, 'overall' for RE, 'within' for FE, and 'between' for BR.

4.2.2.3 On-site visits to selected LAs

On-site visits (Shen et al, 2018; Ingrao et al, 2014) are a commonly used approach to collect data that can help to get a more detailed account of how systems work at a local level. In order to have qualitative evidence that could be helpful to interpret the quantitative analysis, these on-site visits to LAs were performed at three selected LAs within each MA. The six selected LAs are in the extremes of the distribution in terms of SCRs. In Barcelona, selected LAs were Santa Coloma de Gramanet and Sant Adria de Besos among those with lower SCR, and Tiana among those with higher SCR. In London, Newham and Barking & Dagenham are among the underperformers, and Richmond upon Thames among the overperformers regarding SCRs. These cases can be seen in context in Figure 26, which shows SCRs for 2014. On-site visits were focused on waste collection infrastructure as it can be observed from the public space. The main findings are discussed using photographic registry in Section 4.4.3.

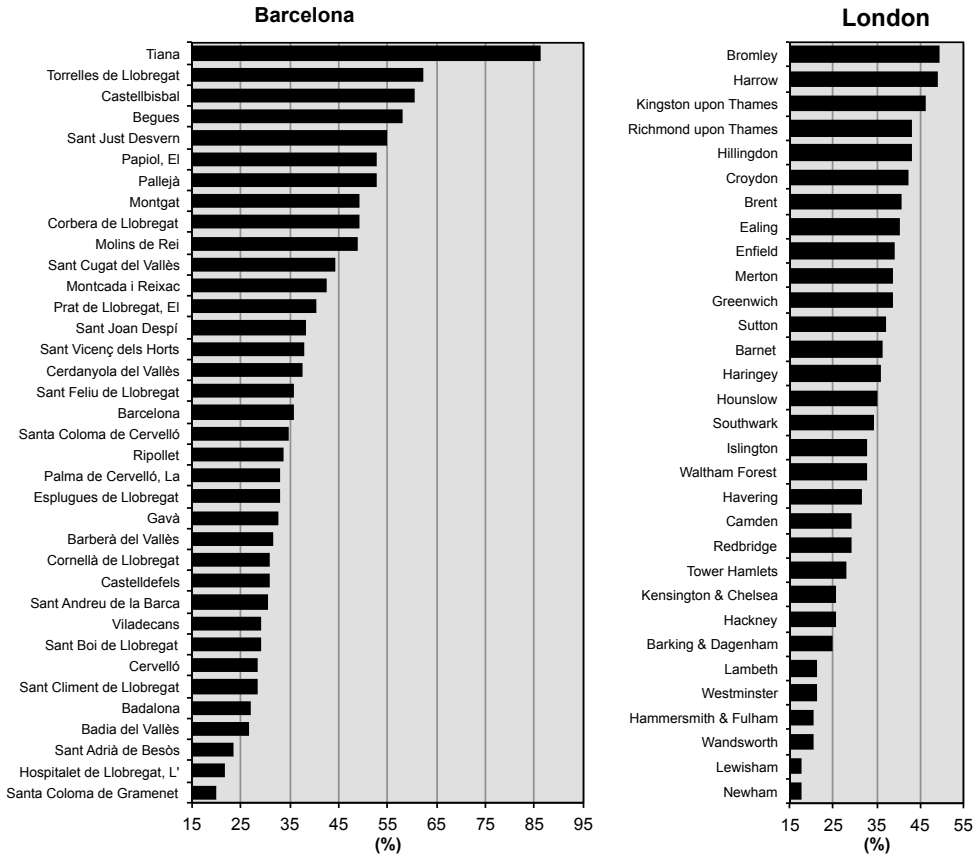

Figure 26. SCR by LA (year 2014)

4.2.3 Data

Whereas qualitative data was collected during on-site visits, quantitative sections of the paper use secondary data from a range of sources. In the case of Barcelona, SCR, mean income per capita and density comes from the Sistema d'Indicadors Metropolitans de Barcelona (SIMBA), published by the Institut d'estudis Regionals i metropolitans de Barcelona (2018). Autonomous revenue percentages for metropolitan municipalities within Barcelona were calculated using figures from the Municipal Budget platform by Gobierto (2018).

In the case of London, SCR, mean income per capita and density comes from the Greater London Authority's London Datastore (2018). Autonomous revenue percentages for London boroughs were calculated using figures from 'Local authority revenue expenditure and financing', as published by the Ministry of Housing, Communities & Local Government (2018a). The latter was done following the methodology proposed by the same source (Ministry of Housing, Communities & Local Government, 2018b) to calculate the reported local authority income from central government grants as a percentage of revenue expenditure. The 'City of London' administrative territory was excluded from the analysis.

In both cities, the figure used for mean income is tax payers declared income. Mean income per capita figures from London were converted to Euros in order to make

coefficients more easily comparable. Summary statistics can be found in Tables 1 and 2. All figures and tables included in the text were produced by the author.

Table 25. Summary Statistics: Barcelona

Variable	Observations	Mean	Std. Dev.	Min	Max
Separate Collection Rate (%)	180	39.86	12.12	16.72	86.36
Mean Income p/c (M EUR)	180	22.30	4.68	15.80	38.61
Autonomous revenue (%)	180	71.80	8.44	42.33	89.59
Density (people p/Km2)	180	4,858.16	5,408.59	125.60	20,730.40

Table 26. . Summary Statistics: London

Variable	Observations	Mean	Std. Dev.	Min	Max
Separate Collection Rate (%)	160	33.39	8.78	14.92	55.21
Mean Income p/c (M EUR)	160	47.64	26.75	24.76	183.70
Autonomous revenue (%)	160	35.80	12.19	1.17	66.63
Density (people p/Km2)	160	7,120.59	3,559.77	2,050.82	14,835.10

4.3 Theory

4.3.1 Income as a demand-side factor influencing recycling

Existent research typically includes income as one of the most relevant socio-economic variables determining SCRs (Agovino et al, 2016). However, as already mentioned, the usual approach tends to look at income as a demand-side variable (see Figure 5). Tadesse (2009:190) provides a good overall framing to understand the difference between demand-driven and supply-driven factors influencing municipal recycling:

> The demand-driven (such as age, education and income) and supply-driven (such as regulation, access and distance to waste containers) factors can also be considered for policy applications as they directly or indirectly influence the environmental attitude (concern) and waste management practices (such as appropriate disposal) (Tadesse, 2009:190).

Placing income on the demand side may follow diverse theoretical justifications (Figure 5). Conversely, different signs of the correlation between income and recycling can be expected according to those justifications. On the one hand, some argue that higher income is linked to lower probability of recycling. An explanation has to do with consumption patterns and waste production. Sidique et al (2010), for instance, expect higher income to be related to more consumption, and therefore greater waste generation and lower recycling rate. Another explanation has to do with the opportunity cost of time: high-earners have a higher opportunity cost, therefore might be more reluctant to recycle (Abbott et al, 2011).

On the other hand, some expect income to be positively linked to recycling. Justifications are related to purchasing patterns: richer people are able to purchase goods with a higher recyclable content (Callan & Thomas, 2006). Other theories argue that, although everyone desires to protect the environment, higher income people are the ones with capacity to pay to do it (Abbott et al, 2011). Moreover, income is seen as intrinsically linked to other demand-side factors. As described by Chen (2010:451), 'rising disposable income may increase the propensity to consume and generate solid wastes, but it also can bring about the increase in recycling rate through rising education levels'. In the same line, Challcharoenwattana & Pharino (2016) find links between income and pro-

environment attitudes, involving a mixture of socio-economic conditions, education and household characteristics that are all inter-correlated.

Although the literature finds mixed evidence on the significance and sign of the link between income and municipal recycling, all the studies put income along demand-side factors. In contrast, they do not seem to see a link between income and supply side determinants. For instance, Starr & Nicolson (2015) mention policy factors along with demographic ones. However, the former are associated to existence of mandatory laws and political affiliations of LAs, whereas income is defined as demand-side. Likewise, Lakhan (2014) focuses on policy measures related to investment on educational programs that should affect people´s behaviour. For Lakhan, these supply-side measures are relevant because education will end up impacting consumer behaviour, or, in other words, demand. Income is expected to reflect relevant characteristics of consumers or voters, but the link with recycling is not expected to say anything about supply-side phenomena. Other views on income, as it could be to see it as a proxy of balances of power within a society, and to particular institutions linked to those balances (Goodfellow, 2017), are not considered.

Some authors, such as Challcharoenwattana & Pharino (2016) and Slavik & Pavel (2013) touch the issue of income and municipal finances when discussing possible pricing schemes. However, the latter are considered as mechanisms to produce behavioural change. What is definitely missing is an account of the influence of the SFR on SCRs. SFRs are defined by LFA and MWM financing models, which are strictly supply-side factors that can reasonably be expected to shape the link between recycling and income. Paying attention to this supply-side is urgently needed.

4.3.2 Local fiscal autonomy and funding mechanisms as supply-side factors shaping the link between income and recycling

The main theoretical proposition in this article is that institutional determinants such as regulations on municipal revenue models and central government grants, might affect the nature of the income-recycling nexus, beyond what happens with the demand for recycling services among people. The notion of SFR allows to characterise ways in which these institutional determinants can be observed in each specific case.

Only after the Great Recession and implementation of austerity policies this issue has somehow emerged in the literature, but it is not yet in the centre of the analyses. For instance, Abbott et al (2011), after discussing recycling in the UK, briefly comment that ‘given limited resources, local authorities have to get ‘more bang for their buck’. Never is this more true than now in the post financial crisis period with local authorities facing dramatic cuts to their budgets’ (Abbott et al 2011:2222).

Therefore, the SFR will be understood as result of the interaction between LFA and funding mechanisms for services. The resulting regime will determine whether SCRs are linked or not to residents’ income. If a SFR is not linked to any socio-economic factor, it can be considered distribution-neutral, and there should not be a link between SCRs and income. If a SFR does depend on socio-economic factors, it can be progressive – when a redistribution system gives more to the poor – or regressive – if distribution of municipal

resources rewards the rich or depends directly or indirectly on having high-income residents. Whereas in a progressive regime income and SCRs should be negatively linked, the opposite sign should be observed in a regressive regime. This theoretical proposition is summarised in Figure 27. In what follows, Sections 4.3.2.1 and 4.3.2.2 explain why the SFR from Barcelona can be considered a regressive regime, while the SFR from London is closer to be distribution-neutral.

4.3.2.1 Local fiscal autonomy

In regard to revenue sources, Spanish municipalities are able to 'take advantage of three mandatory and two optional taxes' (Loughlin & Lux, 2008:220). On the one hand, mandatory are taxes on property, businesses and motor vehicles. Municipalities have a degree of discretion to set these taxes, within limits defined by the central Government. On the other hand, optional are taxes on construction, building installations and works, and on capital gains in urban areas. While law sets the former, each LA sets the latter within state-imposed limits. The nature of these sources of income makes them strongly linked to the inter-correlated presence of wealth, income and economic activity (i.e. number, type ad size of businesses; purchase and use of private vehicles; investment on new buildings; capital gains). Furthermore, the central government grants system fails to equalise differences in tax capacity between the different Spanish municipalities, actually favouring those LAs with greater tax capacity (Loughlin & Lux, 2008).

In the UK, on the other hand, the main source of autonomous revenue is the council tax (Bosch Roca & Espasa Queralt, 2008). LAs can have certain degrees of discretion on setting this tax, within ranges defined by the central Government (Gottlieb, 2016). However, as seen in Figure 2, in contrast with Barcelona, boroughs in London depend mostly on grants, being autonomous revenue a much smaller portion of their budget. This lower level of local autonomy in the UK compared to Spain is also linked to a higher degree of possibilities of equalisation by central government grants. All the other types of taxes are centrally collected and redistributed via these grants. This situation has sparked a long lasting debate on devolution and local autonomy, which involves both territorial equity and the flexibility and pertinence of the 'menu of services' delivered by each LA, almost entirely set by the central Government (Six, 2008).

In the British context, the relevance of central grants also implies that most LAs have very little possibilities of finding alternative revenue sources apart from council tax if there are changes in central fiscal policy, as it was the case after the 2008 financial crisis (Ferry & Eckersley, 2011). 'UK municipalities are compelled by law to deliver austerity and they have no control over welfare reform. They may spend reserves, but deficit budgeting is prohibited. Municipalities have even less room for manoeuvre than in Spain' (Davies & Blanco, 2017:1521).

This is not to say that a higher degree of local autonomy implies to escape the effects of financial crisis and austerity in Spain. All levels of government and sources of revenue have been affected after the crisis, pushing Spanish LAs to perform diverse strategies, which included both reducing services and transferring costs to users (Cascajo et al, 2017). Furthermore, the crisis widened existent inequalities, since 'municipal finance in Spain reflects the uneven distribution and scaling of powers' (Davies & Blanco, 2017:1521).

4.3.2.2 Funding mechanism for recycling services

Funding of recycling services is embedded in each LFA context. As reviewed by Chamizo-Gonzalez et al (2016), existent mechanisms to fund MWM services can be classified in four main systems: undesignated funds, flat fee, variable fee depending on waste generated, and variable fee system not depending on waste generation. Whereas recycling services in most of Barcelona's municipalities are financed by variable fee system not depending on waste generation, in London it is financed by undesignated funds in all boroughs. In Barcelona, fees are charged according to water consumed by each household. However, a minority of municipalities have decided not to charge to their residents but pay it from undesignated funds instead (Rifé & Domènech, 2007) and there are also cases of LAs implementing Pay As You Throw (PAYT) schemes (Puig-Ventosa, 2008). In contrast, 'local governments in the UK are not allowed to charge for waste collection. Funding for recycling and residual waste collections comes from the council tax, a tax on property, and a central government grant, which fund all local government services' (Abbott et al, 2011:2215).

Therefore, both similarities and differences can be stated between the two funding systems. On the one hand, in neither case the way of charging for recycling services is directly linked to waste produced. In Barcelona, it can be charged according to water consumption or considered included in taxes. In London, it is considered paid via taxes. An additional similarity is that LAs in both cities have a certain degree of discretion on local tax rates, although the impact of local decisions on the municipal budget is far superior in Barcelona. However, the biggest difference is that LAs in Barcelona can decide on charging the usual fee, or even to implement additional charges. In contrast, London councils are not allowed to charge apart from the council tax.

High LFA, revenue sources associated to mean residents' income, and discretional charging for MWM makes the SFR in Barcelona to be regressive. Low LFA, with most funding coming from central government grants that do not necessarily follow residents' mean income, and inability to charge for MWM, makes London to be a distribution-neutral SFR.

4.3.3 Structural relation: Environmental Kuznets Curve

In addition to the discussion above regarding demand or supply-based approaches, research on the income-recycling nexus should also consider relevant theories that aim to link income and environmental issues within ecological economics. In this sense, a strong idea that has found mixed empirical support is a structural relation named as the Environmental Kuznets Curve (EKC) (Nassani et al, 2017; Roca & Alcántara, 2001). This idea follows the original seminal work by Kuznets (1955), who claimed the existence of an inverted U-shaped relation between economic development and income inequality: countries might experience an increase in inequality as their income grows, but, allegedly, they will later reach a plateau and finally see a decrease in inequality as they become 'developed'. Although this structural relationship has proved to be inexistent in recent years (Piketty, 2014; Palma, 2011), ecological economists have used the same notion to illustrate a similar link between economic growth and environmental harmfulness (Nassani et al, 2017; Roca & Alcántara, 2001). This idea has been discussed in the case of MWM by works such as Chen & Chen (2008), and Chen (2010). Furthermore, in this study, the EKC hypothesis was also tested (as explained in Section 4.2.2.2).

4.3.4 Hypotheses

Following the aforementioned theoretical discussion, three hypotheses are formulated and tested:

> *H_1: The wider the income inequality between LAs, the bigger the SCR divide will be within a metropolitan area.*
>
> *H_2: LFA and redistribution of resources within a MA can influence the link between residents' income and SCRs.*
>
> *H_3: If SCRs follow income differences, the link between mean income and SC rates at LA level will follow the EKC logic.*

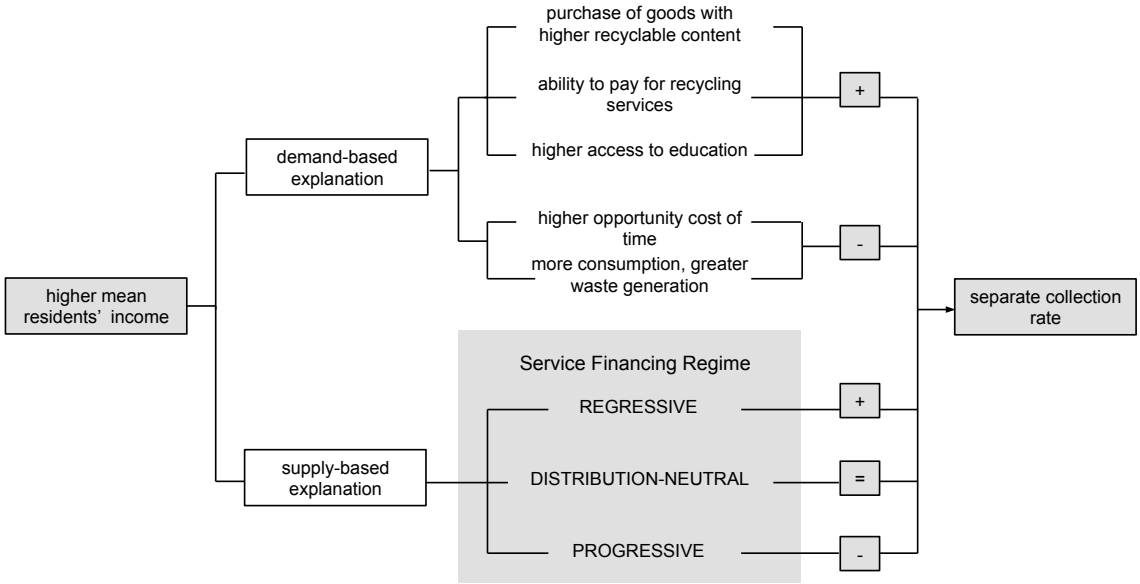

Figure 27. Theoretical explanations for the link between income and SCR.

4.4 Results

4.4.1 Descriptive analysis

Curves representing the LA-level income and recycling gaps within each MA can be found in Figure 28. As expected, the income gap is wider in London than in Barcelona. While in Barcelona the mean income is 2.3 times higher in the richest LA than in the poorest one, in London the equivalent ratio rises to 6.3. However, surprisingly, when it comes to recycling, the gap is wider in Barcelona than in London. In the Catalonian capital, the ratio between the LA that recycles the most and the one that recycles the less is 4.3, while in London it is 3.1.

However, more interesting for the research questions and hypotheses is to consider the trend followed by the two curves in each case. In this sense, the recycling curve only

tends to follow the income one in the case of Barcelona, but there are no signs of any sort of 'mirror effect' in London.

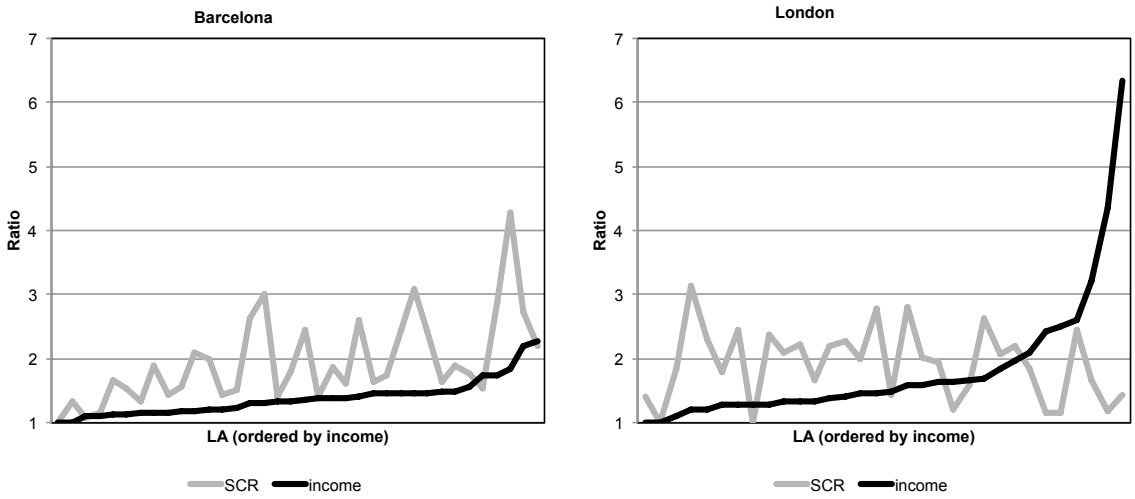

Figure 28. Curves for LA level income and recycling gaps within each MA (year 2014)

4.4.2 Regressions

Just as in the descriptive analysis, regression results show that the link between SCRs and income works differently in the two cases. On the one hand, income is significantly linked to SCRs among Barcelona's LAs. On the other hand, whereas income is not a significant variable in London, percentage of autonomous revenue is indeed significant and positively linked to SCR within boroughs.

Table 26 shows regression results for Barcelona. The Hausman test for FE versus RE produces a p-value above 0.05, which implies that the RE model is appropriate. Therefore, the selected variables can explain changes between and within LAs. In the case of Barcelona, the RE model can explain almost 40 per cent of the variance of SCRs, both between and within LAs. While income is significantly and positively correlated to SCRs, percentage of autonomous revenue is not significant.

In contrast, mean income is not significant in London (Table 27). In this case, the Hausman test t-statistic is below 0.05, which means that the FE model is appropriate. It is notable that, in London, percentage of autonomous revenue is positively and significantly correlated to SCRs within boroughs. 15 per cent of the variance of SCRs within LAs over the 2010-2014 period can be explained by the FE model.

Table 27. Regression Results: Barcelona

	OLS			F-E			R-E			BR		
	Coef.	sig.	S.E.	Coef.	sig.	S.E.	Coef.	sig.	S.E.	Coef.	sig.	S.E.
log Mean Income p/c (thousand EUR)	0.536	***	(0.102)	0.156		(0.522)	0.571	**	(0.193)	0.528	*	(0.217)
log Autonomous revenue (%)	0.327	*	(0.157)	-0.190		(0.239)	-0.025		(0.196)	0.387		(0.349)
log Density (people p/Km2)	-0.058	***	(0.016)	-1.168		(0.813)	-0.077	*	(0.031)	-0.055		(0.034)
constant	1.048		(0.722)	13.076		(7.261)	2.588	*	(1.026)	0.796		(1.592)
Observations	180			180			180			180		
N, groups.				36			36			36		
R^2	0.396			0.026			0.389			0.460		
Hausman test for fixed versus random effects model (p-value)	0.271											

*p-value ≤ 0.05; **p-value ≤ 0.01; ***p-value ≤ 0.001

Table 28. Regression Results: London.

	OLS			F-E			R-E			BR		
	Coef.	sig.	S.E.	Coef.	sig.	S.E.	Coef.	sig.	S.E.	Coef.	sig.	S.E.
log Mean Income p/c (thousand EUR)	0.090	*	0.043	-0.345		0.189	0.121		0.081	0.026		0.088
log Autonomous revenue (%)	0.143	***	0.034	0.060	*	0.026	0.020		0.022	0.320	**	0.098
log Density (people p/Km2)	-0.306	***	0.034	2.224	***	0.482	-0.319	***	0.066	-0.238	**	0.071
constant	5.308	***	0.324	-14.862	***	3.957	5.730	***	0.568	4.334	***	0.748
Observations	160			160			160			160		
N, groups.				32			32			32		
R^2	0.493			0.148			0.462			0.635		
Hausman test for fixed versus random effects model (p-value)	0.000											

*p-value ≤ 0.05; **p-value ≤ 0.01; ***p-value ≤ 0.001

Additionally, as explained in sections 4.2.2.2 and 4.3.3, the presence of an EKC type relation between income and recycling rates was also tested. Results from regressions including the squared term are not shown in detail due to space constraints, but can be requested to the author. Signs of an EKC relation are absent from both cases. Actually, the result from the FE regression in Barcelona – the only case in which the Hausman test assigns efficiency to a model in which squared income is significant – implies that the relation between income and recycling within LAs over time shows the opposite sign than expected by the EKC proposition.

4.4.3 On-site observation

On-site observation provides possible explanations for the links between income, municipal revenue and recycling. What becomes evident after visiting the selected six LAs is that higher SCRs seem to be associated to higher levels of specialisation in the MWM systems. High performers such as Tiana in Barcelona and Richmond Upon Thames in London have in common to provide a more diverse collection service compared to other LAs within the same MA. These services cover a wider range of types of waste, and are also associated to a higher collection frequency of all sorts of recyclables. In contrast, lower performance LAs, such as Sant Adria de Besos and Santa Coloma de Gramanet in Barcelona, and Newham in London, seem to have less specialised collection systems.

This specialisation could be the explanation for the link between autonomous revenue and recycling, which is expressed in the panel data for the case of London, and implicit in the significance of mean income in the case of Barcelona. Specialising requires two

alternatives, both of which would be reflected by higher autonomous revenue. On the one hand, proactive investment on specialised MWM services requires available resources beyond those needed to cover the most basic needs. On the other hand, policies such as PAYT or other price-related policies – which have been implemented in some municipalities in Barcelona (Puig-Ventosa, 2008) – that increase SCRs (Starr & Nicolson, 2015) could consequently produce growth in autonomous revenue. More detailed research regarding timing of decisions on prices and local taxes, as well as of investment on and returns from municipal services, would be needed to solve this causality problem.

Furthermore, a good example of this specialisation can be found in Barcelona. In this city, both Sant Adria and Santa Coloma have a similar dense grid of drop-off points, which provide a standard supply of containers for glass, plastic, paper and mixed waste. Something common in both cases was to find excess of mixed waste surrounding drop-off points, or even additional bins for residual waste (see the case of Santa Coloma shown in Figure 29, letter B). In contrast, drop off points do not include mixed waste in Tiana – that reaches an impressive 85 per cent SCR. As shown in Figure 29 (letters D, E and F), mixed waste containers are considered 'emergency containers', located separated from the recyclable drop-off points. Tiana collects organics 4 times a week using a kerbside service, while mixed waste is officially collected home by home only once a week. Moreover, some drop off points for recyclables include bins that are highly specialised. An example are bins for nappies: given the characteristics of this sort of waste, neighbours are asked to request a key at the town hall to be able to use the service.

A similar pattern can be found in London. Newham, which was the lowest performer within the MA in 2014, only has two types of bins for kerbside collection: non-organic and mixed (Figure 29, letter G). Barking & Dagenham, which performed slightly better, includes a third bin for organic waste (Figure 29, letter H). Bins looked particularly full in Newham, which was paired with excess of mixed waste piled on the streets around drop-off points and litterbins. This might be a sign of a supply of collection frequencies that is not able to meet the existent demand, especially in mixed-use zones.

As in Barcelona, higher SCRs in London seem to be associated with higher specialisation. For instance, Richmond upon Thames has five different classifications of waste. A first bin is paper, card and cardboard; a second one is for plastic bottles, pots, tubs, trays, unbroken glass bottles, food tins, drink cans and empty aerosol cans; a third bin is for food waste; a fourth is for residual waste; finally, the council also provides a service for garden waste collection (Figure 29, letter I). This higher specialisation is also reflected in litterbins located in public spaces (Figure 29, letter L).

Figure 29. Photo-registry of on-site observation.

Sites: Sant Adria (A); Santa Coloma (B); Tiana (C, D, E, F); Newham (G, J); Barkin & Dagenham (H, K); Richmond upon Thames (I, L)

4.4.4 Summary of results

In regard to hypotheses defined in Section 4.3.4, results can be summarised as follow. Firstly, H_1 can be rejected within this two case-comparison (*the wider the income inequality between LAs, the bigger the SCR divide will be within a metropolitan area).* On the one hand, although London is more income-unequal than Barcelona, the recycling

gap is wider in the latter than in the former. On the other hand, the link between income and SCRs is only significant in Barcelona, but not in London.

Secondly, results from regressions and qualitative evidence from the qualitative part allows accepting H_2 (*the institutional regime determining LFA and redistribution of resources within a MA can influence the link between residents' income and SCRs*). Income is significantly linked only under the context of a regressive SFR in Barcelona. In London, in contrast, the link is not significant, but SCRs are significantly and positively linked to changes in autonomous revenue over time within boroughs. Observational evidence about specialisation point to possible specific mechanisms that could explain this nexus, such as availability of investment resources beyond those used to cover basic needs in both MAs, or the consequence of implementing charging schemes in Barcelona. Finally, H_3 is rejected (*if SCRs follow income differences, the link between mean income and SC rates at LA level will follow the EKC logic*).

4.5 Discussion and public policy implications

Existent research on the income-recycling nexus tends to assume that the smaller income differences between LAs are, the less significant socioeconomic level should be to predict SCRs (Passarini et al, 2011). In contrast, results from this study point to the opposite direction. Although income differences between LAs are smaller in Barcelona than in London, the income-recycling link is significant only in the former but not in the latter. As explained above, this contrast between some assumptions from the demand-oriented literature and results from this particular study are linked to institutional factors. Results from comparing Barcelona and London suggest paying higher attention to supply-side factors such as MWM funding mechanisms and LFA. The neglect of institutional elements might be distorting theories and interpretation of empirical results.

Consequently, a relevant question to ask is whether income is always a given demand-side factor, or is it instead institutional design that turns income into a predictor of SCRs. If income is linked to consumer behaviour regardless of supply-side factors exemplified in the SFR, the association between income and SCR in distribution-neutral London should have been significant. In this two-case study, the nexus is only significant in Barcelona, where the SFR is regressive.

Furthermore, although there might be deep historical and path-dependency related explanations for the way municipal services are financed in each context, SFRs can definitely be subject of policy design. For instance, although austerity policies might be damaging the capacity of LAs to recycle (Abbott et al, 2011), they also show that factors such as LFA can be modified by policy decisions, as it can be observed with the generalised reduction in autonomous revenue among London boroughs (Figure 24).

In summary, the demand-side income-recycling nexus should not be taken for granted, since it could be reflecting phenomena beyond consumer or voter behaviour, such as metropolitan tax and municipal funding structures that are regressive.

Furthermore, distribution of municipal recycling budgets should be taken in account when discussing how to accelerate the transition to equitable, sustainable, and liveable cities towards post-fossil carbon societies. In this sense, some suggestions could be made for both research and policy. First, among researchers, to pay attention to how regressive

or progressive SFRs are, in order to understand the way institutions shape the link between recycling and socio-economic factors. Second, among LAs, to provide more detailed account of both expenditure and revenue regarding MWM services. It is very difficult to analyse efficiency of transition strategies, as well as distinguishing between supply versus demand factors, without being able to observe these key financial variables as they interact with other service characteristics. Third, among national, regional or metropolitan governments in charge of defining recycling policies and goals, it is fundamental to give priority to the problem of distribution of resources, so that having effective recycling services – which could even create revenue or at least cost reduction for LAs after proper investment – is something achievable for those LAs where the poor live.

Income inequality within cities can lead to new divides, such as widened recycling gap. However, as shown by comparing the cases of Barcelona and London, recycling does not need to necessarily mirror existing inequalities. Letting income differences determine recycling capacities might lower the peace of transition towards sustainability, making environmental achievements only accessible to the rich.

4.6 Conclusion

The recycling gap within metropolitan areas does not necessarily mirror the existent income inequality. Barcelona and London represent two contrasting examples that can illustrate two forms of this link. In Barcelona, although income inequality between LAs is smaller, SCRs are influenced by income differences between LAs. In London, larger income differences are not translated into SCRs. This research presents consistent evidence to explore the hypothesis that this difference is linked to the SFR, which depends on institutional design. Further research should be cautious about attributing an explanatory power over SCRs to residents' income. Beyond demand-driven phenomena (i.e. expected influence on consumer and voter behaviour), the income-recycling nexus is likely to be strongly affected by how institutions and policies shape the supply-side.

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Part II

5 The written and unwritten rules of internet exclusion: inequality, institutions and network disadvantage in cities of the Global South[4].

Abstract

Studies about the link between income and Internet access tend to focus exclusively on the demand side, or, when considering the supply side, to neglect any possible role of local and informal institutions. This research pays attention to the relationship between income distribution and internet access within metropolitan areas of the Global South, with a special emphasis on local and informal institutions that could shape the ways by which this relationship works. Using a mixed-methods approach, two Latin American metropolitan areas are analysed: Santiago (Chile) and Medellín (Colombia). Although income is clearly linked to household Internet access in both cases, there are supply-side differences that can influence the income-connectivity nexus. The author proposes to introduce the concept of 'institutionally generated network disadvantage'. Examples of formal and informal institutional factors are redlining, informal housing, socio-spatial segregation, tax exemptions and local public provision of services. The urban poor seem to be the most affected by institutionally generated digital exclusion.

Keywords: Internet, inequality, Global South, digital divide, institutions

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5.1 Introduction

Income inequality has joined a central stage in the global development debate. However, in which ways does the income divide influence new divides, such as those related to access to digital connectivity? This research explores this question, focusing on the link between income and access to Internet within cities of the Global South.

To approach the discussion, it is worth mentioning some caveats among dominant perspectives on provision of telecom services. On the one hand, normative narratives are polarised between celebration of market-based provision (Joskow, 2009) and critiques of inevitable forms of exclusion emerging as a product of profit-driven logics (Graham and Marvin, 2002). On the other hand, empirical studies of Internet access tend to provide insightful analyses about the demand-side, but to forget the supply-side. Yet, what is common in all these different approaches is the neglect of the roles played by written and unwritten rules in shaping Internet provision. In particular, the role of local and informal institutions tends to be absent from the discussion. The consequence of this absence an implicit assumption that telecommunications markets are identical everywhere, shaped by the same processes of privatisation, liberalisation and globalisation (The World Bank, 2016).

Here I provide a more nuanced approach, built on the basis of local characteristics rather than universal determinism, as well as on views from supply-side actors rather than just the experience on the demand-side. In order to do so, it presents evidence from mixed methods that include descriptive statistical techniques, regression analysis, and qualitative interviews conducted in Santiago (Chile) and Medellín (Colombia). Although income is significantly linked to material access to Internet, the extent of its influence and specific mechanisms by which this link operates are associated to formal and informal institutions, policy decisions and local history of service provision. These institutional factors can influence access beyond the willingness and ability-to-pay of potential users. Thus, as discussed in Section 5.6, in this paper I introduce the concept of *institutionally produced network disadvantage*: a phenomenon that is shaped by power relations between the poor and the elites.

5.2 Internet access and institutions

Internet studies have moved from the 'first-level' and 'second-level' digital divides, to focus on a 'third-level' (van Deursen and van Dijk, 2015a). The first-level refers to access to infrastructure, continuity and quality of services. The second-level is determined by skills and usage patterns. The third-level has to do with the benefits that users get from their internet use. Although this approach has enormously contributed to a multifaceted model of Internet appropriation and access (van Deursen and van Dijk, 2015b; Helsper and Reisdorf, 2017), it has not provided a perspective on how institutional factors can influence the different levels of the digital divide.

For instance, when Van Deursen and Helsper (2015a) mention institutions, they do so to refer to 'institutional uses' and 'institutional outcomes' linked to public services and government. In a study that looks outside 'developed' countries, Pearce and Rice (2017) consider trust in as a factor that can influence the third-level digital divide. However, this relationship between individuals and institutions does not consider how those institutions are configured or can change over time. More recently, when Fernandez et al (2019) look

at the digital divide within cities, they only briefly mention that poor communities could suffer from redlining by big telcos, but do not discuss the latter as a structural supply-side factor shaping access.

Nevertheless, recent shortcomings from the usual policy recipes that supposed to deliver universal access to internet should spark renovated attention to institutions. While previous generation of telecom services – such as mobile telephony – appeared to be following a path towards universal access, new technologies are being a source of increasing gaps and inequalities. Particularly after worldwide adoption of high-speed Internet, the material access gaps between the rich and the poor have widened (The World Bank, 2016). Additionally, commonly accepted policy formulas, such as privatisation and liberalisation, are now under scrutiny – as it has been recognised, for instance, by the World Bank in its 2016 World Development Report (The World Bank, 2016). As shown by the results bellow, I would add that those policy formulas, deemed universal and homogeneous, can include more local variations than what is usually expected.

Fundamental questions about the supply side are, for instance: does policy matter? Do formal and informal institutions play a role in technology adoption? can local decisions shape the provision of highly globalised services such as Internet?

More specifically, the significance of the link between income distribution and internet access has been studied at country-level by authors such as Fuchs (2009), Gulati and Yates (2012), and more recently by Bauer (2018). The latter provides a theoretical model to explain the relationship between Internet access and income inequality. This model assumes that causal links can be stablished in both directions. On the one hand, higher aggregate inequality is likely to lead to broader internet access gaps, and individual income generation determines ability to pay for internet services. On the other hand, as proposed by the third-level digital divide literature, differences in internet access and use will have consequences in terms of economic outcomes. Conversely, individual and aggregate levels – of both income generation and Internet – are expected to influence each other, configuring a complex net of causal links which are part of the imbrication between digital connectivity and broader social dynamics. Yet, although Bauer (2018) mentions social and institutional factors that may influence these links, he does not explore such factors further.

A useful source from which to obtain some elements to fill this gap is institutional economics. Scholars from this field have introduced the idea of institutions as a way of understanding the 'rules of the game' in which transactions occur (North, 1990). Although this view includes both formal and informal institutions – written and unwritten rules, respectively –, it is difficult to find attention paid to the latter within Internet studies. Institutional perspectives from Internet scholars have taken two paths: one focusing on regulations and policies, and the other focusing on political regimes and democratic values. On the policy side, Beltrán (2014) focuses on governance and finance strategies, Neokosmidis et al (2015) on efficient regulation, public investment, and copper/fibre access prices policy, Haucap et al (2016) on tariff diversity, and Ghosh (2017) on the enunciation of a National Broadband Policy. On the regime and values side, democracy and authoritarianism have been debated as enhancers and inhibitors of Internet penetration first by Milner (2006) and later by Stier (2017). In a middle ground, Gulati and Yates (2012) use models that include both policies and an indicator of perception of democratic values.

While all the studies above come from country-level international analyses or specific case studies from wealthy countries, the reality in the Global South might require devoting more attention to informal institutions. For instance, in his recent ethnographic account of Mexico, García Canclini (2019) mentions that 'it would not be possible to build in Mexico City without the under-the-counter-arrangements with those who give permission or who are responsible for the provision of water, light or the Internet to a new building' (García Canclini, 2019:491).

This example can be understood within a wider theoretical picture thanks to Khan (2010), who provides a description of at least three types of informal institutions that can play a role in shaping transactions. Firstly, there are patterns of behaviour that are based on internalisation of norms and values. Secondly, there are rules that require enforcement but are not written down, and therefore, are informally enforced by extra-state or intra-state actors. Thirdly, there are tacit institutions that emerge simply because of the need for coordination, such as driving on one side of the road without need of enforcement. According to Khan (2010), while mainstream institutional economics discusses the first type of informal institutions as derived from norms and values, he proposes to focus on the second type of institutions. That is to say, those that require enforcement and hence are intrinsically rooted in balances of power.

In order to look at the role of these institutions in economic development, Khan (2010) proposed the 'political settlements approach', which has more recently been adapted to analyse cities in Africa by Goodfellow (2017). A political settlement 'is a combination of power and institutions that is mutually compatible and also sustainable in terms of economic and political viability' (Khan, 2010:4). In this context, 'the "rent-seeking" activities of powerful groups result in the creation of both formal and informal institutions', which 'sustain distributions of economic benefits for the participants in these institutional arrangements' (Khan, 2010:25). The 'under-the-counter-arrangements' from the Mexico example, can be understood as informal institutions that are sustained by a specific political settlement.

Departing from Bauer (2018), I propose a theoretical framework summarised in Figure 30. There is an obvious link between income and access to Internet. However, this link is mediated and shaped by institutional factors. Thus, I add formal institutional factors that are mentioned in the literature, plus informal institutions that emerge as part of the political settlement. Following contributions like Goodfellow (2017), which explores national-level and city-level expressions of the political settlement, I also divide institutional factors between national and local. I will come back to this framework when discussing results, in Section 5.6.

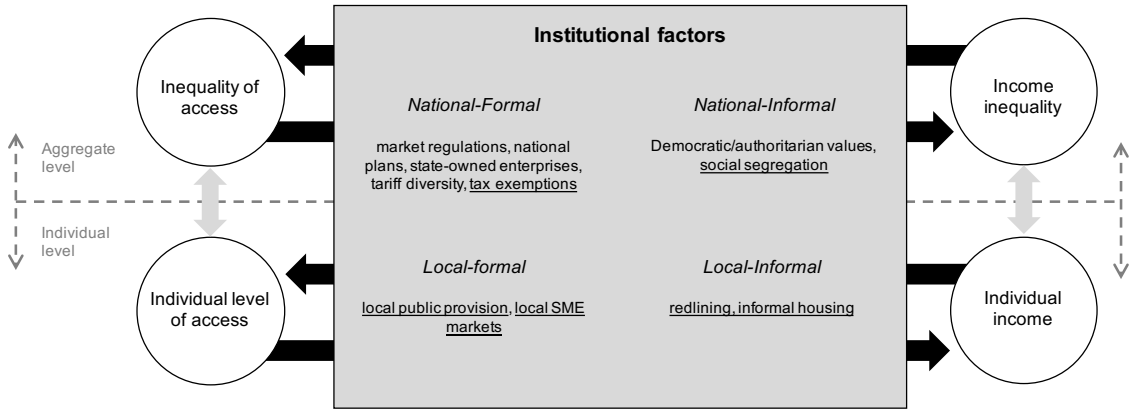

Figure 30. Theoretical links between income and internet access. Institutional factors found in Santiago and Medellín are included and underlined.

5.3 Santiago and Medellín

This research uses the cities of Santiago in Chile and Medellín in Colombia as case studies. Chile and Colombia are among the most unequal countries in Latin America – the most unequal region in the world (Palma, 2011). Both are also part of the same cultural inheritance of Catholic and Hispanic post-colonial norms and values (Khan, 2010). Furthermore, although Internet access might influence income distribution and therefore endogeneity should be taken in account in wider cross-sectional analysis, inequality in these cases is originated in long term processes and factors that came long before Internet adoption, and income distribution has remained stable during the last decades (Rodríguez Weber, 2018; Palma 2011). A key question arising from comparing these similarly unequal Latin American cases, is whether the link between income distribution and network technology adoption changes according to the differences between political settlements.

Metropolitan governance regimes (Kantor et al, 1997) differ in Santiago and Medellín, as do political settlements that sustain their national and local institutional arrangements (Goodfellow, 2017). Although both countries are part of the Pacific Alliance and therefore are usually regarded as 'market-oriented' or 'neoliberal' within Latin America (Aranda and Salinas, 2015), their degree of dependency on private investment is significantly different. Santiago relies heavily on private investment and privatised public utilities, whereas Medellín's local authorities have an unusual advantaged financial position thanks to revenue from their municipal multi-utility company: Empresas Públicas de Medellín (EPM) (Maclean, 2015).

Moreover, both cities are landmark examples of contrasting models of housing provision (Chiodelli, 2016). On the one hand, Santiago is an emblem of slum-eradication through policies that aimed to enable the development of the formal housing sector by means of subsidising demand, as well as giving land ownership to the poor (Gilbert, 2002). On the other hand, Medellín is a well-known case of slum-upgrading, exemplifying the Colombian prioritisation of providing services to informal settlements even before ensuring land tenure or building formal housing units (Gilbert, 2012). As is discussed in Section 5.6, formality and informality of housing appears to be a relevant factor influencing access to digital connectivity.

5.4 Material and methods

5.4.1 Methodology

5.4.1.1 Qualitative

The qualitative part of this study is based on 50 semi-structured interviews conducted in the two case-studies. Interviewees are part of the supply-side: I was able to reach high-level officials (cabinet ministers, heads of departments), public servants (specialised professionals from government teams), local community-leaders (community boards, local NGOs), board members and managers from transnational telecommunication companies, workers and union leaders from the same big telcos, and owners of Small and Medium-sized Enterprises (SMEs).

Internet provision SMEs were not part of the original methodological design. However, soon after starting doing interviews among community leaders in Santiago, the presence of SMEs providing Internet services within the poorest areas of the Chilean capital became relevant. This led to their inclusion in the methodological design for Medellín, where similar phenomena were found.

Fieldwork was conducted in both cities between March and May 2018. A total of 50 interviews were carried out: 22 in Santiago and 28 in Medellín. Distribution of interviewees is summarised in Table 28. In the case of community leaders, SMEs, as well as borough level public officials, a territorial selection criterion was applied. Since both cities are divided in boroughs, interviews targeted areas that included emblematic marginalised neighbourhoods in each city, plus adjacent zones with diversity of income groups. In the case of Santiago, the emblematic marginalised neighbourhoods were La Pincoya in Huechuraba and El Castillo in La Pintana; boroughs included were Huechuraba and Recoleta – in the North of the city –, plus La Pintana and Puente Alto – in the South. In the case of Medellín, marginalised neighbourhoods were Zona Nor-Oriental and Comuna 13; boroughs included were Comunas 1-Popular, 2-Santa Cruz and 3-Manrique – in the East of the city –, as well as 13-San Javier, 12-La América and 14-Laureles-Estadio – in the West.

An interview schedule was utilised to organise semi-structured interviews. Depending on each interviewee, some topics were developed in more depth and extension. Interviews were conducted in Spanish, recorded in audio and transcribed for analysis. Quotations are translated to English by the author. A set of codes was developed based on pilot interviews. These codes were confirmed after transcription and used for content analysis. Specific quotes are presented to exemplify elements that can help to interpret the quantitative data and build an overall narrative.

Table 29. Summary of interviews

Type of actor	Medellín	Santiago	Total
Provision			
Board member /managers	3	3	6
Small/medium-sized enterprises	2	2	4
Workers/union leaders	2	5	7
Constituency			
Community leaders	17	8	25
Policy			
High level authorities	2	3	5
Public servants	2	1	3
Total	**28**	**22**	**50**
Gender			
Female	11	3	14
Male	17	19	36

5.4.1.2 Quantitative

The quantitative data comes from household surveys collected by governments in each city. In both cases, the version used is for the year 2015. In the case of Santiago, the survey is the Encuesta de Caracterización Socio-Económica Nacional (Ministerio de Desarrollo Social, 2015), using a sample limited to 37 municipalities that are considered part of the Santiago Metropolitan Area. In the case of Medellín, the survey utilised is the Encuesta de Calidad de Vida Urbana de Medellín (Alcaldía de Medellín, 2015). The data includes the 16 boroughs that are part of the urban jurisdiction of the Alcaldía de Medellín, plus five semi-rural areas called *corregimientos*. Summary statistics for each city can be found in Tables 29 and 30.

A descriptive quantitative exercise was produced in order to intuitively comprehend the link between income distribution and material access to Internet within each city, and then be able to compare both cities. In order to do so, income-access curves are produced. Income quantiles are ordered from lowest to highest from left to right on the X-axis, and mean household income per quantile is expressed on the Y-axis. Then, a similar curve is generated, showing percentage of access to Internet by households within each income quantile.

Secondly, a logit binary outcome model was developed to be applied using household survey data. Questionnaires from household surveys in both cities were compared in order to find similar questions to account for what interviewees mentioned as factors that might influence access to Internet among households. The dependent variable is a binary variable, INT, defined by each household's declared access to Internet (by any means such as fixed broadband, mobile internet, connected smartphone, etc.), which means a value 1 if it has access and a 0 if it has not. The following explanatory variables were included:

INC = Household total income including subsidies (standardised in order to compare between relative position in income distribution within each city)
EDU = Tertiary education degree by the head of household (has=1, does not have=0)
SEX = Sex of the head of household (female=1, male=0)
AGE = Age of the head of household
ETN = Belonging of the head of household to ethnic or racial minority groups: black plus indigenous in the case of Medellín, indigenous in the case of Santiago (does belong=1, does not belong=0)
PAR = Participation in community organisations by the head of household (participates=1, does not participate=0)
NW = Head of household that does not work (non working=1, working=0)
HOU = Housing typology: apartment building instead of single houses (apartment=1, other=0).
HEL = Self reported bad health by the head of household: Likert scale values 1+2 out of 4 in Medellín, and 1+2+3 out of 7 in Santiago (bad=1, other=0)
BOR = Borough dummies (borough with the highest internet access rate is used as reference, that is Providencia in Santiago and Laureles-Estadio in Medellín)

Average marginal effects were calculated, as well as percentage of correctly predicted values.

Table 30. Summary Statistics for Santiago.

Continuous Variables					
Variable	N	Mean	Std. Dev.	Min	Max
Household Income (CLP)	16,034	1,434,216.0	1,746,909.0	0.0	49,800,000.0
Standarised H. Income	16,034	0.0	1.0	-0.9	28.0
Age of head of household	16,034	53.0	16.2	17.0	104.0
					Dichotomous variables
Variable for household or head of household (yes=1, no=0)	N	% value = 1	% value = 0		
Access to Internet	16,034	74.0	26.0		
Degree	16,034	27.6	72.4		
Female	16,034	41.5	58.5		
Ethnic/Race minority	16,032	5.4	94.6		
Participation in Organisations	16,022	25.1	74.9		
Non working	16,034	30.4	69.6		
Housing Typology: flat	16,034	25.4	74.6		
Health problems	16,034	8.5	91.5		

Table 31. Summary Statistics for Medellín.

Continuous Variables					
Variable	N	Mean	Std. Dev.	Min	Max
Household Income (COP)	8,810	1,593,742.0	1,709,075.0	6,666.7	20,200,000.0
Standarised H. Income	8,810	0.0	1.0	-0.9	10.9
Age of head of household	8,810	52.8	16.4	17.0	104.0
					Dichotomous variables
Variable for household or head of household (yes=1, no=0)	N	% value = 1	% value = 0		
Access to Internet	8,810	55.4	44.6		
Degree	8,810	22.7	67.3		
Female	8,810	46.3	53.7		
Ethnic/Race minority	8,810	3.6	96.4		
Participation in Organisations	7,381	8.1	91.9		
Non working	8,810	44.2	55.8		
Housing Typology: flat	8,810	52.4	47.6		
Health problems	8,810	22.8	77.2		

5.5 Results

5.5.1 Interviews

5.5.1.1 Similarities

There are relevant shared views among all the interviewees, in both cities. In general, they see Internet as an increasingly fundamental service, and access to it as essentially depending on ability-to-pay. Additionally, the entirety of them considers that income inequality is a central issue in both Santiago and Medellín. Socio-spatial segregation and differences in access to opportunities are perceived as the way income inequality can be noticed in each city's daily life. However, with regard to income inequality and material access to Internet, important differences can be found when it comes to the mechanisms by which the link operates in each city.

5.5.1.2 Redlining

A first element that appeared as a key issue regarding the income-access link is the idea of zones that are excluded from service provision. These are specific neighbourhoods or areas within a neighbourhood where services are not available. This notion was present among almost all actors interviewed in Santiago, named as 'red zones' – *zonas rojas*. In Medellín, although exclusion zones were also present, the reasons given for their existence were different. While in Santiago the red zones are stablished unilaterally by big private corporations, in Medellín they are associated to areas designated as hazardous for human settlements by the municipal planning instruments.

In Santiago, providers, community leaders and local government officials mentioned red zones as the ultimate problem to produce universal access to Internet. However, they differ in the causes that explain their existence. For instance, for a transnational company's high ranked manager, their origins are a structural link between poverty and crime:

> In the case of the older technology, which is copper, and particularly in poor zones, cables are stolen. Since having copper in the streets is the same as hanging one dollar bills (laughs), if you have one dollar bills hanging on the streets, evidently people that has economic needs will collect those dollars.

For community leaders, cable robbery is in the past. However, it produced a stigma over those who live in affected neighbourhoods:

> no internet provider that uses cables reaches us. Why? Because this is a red zone, because here copper cables used to be robbed… so they decided to call us red zone, and now no one arrives with Internet… no one!

Furthermore, SMEs that provide Internet services in red zones point to masqueraded business-model decisions:

> If you call to hire the service, they will tell you that your area doesn't have technical viability. That is because it is a red zone, and a red zone are all these sectors that big companies stay away from. Their characteristics are that at some point copper cables were stolen, or that people there has liquidity problems that makes them be outside the big telcos' business model. They call these neighbourhoods red zone and use a technical excuse to discriminate.

Finally, workers from big companies share the idea of business-model-related origins. They also point to illegal activities, but closer to illegal connections than to cable stealing:

> If there are too many illegal connections, the network fails. You will have too many technical service requirements. It is not convenient for the company to send 20 times a technician to the same place within one week or one month. (…) So, what the company does is that drops the services where it will have too many problems. (…) That is what happens, and that is why these areas are called red zones.

There is a consensus around red zones being a relevant factor that affects access to Internet in Santiago. However, it is not clear who decided to implement them, the legitimacy of the exclusion, and how do telecommunication policies interact with other policies, such as those related to crime. In contrast, a different situation was found in Medellín. There, exclusion zones are areas of natural risk defined that were openly debated in the City Council. As a community leader told me, in Medellín,

> to say that all the poor can't have access would be a lie. (…) There are certain places that are precarious in terms of access to any sort of service: transport, water, Internet. (…) Here usually poverty is concentrated in places with natural risk. The slope is too high, access is difficult, so installing an antenna is difficult, but it also happens that those are the poorest areas.

5.5.1.3 Local public provision of services

Something that only emerges in Medellín is a view shared by all interviewees, according to which the historical presence of the local public company EPM, and its telecommunications branch 'Une' – *unite* in Spanish –, has a fundamental role. As a community leader told me, 'it used to be the company of the *Antioqueños'* – the people of Antioquia, the region of which Medellín is the capital.

The presence of EPM, which only was half-privatised as recently as 2014, is seen as a difference-maker in terms of how does the Internet market work in Medellín. A strong sense of localism can be perceived in many of the interviews, as exemplified by the idea of 'the company of the *Antioqueños*'. As a public official from the Municipality puts it:

> EPM has coverage in absolutely all corners of the city. (…) When new foreign actors entered (…), EPM took the decision of taking Une as a different business unit. But that work essence and that ability to manoeuvre to reach all corners stayed. (…) New companies had to compete under exactly the same conditions. Therefore, I think that, in contrast with what happens in Chile, no operator can dare to deny coverage to any neighbourhood.

These ideas of localism and pre-privatisation patterns were completely absent from interviews in Santiago. This difference probably comes from the late privatisation in Antioquia, compared to the widespread shrinking of the state a few decades before in other parts of the world, including Chile. For instance, Telefónica-Chile and Entel, two of the main companies in the Chilean Internet oligopoly, were state-owned only until the mid-1990s. Consequently, the Chilean companies were never involved in Internet provision while being under public ownership.

5.5.1.4 Neighbourhood-based SMEs

A third key topic is the emergence of SMEs that only serve specific neighbourhoods. Their presence emerged for the first time in the interviews with community leaders. They are a strictly local phenomenon, as one of the community leaders from La Pintana puts it:

> The internet that I have now is provided by a guy from the neighbourhood. I met him in the street market. (…) this guy was offering his Internet… I didn't hire him at once… I didn't want to hire a company that I never heard of, doesn't have a TV commercial… you know? But my friend next door bought it, and it worked… so I called the guy and he installed the Internet that I have now.

Both the awareness of being a red zone and presence of these local SMEs were common in La Pincoya and El Castillo in Santiago. In contrast, only one similar SME was found in Medellín, in Comuna 3-Manrique. However, this lone case has some differences compared to those from Santiago. Although similar wireless technologies are used for providing the service, owners of the local company from Manrique declared having a bigger number of clients compared to the SMEs from Santiago. While the latter claim to have around 1,000 clients, the former declares more than 2,000. Another difference is how the companies were founded. While entrepreneurs in Santiago come from the same borough where they provide services, the SME found in Medellín is a local branch of an existent Argentinian company, which decided to operate in Manrique for strategic reasons.

However, in both cities, these SMEs mention the rigidity of the big companies' business-model as an opportunity that they saw to emerge as competitors. Nonetheless, in Santiago, SMEs and big companies do not really overlap. SMEs rather take advantage of potential clients that are excluded by the red zones. In Medellín, the opportunity comes from a lack of adaptation to users' preferences and ability to pay, and bad quality of cable-based services. As one of the owners of the SME from Manrique told me, their

> target will be where others aren't present or they have bad quality of service. Because if you use copper, the more distant the worse the speed (…) Secondly, there is a group of young people that does not want fixed telephone line, or cable TV (…) here they force you to buy a triple-pack. There is a market demand by people that only wants Internet.

5.5.1.5 Policies

Furthermore, in words of its owners, the emergence of an Internet-provision SME in one of Medellín's neighbourhoods was a product of a public policy:

> There is a regulatory body, the Ministry of Telecommunications, which started a plan called Internet for Everyone. (…) In fact, we are part of the plan, and what the government does is to give tax exemptions. So, strata 0, 1, 2, and 3 – the poor – don't pay taxes for these types of services. They don't pay VAT.

In contrast, the emergence of SMEs in Santiago does not respond to any public policy. In fact, their owners complain that existent regulations impose entry-barriers that are designed for bigger companies, and that the data regarding where the red zones are located is not publicly available. Furthermore, the policy that big companies are advocating for in Santiago is to treat the problem as a demand-side issue. They propose to subsidise poor individuals to pay for internet, without substantially altering the pre-existent business-models within the sector. A high ranked manager from a transnational telco puts it this way:

> Our position as company is that the solution is subsidizing demand (…) in Chile, that was the way we solved access to electricity and sanitation. This is similar. You have parts of the population that wouldn't have access to drinkable water without subsidies for utility bills. Well, that would be unacceptable, so the Government puts the money. We believe it's the same with Internet. If the Government subsidises those in need within neighbourhoods that today aren't economically viable… one will say here we will get the same effect that we get in a middle-class neighbourhood. This means that half of the users will hire us if we put a cable there. Therefore, we will invest and install the cable. Problem solved.

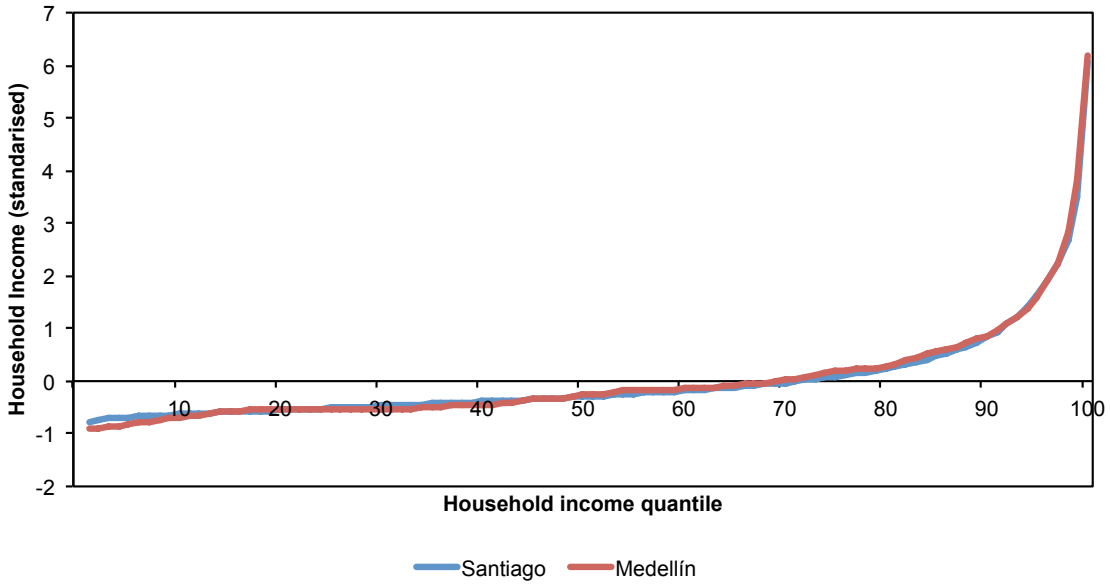

Figure 31. Income curves in Santiago and Medellín.

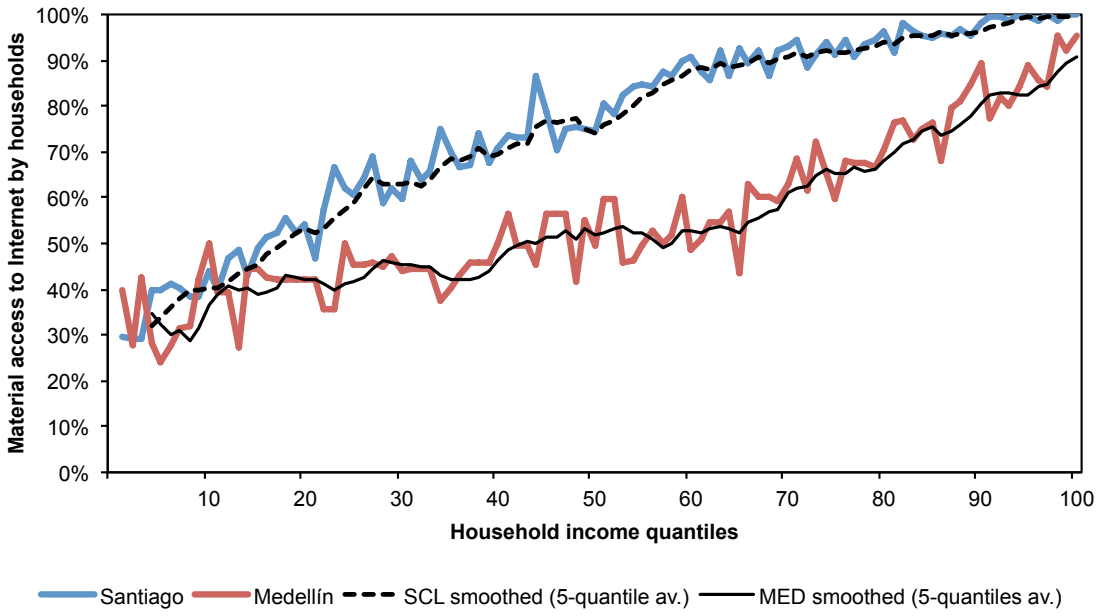

Figure 32. Internet-access curves in Santiago and Medellín.

5.5.2 Income-access curves

Income and Internet access curves for each city provide a clear picture of similarities and dissimilarities between the two cases. For instance, on the one hand, the income curves are almost identical, as can be seen in Figure 31. On the other hand, in contrast, the

Internet access curves evidence some differences, as seen in Figure 32. The chart shows a higher slope of the access curve in Santiago between percentiles 1 to 60, followed by a flatter section between percentiles 60 to 90, and virtually universal access by the 10 richest per cent. In contrast, the access curve is flatter between percentiles 1 to 60 in Medellín, followed by an increased slope between percentiles 60 and 100.

Part of these differences can be attributed to overall gaps between the two cities, since they have different aggregate access rates – 74 per cent in Santiago and 55.4 in Medellín. However, two facts can be highlighted. On the one hand, income and Internet access seem to be more strongly correlated within different groups in each city. While in Santiago this group is the poorest 40 per cent of the population, in Medellín it is the richest 40 per cent. On the other hand, it is notable to see that, although Internet access in Santiago is higher than Medellín among most income quantiles, the two curves intersect bellow percentile 15. The overall higher Internet access in Santiago does not translate into what happens among the poorest of the poor. If a household is part of that poorest group, it does not seem to matter whether to live in Santiago or Medellín in terms of access to Internet. Santiago's advantage in aggregate access vanishes in this segment. This could be interpreted in two ways: as an achievement of Medellín, lifting its poorest population to the level of more advantaged cities; or as a proof that, in Santiago, trickle-down economics does not work for Internet. Furthermore, one could hypothesise that wider access to smartphones might be mitigating this stark drop in Internet access among the poor in Santiago. However, Figure 33 shows that such hypothesis has to be rejected.

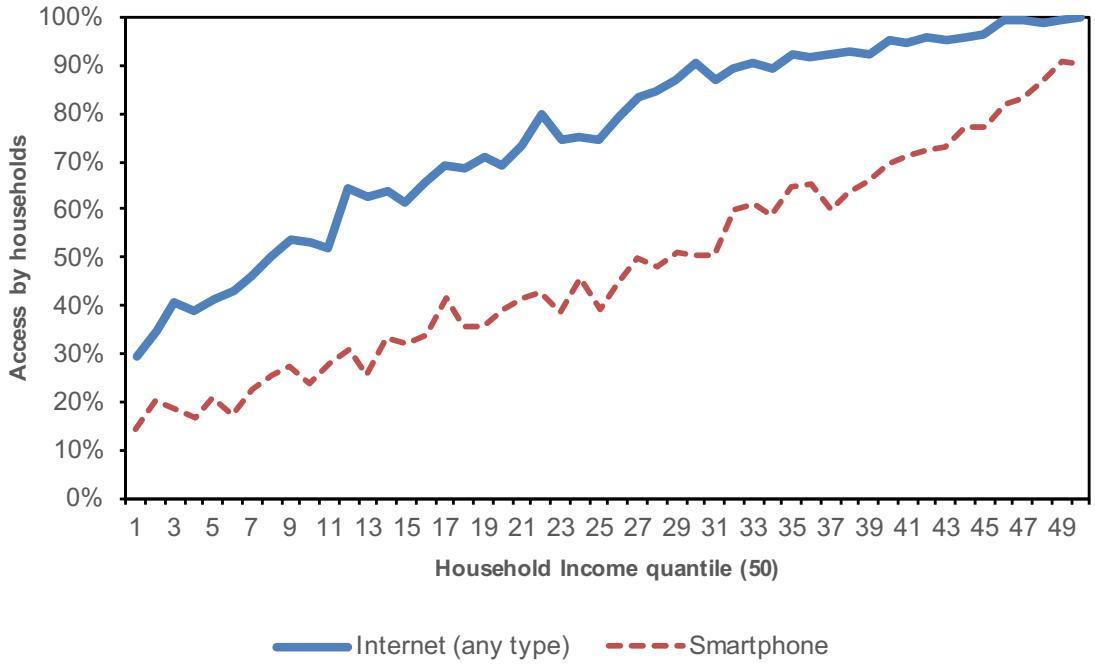

Figure 33. Internet and Smartphones by quantile in Santiago

Table 32. Logit model regression results: Santiago

Variable	Coef.	S.E.	Dy/dx	S.E	95% conf. int.		Coef.	S.E.	Dy/dx	S.E	95% conf. int.	
INC = Standarised H. Income	3.81***	(0.09)	0.33***	(0.01)	0.32	0.34	3.68***	(0.11)	0.26***	(0.01)	0.25	0.28
EDU = Degree							0.89***	(0.08)	0.06***	(0.01)	0.05	0.07
SEX = Female							-0.02	(0.04)	-0.00	(0.00)	-0.01	0.00
AGE							-0.04***	(0.00)	-0.00***	(0.00)	-0.00	-0.00
ETN = Ethnic/Race minority							-0.15*	(0.09)	-0.01*	(0.01)	-0.02	0.00
PAR = Participation in Orgs.							0.05	(0.05)	0.00	(0.00)	-0.00	0.01
NW = Non Working							-0.01	(0.05)	-0.00	(0.00)	-0.01	0.01
HOU = Housing Typology: flat							0.12*	(0.06)	0.01*	(0.00)	-0.01	0.01
HEL = Health problems							-0.07	(0.07)	-0.00	(0.00)	-0.01	0.00
Borough dummies	No						Yes					
Constant	2.31***	(0.05)					4.81***	(0.18)				
Observations	16,034						16,020					
Pseudo R^2	0.2023						0.2871					
Correctly classified	77.30%						81.06%					

p-value * p<0.1, **p<0.05, *** p<0.01 Note: reported coefficients are marginal effects.

Table 33. Logit model regression results: Medellín

Variable	Coef.	S.E.	Dy/dx	S.E	95% conf. int.		Coef.	S.E.	Dy/dx	S.E	95% conf. int.	
INC = Standarised H. Income	1.04***	(0.04)	0.25***	(0.01)	0.23	0.27	0.76***	(0.05)	0.18***	(0.01)	0.16	0.20
EDU = Degree							0.658**	(0.07)	0.14***	(0.02)	0.10	0.17
SEX = Female							-0.00	(0.05)	-0.00	(0.01)	-0.03	0.03
AGE							0.00	(0.00)	0.00	(0.00)	-0.00	0.00
ETN = Ethnic/Race minority							0.05	(0.14)	0.01	(0.03)	-0.15	0.08
PAR = Participation in Orgs.							0.08	(0.10)	0.02	(0.03)	-0.03	0.07
NW = Non Working							-0.09	(0.07)	-0.02	(0.02)	-0.05	0.01
HOU = Housing Typology: flat							-0.10*	(0.05)	-0.02*	(0.01)	-0.05	0.00
HEL = Health problems							-0.20***	(0.06)	-0.05***	(0.01)	-0.08	-0.02
Borough dummies	No						Yes					
Constant	0.34***	(0.02)					1.36***	(0.21)				
Observations	8,810						7,381					
Pseudo R^2	0.0770						0.1261					
Correctly classified	62.58%						66.45%					

p-value * p<0.1, **p<0.05, *** p<0.01 Note: reported coefficients are marginal effects.

5.5.3 Regressions

Regression results (Tables 31 and 32) confirm findings from access curves. In both cities, income is significantly and positively correlated to material access to Internet. However, income is a much better predictor in Santiago than in Medellín. Pseudo R^2 is 0.287 in the former and 0.126 in the latter. Furthermore, after dropping all the rest of the variables from the model, income alone still has a pseudo R^2 of 0.202 in Santiago, while in Medellín the equivalent indicator drops to 0.077. Marginal effects of standardised income, after controls, are also higher in Santiago than in Medellín.

Results regarding other variables are worth commenting. The only three factors that are non-significant in both cases are sex, participation in organisations, and work status of the head of household. Having a degree is significant and positive in sign in both cities but has a much higher marginal effect in Medellín. Interestingly, the housing typology is significant in both cases, but with a different sign. To live in a flat instead of a house seems to affect Internet access in opposite ways: slightly rises the probability of having Internet connection in Santiago and decreases it in Medellín. Furthermore, as results for age and ethnic group show, while in Santiago households with a head that is older and belongs to an ethnic minority have less probabilities of accessing Internet, these factors are not significant in Medellín. Finally, notable are results for health. Self-perceived 'bad health' is only significant and negative in the case of Medellín. One possible explanation came from the interview with one of the board members of EPM, who mentioned that Medellín implemented a policy that made compulsory for all primary health appointments

to be made online. This link would require further analysis, but it is remarkable that health in Medellín has a marginal effect almost as high as education in Santiago.

5.6 Discussion

As results show, informal institutions and policies represent institutional factors that can play a role in the income-internet nexus. They mediate the relationship between income and access to Internet, as summarised in Figure 30. However, consequences of these institutional factors do not affect all the population equally. Their potential impacts concentrate on one specific segment: the urban poor. In this sense, adapting a notion that is increasingly being used in mobility studies (Walks, 2018), I propose to use the concept of network disadvantage. By this concept I mean a supply-side problem of lack of connectivity options available to people, regardless of their individual ability and willingness to pay.

In this sense, bringing back the discussion about the digital divide, institutionally produced network disadvantage should be a factor to consider when analysing all levels. For instance, the first-level digital divide in Santiago and Medellín does not have to do with any structural supply-side technical incapacity to reach all corners of the city. The internet oligopoly is fully developed, and within it, exclusion of clients is part of deliberate decisions to maintain profitability levels. However, this exclusion is not just based on income generation, since we find evidence that individual households are excluded by institutional mechanisms such as the red zones even if they have ability and willingness to pay for connectivity. The exclusion of these households is not a technological problem, nor one of individual income poverty. It is institutionally produced network disadvantage.

Results also provide elements to illustrate second and third level digital divides playing a strong role in both Santiago and Medellín. For example, the educational level of the head of household is significant in both cities after controlling for all other factors. Considering that inter-generational educational levels are deeply correlated in unequal societies (Neckerman and Torche, 2007), this result is probably signalling to second level divides, related to education, that are being reproduced among new generations. Another example is the significance of the link between the head of household having health problems and less probability of having internet in Medellín. This illustrates possible third-level digital divides involving outcomes in health. Such result, along with the fact that Medellín has enforced online medical appointments, deserves further research.

Nevertheless, institutions are embedded in these multi-level digital divides. The usually studied explanatory variables such as income, age and education are just not enough to understand how these divides are produced. Formal and informal institutions are key factors shaping the degree of network disadvantage. Moreover, a feedback loop can be expected since network disadvantage will probably produce third-level digital divides, which in turn can influence the political settlement that defines institutional mechanisms in the first place. Since institutions emerge as a result of rent-seeking behaviour by those who concentrate power (Khan, 2010), Internet-related network disadvantage in these cities depends in part on the balance of power involving big telcos, local and national elites, and the urban poor.

Moreover, a set of new elements can be proposed for future inquiries about institutions affecting the digital divide (all included in Figure 30). On the formal side, at a national level, notable are VAT exemptions for the poor, and at a local level, public ownership of companies and inclusion of SMEs in Internet provision. However, as already examined, informal institutions are also present and deserve attention. Informality plays three types of roles, which can be classified as direct, indirect and contextual.

Firstly, redlining has a direct role, central to the telecommunications markets. In Santiago, redlining is informally enforced by big telcos at a local level, and is viable thanks to a lack of control by the national government. Although the excuse of crime is used as the justification for having red zones, it is revealing that what big telcos propose as a solution is not focused on crime, but on demand-subsidies to make the poor more attractive under their current business model. Advocacy for this approach by transnational telcos confirms what is claimed by their own workers, community leaders, local governments and SMEs: that the problem is one of profitability under a specific business model, and not necessarily one of crime.

Secondly, informality in housing provision plays an indirect but still remarkable role in Internet access. As already mentioned, Santiago and Medellín have opposing approaches to housing provision for the urban poor – slum-eradication in the former and slum-upgrading in the latter. It is notable that the housing typology variable is significant in logit regressions for both cities, but showing opposite signs. It is likely that higher density has different consequences for economies of scale that might play a role in facilitating Internet access, depending on being part of formally or informally generated built environments. This is outstandingly important under new ideas regarding 'connected homes', as is the case of the Internet of Things (Atzori et al, 2010). Unless such vision is expected to be limited to rich countries where informal housing is virtually inexistent, attention must be paid to the link between informal housing and provision of network services. The historical path of slum-upgrading in Colombia is a useful source of practical experiences (Gilbert, 2012). Paradoxically, while in Colombia the exclusion from network services serves as a formal instrument to regulate informal settlements, in Chile red zones are an informal instrument to shape the market in formal state-funded housing developments.

Thirdly, informality also plays a contextual role, one that is much more difficult to measure and to confront via policy approaches. This role has to do with wider social and cultural norms and values. What I mean is the tendency to spatial segregation in Latin American cities, which is central to any attempt to extract conclusions regarding the link between income distribution and Internet access. As extensively discussed by Ruiz-Tagle and López (2014), a 'mirror effect' is usually assumed between income inequality and socio-spatial segregation.

However, although inequality is a condition required for segregation, inequality does not necessarily translate into segregation. In other words, countries with the same levels of income inequality do not necessarily have cities with the same levels of segregation. While both redlining and informal housing have to do with what Khan (2010) identifies as informal institutions that require enforcement – or deliberate lack of it – and can be analysed under the political settlements approach, the tendency to segregation in Latin American cities is a much more complex and long-term phenomenon. Being probably rooted in colonialism (Ruiz-Tagle and López, 2014), it is much closer to discussions such

as those on the cast system in India than on telecommunication policies in emergent economies. It does, however, have a relevant effect on Internet access, since spatial segregation defines the conditions for housing provision and redlining.

5.7 Conclusion

Although there is an evident link between income distribution and Internet access, institutional factors play a role in shaping the ways by which this link operates. Institutions matter both at a national and local level. Particularly in the Global South, informal institutional factors such as redlining, informal housing and socio-spatial segregation need to be considered when analysing digital divides. Additionally, some nuances should be added to the usual narrative that sees digital connectivity services as an eminently globalised and technological phenomenon that is beyond possibilities of self-determination by local communities. Local institutions and balances of power matter for defining the digital divide.

Moreover, two topics deserve particular attention in future research. One is the processes that lead to the implementation of unwritten rules. The other is the role of SMEs in providing internet access to the poor. Both Santiago and Medellín offered evidence of a recent but growing presence of these smaller and locally engaged internet providers. They represent an interesting innovation that entails technological, social, economic, spatial and political phenomena, all of which deserve attention in order to expand the chances to narrow down the digital divide.

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6 Unravelling waste political settlements in Medellin and Santiago: income inequality, recycling, and the role of formal and informal institutions[5].

Abstract

Institutional factors are crucial mediators of the relationship between income and adoption of recycling. However, a North versus South divide in recycling studies produces a scarcity of analytical frameworks for integrating institutions and recycling performance in the study of municipal waste management systems, especially in the Global South. On the one hand, the Northern literature, strong in empirical analyses on performance of municipal recycling services, rarely considers institutional factors. When it does, theoretical approaches are limited, especially in regards to the role of informal institutions. On the other hand, the Southern literature strongly discusses informality, but it does so by focusing of the struggles of waste pickers more than on performance of services. In this paper, the author attempts to approach the role of income inequality in recycling by unravelling waste regimes in Medellín (Colombia) and Santiago (Chile). The focus is put on the political settlements that can explain the formation of these regimes. As a result, firstly, political waste regimes are explained as product of the interplay of balances of power, institutions and distribution of benefits. Secondly, a focus is put on the need to understand informal institutions as a relational phenomenon associated to both the rich and the poor, and not just as a subsistence strategy by the latter.

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6.1 Introduction

Promoting the circular economy and reducing income inequality are crucial challenges of our time. The two are included in the Sustainable Development Goals by the United Nations (2016). On the one hand, target 12.5 is 'By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse'. On the other hand, target 10.1 defines by 2030 to 'progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average'. The increasing urgency of transitions towards lower resource-intensive development paths, occurs in the context of high levels of income concentration by the rich. But little is known about how existent inequalities might affect environmental challenges such as reducing waste generation.

Furthermore, the global nature of the Sustainable Development Goals requires the involvement of countries in the often called periphery, and not just from the North. However, those countries in the South are at the same time the ones falling behind in circular economy efforts, the less covered by recycling scholars, and those dealing with the most rampant inequalities.

For instance, the indicators to measure target 12.5 are the 'national recycling rate' and 'tons of material recycled' (United Nations, 2019). Yet, the United Nations have only been able to collect data from a handful of countries from the Global South (United Nations, 2019). Most of the empirical knowledge about effectiveness of household recycling is based on studies carried on in rich countries with decades of experience in formal recycling (Gregson and Crang, 2015; Millington and Lawhon, 2018). In these contexts, policies that promote and regulate recycling have long ago been enforced. In contrast, recycling in most African, Asian and Latin American countries emerged as an informal activity that was driven by a rising global demand of recycling materials (Brooks et al, 2018), in most cases without any formal policy.

Different disciplines that study recycling are also distanced from each other. On the one hand, studies that analyse performance of mature municipal recycling services (Peretz et al, 2007) tend to be quantitative, come from engineering and economics, and have a particular lack of attention to any form of institutional factors. On the other hand, while in the north the focus is put on effectiveness of actually existing recycling services, in the Southern studies that examine adoption tend to explore possibilities of hypothetical willingness to recycle (Challcharoenwattana and Pharino, 2016; Vasquez et al, 2014; Tadesse, 2009). Moreover, in a recent review of social studies of waste, Millington and Lawhon (2018) identify a similar North versus South divide within research on waste made by social scientists. In regard to Latin America, in particular, social studies have focused on waste pickers, who have been analysed from the perspectives of social inclusion (Magni & Günther, 2014), precarity (O'Hare, 2018), mobilisation (Sorroche, 2017), and hybridations between formal and informal sectors (Guibrunet, 2019).

It is difficult, however, to find an integration of these stories of struggles of waste pickers into an analytical framework aiming to explain performance of recycling systems. In the North, where literature is more abundant, studies that look at performance and include factors such as electoral politics (remarkably Sidique et al, 2010 and Laidley, 2013), tend to focus on local level election results as a proxy of political leanings of individuals. Politics, in this sense, is more a variable to characterise demand than one to analyse institutions. More recent works, such as the study of Italian municipalities by Agiovino et al. (2019), have attempted to introduce corruption and culture as institutional variables to explain separate collection rates. These authors point to the need to understand failure and success as linked to specific local

contexts. A theoretical framework that has integrated these issues in a more systematic way is the proposal of 'waste regimes' by Gille (2010), applied to the case of Hungary. Although waste regimes are useful for this analysis, they do not, however, involve any discussion about performance or efficiency.

What does the literature say about the role of income inequality? Within the performance-oriented literature, income generation is seen as a fundamental factor to explain adoption of recycling by households and service performance by local authorities. However, income distribution is seen in those studies as a mere demand-side issue, without questioning its intrinsic association to balances of power and institutional settings (see Chapter 4 for a thorough discussion). In the context of Latin America, the most unequal region of the world (Palma, 2014), adoption of recycling by households is obviously conditioned by the politics of waste and the usually studied tensions between formal and informal actors (Millington and Lawhon, 2018). Issues such as marginalisation and dispossession are recurrent topics when discussing the role of waste pickers as service providers. Nonetheless, the lack of integration between views on actual adoption, performance in provision, and waste regimes, limits our possibilities of understanding how overall income inequality, so rooted in the region, is linked to the political economy of the circular economy.

Departing from these gaps, the present research has two main goals. On the one hand, to explore how adoption of recycling is influenced by the interdependence of balance of power, institutions and distribution of benefits in two South American cities. On the other hand, to use these cases to shed some light on the role played by income inequality, income generation, and institutional factors in adoption of recycling.

This article draws from mixed methods research in Medellín (Colombia) and Santiago (Chile). Chile and Colombia are among the most unequal countries in Latin America (Palma, 2014). Furthermore, Medellin and Santiago have almost the exact same household level distribution of available income (See Chapter 5). In regards to waste management and recycling, whereas in Medellín residential recycling operates based on formalisation of local waste pickers and a single municipality-owned waste management company, in Santiago services are based on an oligopoly of private companies competing for contracts with municipal governments, including a strong presence of transnational capital.

Using both qualitative semi-structured interviews and collection of quantitative data on recycling, I characterise how waste management systems are incorporating recycling in both cities, their achievements in terms of separate collection, and the set of balances of power, institutions and distribution of benefits that shapes each system. Fieldwork consisted of surveys among recycling service providers, and a total of 50 interviews that focused on understanding the views of supply-side actors: managers and unions from waste management companies, recycling cooperatives, small and medium enterprises, national and local government officials, and community leaders.

Two are the main theoretical contributions of this research. First, I integrate the frameworks from political settlements and waste regimes. Second, I illustrate the need to look at informal institutions as parts of these political settlements, and also as a phenomenon that has to be observed in relational terms, both among the rich and the poor, and not just as a survival strategy by the latter.

6.2 Political Settlements and Waste Regimes

Although some scholars have recently acknowledged that waste management decisions take place under specific institutions and political economy factors (see notably Moreau et al, 2017), these factors have been missing from most recycling studies, especially those that analyse performance of waste management services. A possible explanation for the neglect of institutional factors is that studies tackling economics of municipal recycling tend to select samples of cases that belong to the same institutional framework (See Chapter 4). Hence, they do not include the possibility of comparing two or more institutional settings.

Outside this performance-oriented literature, Gille (2010) developed the notion of 'waste regimes'. This author understands these regimes as, 'a specific set of social institutions' that determine what wastes 'are considered valuable by society, that lay down the principles of valuation, and that resolve the resulting value conflicts' (Gille, 2010:1056). More precisely,

> At their core is a structure of rights and rules, which implies a certain distribution of advantages and disadvantages. Social institutions determine what wastes (…) are considered valuable by society, and these institutions regulate the production and distribution of waste in empirically tangible ways. Waste regimes differ from each other according to the production, the representation, and the politics of waste. In studying the production of waste we are asking questions such as what social relations determine waste production, and what the material composition of wastes is. When we inquire into the representation of waste, we are asking which side of key dichotomies waste has been identified with, how and why waste's materiality has been misunderstood, and with what consequences. Also to be investigated here are the key bodies of knowledge and expertise that are mobilized in dealing with wastes. In researching the politics of waste, we are first of all asking whether, or to what extent, waste issues are a subject of public discourse, what is a taboo, what are the tools of policy, who is mobilized to deal with waste issues, and what nonwaste goals do such political instruments serve. Finally, no waste regime is static, thus we must study them dynamically, as they unfold, as they develop unintended consequences and crises (Gille, 2010:1056).

Furthermore, in their account of literature on wastes and global recycling economies, Gregson and Crang (2015) mention the 'connection to political waste regimes' of waste as a fallout of social practices. They therefore emphasise the political dimension of the work by Gille (2010). However, as discussed by Gragson and Crang (2015) this analytical framework could fall short to analyse the reality in the Global South. An interesting exercise would be to explore the broader field of political economy and institutional economics, which has indeed largely discussed sets of 'social institutions' when attempting to account for performance of diverse productive sectors in the Global South. In what follows, I will explain some basic notions from these fields, and argue in favour of the use of the political settlements approach to enrich our understanding of waste regimes.

Building on the idea of transaction costs and market failures (Coase, 1960), the second half of the 20th century saw institutional economists attempt to study the rules of the game in which transactions occur (North, 1990), leading to different degrees of overall efficiency in markets. However, the beginning of the 21st century brought strong criticism on hegemonic neoclassical analyses of the roles of markets, the state and institutions. Chang (2002), for instance, provides a thorough analysis of post-war institutional approaches among mainstream economists, and highlights how incomplete they are in regard to four main problems: 'the definition of the free market; the definition and the implications of market failure; the market primacy assumption

(namely the view that the market is logically and temporally prior to other institutions, including the state); and the analysis of politics' (Chang, 2002:557). Chang claims that conceptual downsides in economics are not able to be solved by just countering state-interventionist policies to anti-interventionism. Crucially, the problem requires developing an *institutionalist political economy* to bring institutions and politics to its analytical core.

Criticisms by Chang exemplify what has been called 'heterodox economics' (Pike, 2004). Particularly after the 2009 financial crisis, this heterodox field has been enriched with new theoretical and empirical works. For example, new approaches have included building on Karl Polany's 'network and embeddedness' approach (Peck, 2013), applying it to real-life case studies that also introduce the problem of space into the analytical effort (Cahill, 2019). Another recent work that attempts to integrate heterodox economics and the role of urban agglomerations in current capitalist development is the work by Goodfellow (2017), who applied Khan's (2010) 'political settlements approach' to comparative analyses of sub-Saharan cities.

Khan (2010) originally proposed this framework to look at government failure, transition costs, and growth-enhancing institutions in the Global South. In his words, a political settlement 'is a combination of power and institutions that is mutually compatible and also sustainable in terms of economic and political viability' (Khan, 2010:4). In this context, 'the 'rent-seeking' activities of powerful groups result in the creation of both formal and informal institutions', which 'sustain distributions of economic benefits for the participants in these institutional arrangements' (Khan, 2010:25).

Goodfellow's (2017) use of the political settlements approach makes it attractive to this particular analysis of institutions within waste regimes in the Global South. As shown by his account of Kampala (Uganda), Kigali (Ruanda) and Addis Ababa (Ethiopia), political settlements are useful to inform comparative analyses of the national and metropolitan political economy in the so called developing countries, especially in regard to the historical processes that explain current institutional configurations. Moreover, the political settlements approach puts effort on trying to identify and explain a diverse range of informal institutions, which appeals to the problems of formality and informality that are crucial in economics of recycling. Moreover, because of Khan's original interest in transition costs, understood as those costs that emerge from conflict between policy, formal and informal institutions, powerful actors and different incumbent groups in society, political settlements can help to extract lessons for adoption of environmental technologies, such as recycling, that require fundamental change of the current business as usual.

I propose to use the political settlements approach to look at Santiago and Medellin, this time not to account for economic growth, but to adopt it as a tool for explaining waste regimes, at least in their political dimension. Such exploration requires to pay attention to the configuration of broader rules of the game in order to reach the specific case of waste management and recycling. The characterisation of the balance of power obliges us to understand how different groups are able to hold power and impose their will via formal and informal institutions. Institutions are therefore looked as an expression of that balance of power – both from the perspective of policy and formality, as well as informality – and as enablers of the distribution of benefits that is allowed by each political settlement.

Something that is relevant in this approach is that Khan (2010) sees informal institutions emerging when formal institutions do not distribute benefits in line with balances of power. In

this sense, informality can be expected to be observed in all groups, and not just among the poor. As largely discussed by Millington and Lawhon (2018) there is a dominant view in recycling studies that associate the Global South with informality as a survival strategy among the poor. As discussed by Rosa and Cirelli (2018), this divide of the informal and the formal is not just between the Global North and South, but even in places like Europe informality, although permanently present, tends to be ignored. In all these views, however, as criticised by McFarlane (2012:91), 'informality is represented by unorganised, unregulated labour, although in practice such labour is often highly organised and disciplined'.

As the account of the following cases show, the political settlements approach opens the possibility of integrating informality as a relational issue: a phenomenon that involves both the rich and the poor. Even in accounts that attempt to provide innovative frameworks based on research from the South, informality keeps being seen as an issue of the poor. For instance, when Millington and Lawhon (2018) discuss efforts to understand the 'informal waste sector', they focus on 'informal waste as marginal livelihood strategy', 'informal work as environmental and economic contribution', and 'coordination and formalization of informal work'. They then separately discuss 'privatization and multiscalar governance'. However, words such as 'corruption' or 'illegal' are never discussed in this governance level. In contrast, Khan (2010) would discuss corruption, for instance, as part of the informal arrangements that emerge to conform privatization and multiscalar governance.

Is it acceptable to talk about waste in the Global South without mentioning the role of corruption and illegal activities among the rich, and not just among the poor? Valuable efforts such as Millington and Lawhon (2018) do not provide any tool to do so, and perpetuate the focus on the 'informality of the poor'. The introduction of the political settlements approach into the analysis of waste regimes can help to overcome this limitation. In the following section, I attempt to explain the particularities of waste political settlements in each city.

6.3 Case studies

6.3.1 Medellin

It is a morning of April 2018, and I am sitting in a McDonalds in Medellin´s financial district, in Colombia. My interviewee asked me to convene there to use some spare time during his busy day. He works for a transnational waste management company that is looking for new business opportunities in Colombia. I got his contact after interviewing managers from the same company during previous fieldwork in Santiago, Chile. This same company owns the landfill where 54.7 per cent of tons of household waste produced Santiago goes to. He tells me that

> one time, an Austrian recycling expert came to Medellín to get to know our system. After seeing how it works, he described it as a Gipsy bazaar.

He uses the visit of the Austrian expert and the image of the 'Gipsy bazaar' to explain me how unusual the Colombian waste management sector is. After a Constitutional Court ruling, separate collection service in residential areas must formally include waste pickers, who are grouped in recycling cooperatives. My interviewee is emphatic to say that the ruling is inhibiting capital investment in the waste sector. Because of that, – he explains – recycling will never be seriously developed in Colombia.

According to municipal data, by 2017, separate collection rates reached 17.4 per cent of total waste collected in Medellin (Medellín Cómo Vamos, 2019). The system is strongly based on the work by the recycling cooperatives, which include 3,662 registered *recicladores de oficio*. This separate collection rate has been continuously increasing from 13.5 in 2013, and reached a peak of 23 in 2018. According to municipal authorities, recent increases have to do with the strengthening of capacities of recyclers, thanks to support programs by the municipality. The mean recycling capacity per recycler increased from 78.1 kilograms per day in 2017 to 113 kilograms per day by the fourth trimester of 2018 (Medellín Cómo Vamos, 2019). These municipal support plans are a consequence of the local waste management plan, which explicitly commits to trace separate collection rates according to the target 12.5 of the Sustainable Development Goals, aiming for a 70 per cent rate by 2030 (Medellín Cómo Vamos, 2019).

In the case of Medellín, separate collection data does not differentiate between household and commercial waste. This is a common problem with this sort of data, which has been acknowledged by teams from the United Nations (2019) and the European Commission (2015). For instance, similar problems make data from European capitals difficult to compare. As a reference, it could be useful to consider data provided directly to me by the recycling cooperative ASEMAR, which is part of the Recycling Board of the Department of Antioquia – the region of which Medellín is part of. Collected tons of material collected by recycling cooperatives, as claimed by them, reaches 8.2 per cent of total tons collected in 2017. The rest of tons collected for material recovery would therefore correspond to commercial waste, not collected by waste cooperatives. All the aggregate files are traced by yearly updates of the Integrated Waste Management Plan 2016-2027, in charge of the *Alcaldía de Medellin* (2019), and in the reports by the citizen watchdog entity *Medellín Cómo Vamos* (2019).

But, what happens with the link between income distribution in the city and adoption of recycling? At the base of this relationship is the fact that the formalised work of waste pickers spreads all over the city. The municipality and recycling cooperatives coordinate a distribution of routes covering the entire territory. On the basis of this full territorial coverage, waste pickers recognise differences that have to do with income among residents of specific areas. As a member of a recycling cooperative in Medellin explained to me:

> In poor boroughs there is less material and its selection is inferior. In the rich areas people go to the supermarket, which means the material is better and comes in bigger quantities. (…) It is not that they separate better, because we do that job. Take for instance cans. Only here in richer boroughs we find good quality aluminium.

As the interviewee from the transnational company told me in Medellín, it is big business, and not the waste pickers, who seem to feel excluded:

> recyclables from residential areas can only be collected by recycling cooperatives. No one else can enter there. For instance, if a company wants to implement a recycling route, it can't do it because recycling cooperatives that are associated to that area can accuse them and the court will rule in favour of them.

Such is the recycling landscape in Medellin after implementation of the Constitutional Court rulings at a local level. On the one hand, the territory is covered by recycling cooperatives, in agreement with the municipal government. Different areas of the city are responsibility of specific cooperatives. On the other hand, at a smaller scale, each cooperative organises the

coverage of their assigned territory. This organisation is illustrated by a map showed to me in the cooperative ASEMAR, in which smaller areas were assigned to each one of a total of 800 recyclers. As seen in Figure 34, density of recyclers becomes lower as routes get closer to the city boundaries, which means higher slope of the mountains and lower density, at the left of the map.

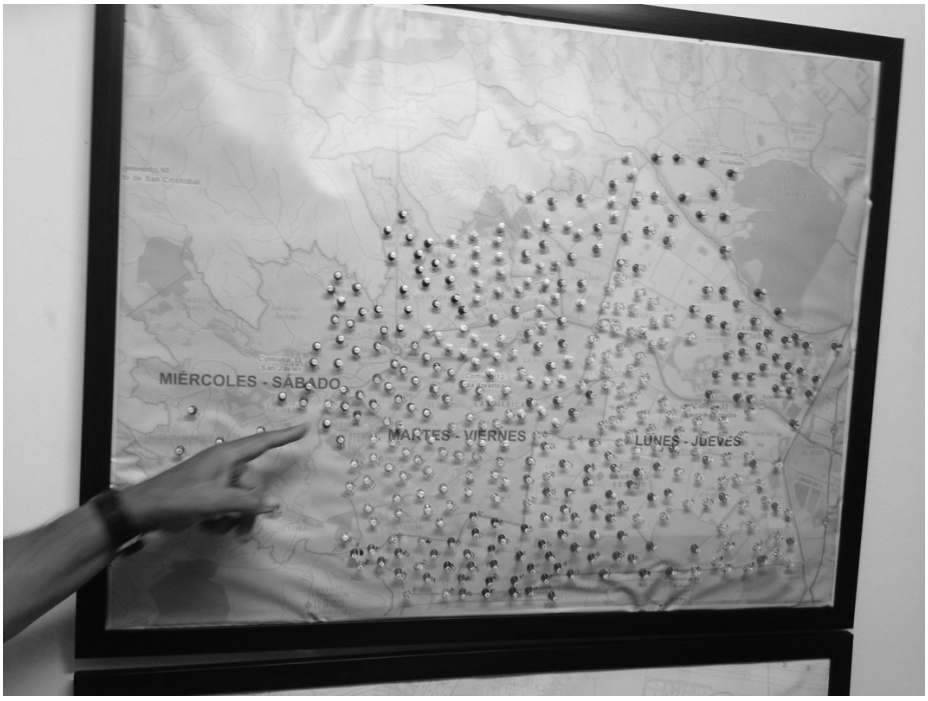

Figure 34. Photograph of a map showing distribution of micro-routes for separate collection that distributes zones for 800 recyclers in the recycling cooperative ASEMAR.

Source: the author.

This high level of organisation has been crucial to implement what was a notable local consequence of the Constitutional Court ruling from 2011: the participation of recycling cooperatives in part of the municipal waste management revenue. This was implemented the year before this fieldwork was conducted. The process and its implementation is described as follows by one of my interviewees from the recycling cooperatives. He refers to Empresas Varias, which is a waste management branch of EPM [Empresas Públicas de Medellín], the multi-utility company owned by the municipality (Dávila, 2012).

> The executive order No. 596 from year 2017 introduced the possibility for the recycler to receive part of the municipal waste management fee, (…) what we recycle does not go to that service provided by Empresas Varias. This is not collected by them. Therefore, Empresas Varias was charging something without retribution for the recyclers. Thus, now we are generating a daily report that is sent to the Superintendence of Public Services. (…) Each report includes a detail of receipts from materials that we sell, and the name and identification of each recycler, plus how many kilos he brought each day to the storage point.

This additional income allows recyclers to earn slightly above a minimum wage, something that was not possible only by payment from sold materials. It is also an income that does not depend on the price fluctuations of materials. Since it is still based on tons collected, it increases the incentives for the recycling cooperatives and their members to cover as much as territory

as they can. This is one of the last elements added to the waste regime in Medellín. The definition and distribution of value is based on formalisation of informal recycling, and it includes a fiscal component by redistribution of the local municipal revenue, and not just by market participation in the trade of recycling materials.

Something notable was that interviewees in Medellín never mentioned corruption as an issue. Although I directly asked about it, not a single interviewee corruption to be a relevant issue. There were conflicts in place, such as claims by some cooperatives that they receive unfair treatment by the municipal government, and tensions between trade unions and EPM, the municipal public utility company. However, since collection and disposal are in charge of EPM, which is owned by the municipal government, and actors have granted participation based on political decisions, there seems to be no need for using corruption strategies that, as commented in the next section, are associated to competition for public bids in Santiago.

But, how was this waste regime originated? What is the origin of the political settlement that sustains it? An answer requires to review the long term peace and state-building process in Colombia, which is is still ongoing.

Long lasting violence was one of the main characteristics of Colombia during the 20th century. Between 1946 and 1964, there was a period called *La Violencia* – The Violence –, which involved armed clashes between the Conservative and Liberal parties. After more than 200,000 deaths, the two parties agreed to alternate the presidency without real competition, initiating a period called 'National Front', which lasted until 1974 (Skidmore & Smith, 2005). The consequent lock down of the political system (Acemoglu and Robinson, 2006) motivated the emergence of three left-wing guerrilla groups between 1962 and 1970. The decades after saw the emergence of self-defence groups and drug cartels, in an escalation of violence that reached its peak in 1990, with the assassination, in hands of the drug cartels, of four candidates for that year's presidential election (Skidmore and Smith, 2005). The crisis was particularly ruthless in Medellín, which in 1991 was the home of the deadly Medellín Cartel and had the highest murder rates in the world: 375 homicides per 100,000 people (Maclean, 2015).

The high-profile assassinations and unprecedented murder rates were the peak of a crisis that different actors where attempting to confront by the end of the 1980s. As part of these attempts, in 1988 Colombia experienced its first democratic election of mayors (Maclean, 2015), which was seen as a way of giving more legitimacy to formal institutions. Later, political elites agreed to call for elections to conform a Constitutional Assembly, which established the basis for structuring a democratic peace process in Colombia (Gómez 2011; Garcia-Guadilla and Hurtado 2000; Nielson and Shugart 1999). Apart from the democratisation of local governments, the call for the Constituent Assembly included offering amnesty and participation to the guerrillas. One of them, the M-19, answered positively to the call, managed to get almost one third of the total seats, and held the presidency of the Constitutional Assembly (Nielson and Shugart, 1999). The assembly led to a new institutional arrangement that favoured political participation, decentralisation, and granted unprecedented social rights (Henao, 2012; Saffon and García-Villegas, 2011; Fernandez, 2009). Underrepresentation of urban areas and exclusion of left-wing groups were seen as major causes of violence and lack of governability (Skidmore and Smith, 2005).

Both the local government democratisation of 1988 and the 1991 Constitution are fundamental to understand the waste regime in Medellín. Firstly, social and economic development in general, and private-public relationships in particular, can not be understood in the Colombian

city without paying special attention to EPM (Dávila, 2012). Attempts to privatise it, as it was the global trend at the time (Goldman, 2014), faced a new level of local political control after democratic election of mayors and city councillors (Maclean, 2015). Proposals for privatisation were discussed during years 1996 and 1997, but they were strongly rejected by mobilised citizenship groups, trade unions, and crucially, by the majority of the political elites with representation in the City Council (Barrios, 2010).

Not only has EPM not been privatised – with the exception of half of its telecommunications branch in 2014 –, but it has grown in its pool of services. That is how in 2013 Empresas Varias, the municipal waste management company, was incorporated to the EPM Group (Empresas Varias de Medellín, 2019). The relevance of EPM, and the opposition to its privatisation (Maclean, 2015; Barrios, 2010) can be understood in the context of role that services play in integrating the displaced by the armed conflict into the city. As discussed from a compared international perspective by Gilbert (2012), Colombian slum dwellers have the peculiarity of been granted access to basic services even if they have not secured land tenure. The result in Medellin is that local political elites have protected the role of the public sector in managing these basic services. In this environment, waste management in Medellin has long ago been planned and executed exclusively by the municipal government, which includes managing a succession of landfills that have been the only destiny for disposal in the city (Empresas Varias de Medellin, 2019).

Secondly, apart from the role of EPM, a fundamental part has been played by the 1991 Constitution and, in particular, one of the organisms created by it: the Constitutional Court. In words of the then president César Gaviria, the aim of the new Constitution was to implement a 'Social State, agreed with different social and political sectors, as well as with guerrilla groups' (Gaceta Constitucional 1991, cited in Henao, 2012). This recognition of demands by left-wing guerrillas had the effect of an unprecedented recognition of social rights in the new constitution. Although the strength of left wing groups vanished in the following years, the rights defined in the constitutional text, and the composition of the Constitutional Court, led to decades of progressive rulings (Henao, 2012; Saffon and García-Villegas, 2011; Fernandez, 2009),

As already mentioned, the Constitutional Court established a new regime for waste management and recycling in 2011 (Fernanda-Tovar, 2018). Before that, another relevant ruling came in 2003, when the Court explicitly defined that organised waste pickers had to be recognised by public authorities and included in recycling efforts. The Constitutional foundation of these rulings was the right to work by those groups that had found in recycling a way to sustain their livelihoods (Amórtegui, 2018).

The interpretation of the waste pickers' constitutional rights reached a tipping point after a conflict over a public bid for waste management in Bogotá in 2011. The terms for participating in the bid included that companies had to be partially owned by recycling cooperatives. However, the cooperatives' share of companies that participated was in some cases as low as 0.1 per cent of the ownership, and some recycler organisations were accused of only existing in paper (Amórtegui, 2018). The ruling not only suspended the public bid in Bogota, but ordered measures such as a new census of recycling cooperatives by local authorities, and the obligation for national regulators to provide a framework for the effective inclusion of waste pickers, all of which had to be applied in in the whole country (Amórtegui, 2018).

One of the most notable policy effects in Medellín is the already mentioned payment that waste pickers receive according to the weight of recyclables that they hand in designated collection centres (Fernanda-Tovar, 2018). In Colombia, public services are funded via differentiated fees charged to all households (Murcia and Daza, 2008). Fees are defined according to an official social stratification system named 'strata' [estrato], and richer households are supposed to subsidise poorer ones (Uribe-Mallarino, 2008). Revenue from fees is supposed to cover operation costs of public services. In special cases, authorities can decide to subsidise some groups according to socio-economic criteria, or to inject additional resources to expand coverage (Murcia and Daza, 2008). These municipal waste management fees are the source of payments for each waste picker, thanks to a highly organised accounting system executed by each cooperative. In contrast, as vividly illustrated by the interviewee at the beginning of this section, transnational companies do not have any relevant role in household waste recycling in Medellín.

6.3.2 Santiago

In Santiago, it is transnational companies who lead household waste management. According to data collected for this research, by 2015, 23 municipalities disposed their waste in two landfills owned by transnational companies. One is owned by the Spanish-American Urbaser Danner group and concentrates 54.7 per cent of tons disposed. Another is owned by the Chilean holding Consorcio Santa Marta and receives 39.5 per cent. A third one is owned by the French company Veolia and gets 5.8 per cent of disposed tons. This private solution to a public problem has been achieved despite high sunk costs – or, in other words, investments that can not be recovered when exiting the market – that would usually lead to establishing a government monopoly (Joskow, 2007). The usual model to generate participation of the private sector would be to make companies compete for one centralised monopolistic market, but instead, in Santiago landfills compete in the market, thanks to disaggregation of disposal contracts between municipalities.

In line with the guidelines being put forward internationally by the Washington Consensus (Goldman, 2014), devolution of services was accompanied by the possibility of outsourcing the different parts of these services, including waste collection and disposal (Adapt Chile, 2016). This led to the privatisation of waste management in most of the 37 municipalities of the Santiago metropolitan area. While a few of them kept collection and transport partially or totally in-house, all of them privately contracted disposal (Reyes, 2004). Until the beginning of the 1990s, when the new regime was implemented, landfills were planned jointly by regional authorities and mayors (Quezada, 2016). After the closure of the last publicly planned landfill in 1996, initiatives for creating new disposal facilities were expected to come from private capital, which led to an oligopoly in which three landfills compete for each municipality's contracts (Pizarro and Jara, 2015).

It has been under this context that household recycling has emerged as an uncoordinated initiative, some times provided by municipalities (Valenzuela-Levi, 2019), and some times by private providers that can be formal or informal (Vasquez, 2011). Furthermore, as in other Latin American cities, the boundaries between formal and informal are not straightforward (Guibrunet, 2019). For instance, while richer municipalities tend to rely on industrial formal services, a few poorer municipalities declare to partly or entirely base their separate collection on collaboration with informal waste pickers (Valenzuela-Levi, 2019).

Official waste management data on generation and treatment is available for commercial waste on the National System of Waste Declaration (Ministerio de Medio Ambiente, 2019). However, data from municipalities is incomplete. Official figures in Santiago are contradictory and tend to come from broad estimates. For instance, the Regional Government launched a recycling program, *Santiago Recicla*, in 2009, which has provided conflicting figures of total recycling (see for instance Corporación Nacional de Medio Ambiente Región Metropolitana, 2005; Intendencia Region Metropolitana de Santiago, 2009; Santiago Recicla, 2017). A study paid by the Regional Government itself stated that official figures on household waste recycling were unreliable (Pontificia Universidad Catolica de Valparaiso, 2006).

However, since household waste management is a legal responsibility of municipalities – bellow the regional level – and thanks to a functioning Transparency and Access to Information Law, it was possible to collect primary data on separate household waste collection rates[6], and complement it with official data from commercial and industrial waste. By 2017, the overall separate collection rate was 15 per cent of waste generated in the Santiago Metropolitan Area. However, while this rate was 22 per cent for commercial waste, it was 1.1 per cent for household waste collected by municipalities. While household waste collected by municipalities was one third of total waste collected, it accounted just for 2.5 per cent of tons recycled, and for 0.4 per cent of total waste produced in the metropolitan area.

Beyond these overall figures, when it comes to the link between income distribution in the city and recycling, actors share similar notions to those found in Medellín. On the one hand, socio-economic inequality is expressed by territorial segregation between boroughs, and, on the other, quantity and quality of recyclable material will be higher in more affluent areas.

However, as a member of waste pickers association told me in Santiago, they recognise differences in material but not in pro-environmental behaviour. He dismissed the idea of richer people doing better waste separation because of more environmental awareness or education. For instance, he highlighted that, many times, in richer households, it is not a member of the family who separates waste, but their handmaidens. The same member of the recycler association from Santiago describes that, in recent years, waste pickers have seen their access restricted in richer boroughs:

> Waste pickers used to go to the poshest neighbourhoods. But about eight years ago, when all these private security services boomed, they started to be kicked out.

This physical expulsion of waste pickers has occurred at the same time than implementation of municipal recycling services in the most affluent boroughs of Santiago. The best example is Vitacura, the richest borough of the entire country, which implemented recycling in 2006 and has the highest recycling rate within the Metropolitan Area – 8.5 per cent in 2017. Figure 35 illustrates the relation between autonomous revenue per capita – which is a reflection of income level among residents – and recycling rates in Santiago. Despite the exception of one poor borough, La Pintana, and many affluent local governments that have not implemented recycling, the highest SCRs can only be found among the richest areas of the city.

Figure 2 shows both recycling reproducing existing inequalities, and a general low penetration of recycling, with many boroughs lacking any recycling service. To explain this, high-ranking

[6] I asked the 37 municipalities for their collection data using the Transparency Act, obtaining answers from 36 of them. The separate collection rate (SCR) was then calculated for year 2017 using the formula SCR = R / (R + L), where R is Tons collected for material recovery (inorganic recycling and/or composting) and L is Tons collected for disposal at the landfill.

officials from the waste management sector in Santiago share a common view, according to which separate collection rates are low in Santiago not because of unwillingness to participate in recycling among people, but because of differences in resources available in each municipality. As a member of a Metropolitan Waste Management Association explained me,

> There is people that want to participate in recycling, but the supply is clearly insufficient and expensive. So, in this case, demand is much higher than supply.

Managers from the oligopoly of landfills express the same vision. As one of them told me,

> There is recycling because nobody pays for it. It has nothing to do with intrinsic evilness of companies or people. There is no more recycling because somebody has to pay the bill. Today municipalities have more needs than money, and recycling is not convenient because it is not profitable for companies.

Profitability of the dominant waste management business model in Santiago, immediately emerges as a key reason to hold back recycling, and managers from landfills are transparent about it. Moreover, as another landfill manager – one that claims that their business is not only landfills but also other forms of waste management – told me, inequality, taxation, redistribution of resources and the power of the waste management companies themselves were part of the explanation:

> Taxes do not balance inequalities among municipalities. So you have a couple municipalities with many resources and others that simply can't afford changing their system. Moreover, where resources are present, those whose bottom line depend on the business-as-usual have power to avoid that the municipalities change their traditional way of managing waste.

This fact that big companies 'have power' over municipal decisions was present in all interviews. There was no interviewee which did not mention corruption and the legal structure of waste management contracts as main factors defining how waste is managed in Santiago. The two main mechanisms to exercise this power, according to the interviewees, were abusive long-term contracts, and bribes to municipal officers during public bids to capture these waste collection and disposal contracts.

Income inequality and residential segregation do not only produce concentration of recycling among the richest boroughs. For instance, the rare exception at the left of the chart in Figure 34 is La Pintana[7], an emblematic working-class borough that was created in Santiago during the Dictatorship by forced displacement of slum-dwellers from more affluent areas (Morales et al, 1990). The 2.9 per cent of material recovery reached by La Pintana is not based on inorganic recycling, as all the rest of the municipalities, but on composting of vegetable waste. This initiative, started in 2005, was possible thanks to the availability of rural land in the borough. La Pintana is located in the Southern outskirts of the city, in what by then was the less demanded land in the Metropolitan Area, almost two hours away by bus from the city centre, and close to old gravel pits and landfills.

[7] The other outlier is Ñuñoa. However, in this case the separation from the columns on the right is due to the use of autonomous revenue per capita. Ñuñoa is a high income municipality adjascent to Providencia, but has a more residential use compared to the high density of comercial uses located in the latter. Given that autonomous revenue comes mostly from council tax and comercial permits, Ñuñoa, although being a high-income borough, appears slightly moved to the left in the chart.

The Municipality of La Pintana implemented an in-house composting service, that also aimed to create jobs in a context of high structural unemployment in the borough. Remarkably, as one public servant from La Pintana explained me, they considered expanding their operation and offering composting services to other near-by municipalities. However, as he explains, the long-term exclusive contracts between municipalities and landfills, mentioned above, blocked the expansion of this service:

> We started a network of eleven municipalities to provide composting service for vegetable waste. We were ready to sign the contract, but the other municipalities realised that their landfill contracts were long term and exclusive: it was compulsory for municipalities to send their waste to the landfill. Breach of those contracts meant the Pains of Hell.

All issues of socio-economic segregation between boroughs, distribution of resources among municipalities, profitability of the waste management business model, long-term contracts and corruption involved in bidding, are integral parts of the waste regime in Santiago. Similar to Medellín, the political settlement that can explain this regime is related to conflict and and a long term state-building process.

As many other aspects of life in Chile, the waste sector is regulated by neoliberal reforms that were implemented during the Military Dictatorship led by Augusto Pinochet between 1973 and 1990 (Atria, 2013; Gárate, 2012). In 1988, a special law for local governments was enacted, and many basic services such as school education, primary health care and waste disposal were entirely devolved to municipalities (Subsecretaría de Desarrollo Regional, 2016). The 1988 reforms need to be understood in the context of a process in which a 17 year-long dictatorship defined an institutional environment whose acceptance was later, in 1990, the condition to hand over power to civil authorities. This process was based on a constitution passed through a first fraud referendum in 1980 (Fuentes, 2013) that was later legitimated – after negotiations with the opposition – in a second referendum held in 1989 (Andrade Geywitz, 2003). The constitution established a set of Organic Laws, whose modification requires 4/7 of the members of the parliament. One of those Organic Laws was the one regulating local governments.

The 1973 coup that gave place to the Dictatorship was planned to end a period of strong politicisation and hyper-mobilisation of society during the 60s and 70s (Landsberger and MacDaniel, 1976). These decades led to Salvador Allende becoming the world's first democratically elected openly revolutionary socialist president in 1970. The constitution, and the Organic Laws, implied reinforcing an historically concentrated presidential power (Valenzuela, 2015). Furthermore, main urban agglomerations became underrepresented in the parliament, and Santiago was fragmented into small municipalities without a metropolitan government. A military rationale for the new administrative division was established, based on generating smaller socially-homogeneous units that would be easier to control. Following this rationale, residents from slums that in the 1950s and 1960s were stablished in higher-income areas were evicted and forced to re-settle in newly-created peripheral municipalities, such as La Pintana (Valdivia Ortiz de Zarate, 2011; Morales et al, 1990).

Funding from local governments is supposed to come from local taxes. However, these taxes depend on property values, commercial activity and car ownership, which are all concentrated in richer areas (Livert and Gainza, 2018). Funding from waste management reproduce these un-equaliser dynamics. In terms of revenue, municipalities in Chile are allowed to charge residents a flat fee, but services are financed by undesignated funds. Social housing dwellers

are exempted from waste management fees, and municipalities can add exemptions according to their own criteria (Vasquez, 2011; Vasconi, 2004). Interviewees from the waste management companies agree in assuming that between 70 and 80 per cent of Chilean households are exempted from paying waste management fees, which leads most collection and disposal services to run in deficit and to require cross-subsidies within each municipality. Given strong levels of territorial segregation (Ruiz-Tagle & López, 2014) the small number of municipalities where the majority of people pay both the council tax and the waste management fee are the richest ones concentrated in the Eastern areas of Santiago, such as Vitacura, Las Condes, and Providencia.

In this context, formal, and informal institutional adjustments have emerged to ensure sustainability of profit rates and mitigate risks among private investors. Among formal mechanisms, municipalities have granted long term disposal contracts through their bids. The most emblematic case is a contract from 1995 to 2027 that ensured disposal from 22 municipalities at the landfill now owned by Urbaser Danner (Pizarro and Jara, 2015). Additionally, vertical integration has been achieved via capturing of collection contracts by the same companies that own the landfills (Pizarro and Jara, 2015). This is done through strategies that have been deemed illegal, but nonetheless have not been stopped. For instance, the Chilean Preventive Antitrust Commission stated in 1995 that the same company – now owned by Urbaser Danner – was competing with different subsidiaries to have advantages in collection bids, and by 2002 the same subsidiaries shared more than half of the collection contracts in the Santiago Metropolitan Region (Reyes, 2004). Finally, corruption, in forms of bribes, is a consolidated strategy to capture bids. Corruption cases have been a constant in waste management bids from the early 1990s (Rehren, 1996) until the late 2010s – as it is the case of an investigation involving mayors of four municipalities, again, accused of colluding with the company owned by Urbaser Danner, in detriment of the one owned by Veolia (Pizarro and Jara, 2015).

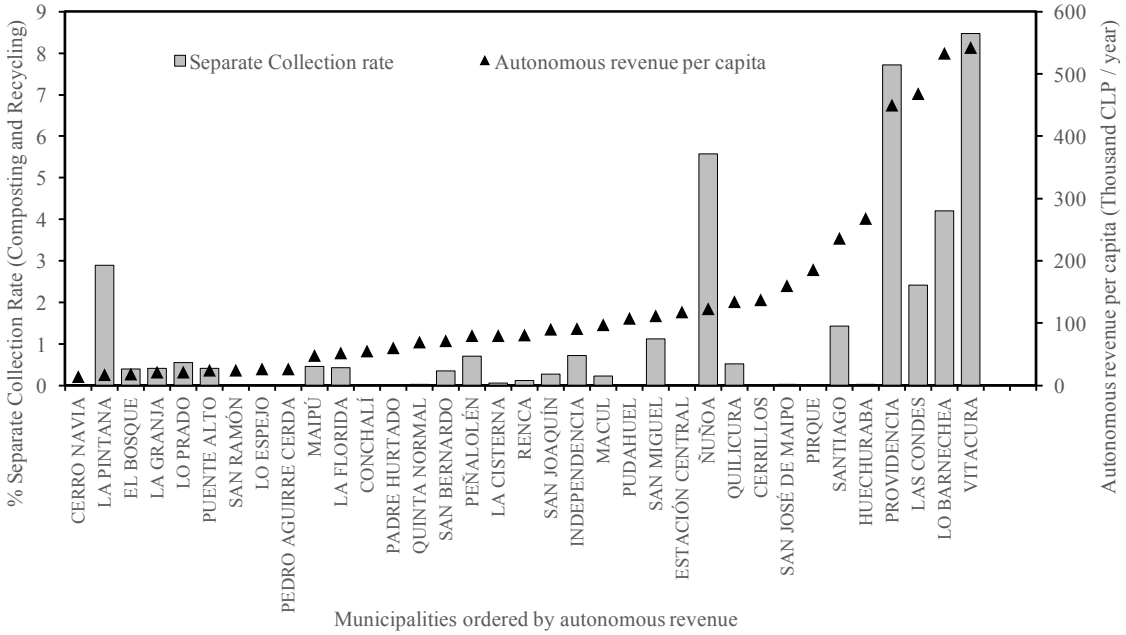

Figure 35. Separate collection for material recovery and autonomous revenue per capita in municipalities that conform the Santiago Metropolitan Area.

Source: The author and Subsecretaría de Desarrollo Regional (2020).

6.4 Final Remarks

Although income inequality and segregation have a lot in common in Santiago and Medellin, the differences in the political settlements generate contrasting waste regimes. In Santiago, waste management is privatised and dominated by transnational capital, formal services are concentrated in specific areas according to profitability or excess of resources, recycling is limited by long-term contracts, and waste pickers can not work in some boroughs of the city. In Medellin, waste management is led by the municipal public utility company, waste pickers have own the right to collect household recyclable materials, their services spread all over the city, and part of their income is produced by redistribution of the local tax revenue. Separate household waste collection rates are dramatically lower in the Chilean capital, and overall recycling figures are higher in the Colombian city. Considering that studies evaluating potential of recycling have usually recommended inclusion of informal recyclers, it is plausible to hypothesise that lower recycling rates in Santiago are linked to legal restrictions of recycling initiatives, and lack of integration of waste pickers.

Moreover, the comparison between Santiago and Medellin shows how crucial is to pay attention to political settlements as the basis of waste regimes. A crucial environmental technology adoption process, such as the municipal recycling services needed to achieve target 12.5 from the Sustainable Development Goals, will not occur just by mere change in consumer behaviour. It depends on collective decisions and the way institutions work. In this sense, at least three main points deserve to be highlighted as final remarks.

First, informal institutions are present in both cases, but in very different ways. On the one hand, although informality 'from bellow' exists in the form of waste pickers in Santiago, it involves crucial mechanisms at the elite level, with a consistent long-term presence of corruption as a form of making capital investment less risky and more profitable. Informal waste picking, on the other hand, will keep playing a role as long as the political settlement keeps excluding large territories and communities from formal recycling. In Medellin, labour-intensive presence of waste pickers in the collection service might look like what is usually understood as informality, but it has been formalised and even incorporated in sophisticated cash flow accounts, which enables payments to individual recyclers funded by municipal revenue.

Second, we see different business-models of waste management competing, particularly landfill disposal and separate collection. In both cities, which business-model prevails does not depend primary on the will of consumers, but on political settlements that shape waste regimes. The power that each actor holds depends, in both cases, on the more general political settlement in each country, which was defined in state-building processes linked to violent conflicts. On the one hand, fragmentation of municipal responsibility and privatisation of landfill planning in Santiago is a product of a violent conflict in which the neoliberal agenda was imposed and political control over public services was reduced to a minimum. The primacy of the landfill business-model in Santiago must be understood as a manifestation of primacy of oligopolistic capital over local and small-size competitors – as exemplified by exclusion of waste pickers in general, and the case of the failing attempt to expand composting services in La Pintana. On the other hand, the power of waste pickers in Medellin is only possible because of the compromise of the political elite and part of left-wing guerrillas in 1991, which made the Constitutional Court a space to enforce strong recognition of social rights. This political settlement will be sustained only as long as the political elites see this compromise as the fair

price to pay for peace and rule of law in an armed conflict that by the beginning of the 1990s did not have clear winners.

Under these circumstances, the key difference between the two cities does not seem to be what can be technically achieved in terms of recycling. Moreover, the main difference seems to come from exclusion of some communities from service provision. This exclusion leads to service disadvantage (See Chapter 5), that is to say, total or partial absence of supply of services, regardless of the demand. It is supply-side exclusion from recycling services, and not so much consumer preferences, what defines the link between socio-economic inequality and recycling in Santiago and Medellin.

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7 Income distribution within urban transport networks: the role of informal institutions

Abstract

There is increasing interest in the measurement and evolution of income inequality within mainstream economics. However, although income has always been considered a determinant of modal choice and travel behaviour in transport studies, the link between income inequality and public transport is less studied. This paper uses mixed-methods to analyse income groups and their participation in public transport in Santiago (Chile) and Medellín (Colombia). The two cities have similar income distributions, public transport systems composed by fare-integrated metro and buses, and are part of the two South American countries that are members of the Organisation for Economic Cooperation and Development. In both cities, there is almost equal shares of public transport as main mode for commuting, and an 'inverted U' curve is found in terms of ridership according to income group. However, participation of the poor is higher in Santiago, and presence of the rich is higher in Medellín. Informal institutional factors, such as fare evasion in Santiago, and formalisation of informal transport providers along with adherence to 'good behaviour' campaigns in Medellín, are proposed as explanations for these differences. Informal institutions are analysed using a political settlements approach, and new elements are added to theories that aim to integrate institutional economics or political economy to transport studies.

7.1 Introduction

After the 2009 financial crisis, distributional and social justice issues have received increasing attention by scholars from different fields. In mainstream economics, the answer has been an unprecedented surge in studies about income and wealth distribution (Milanovic, 2011; Palma, 2011, 2014; Piketty, 2014). Among those that study passenger transport, the emphasis has been affordability, transport disadvantage and barriers to mobility among vulnerable groups (Mattioli, Nicolas and Gertz, 2018). Ideas such the right to the city and spatial justice are beginning to permeate transport studies (Verlinghieri and Venturini, 2018).

Moreover, income distribution scholars within the field of economics have brought new discussions to the table. Notably, Palma (2011, 2014) has reinforced the idea that 'it's about the share of the rich', and not just about what happens with the poor. Among mainstream economics and development institutions, efforts by Palma and others like Piketty (2014) changed the attention from an almost exclusive focus on the 'super poor' into new debates about the 'super rich'. Following this trend, a limited number of studies in the field of transport economics have attempted to introduce income distribution as a factor to understand issues such as household transport expenditure (Lescaroux, 2010), or supply and demand for public transport (Albalate and Bel, 2010).

This research aims to explore the possibilities of applying recent findings from income distribution studies into transport studies. In particular, the 'Palma proposition' (Cobham et al, 2016) is used as a departing point to explore integrated public transport systems. This proposition states that, across societies, most changes in income distribution happen between the 'tails', meaning the bottom 40 poorest per cent and the 10 richest per cent of the population (Palma 2011, 2014). In turn, the share of the 'middle' – percentiles 41 to 90 – tends to remain the same across countries. Thus, this article looks at the income distribution groups observed by Palma, and their participation in public transport. It also analyses the institutional factors that play a role in the interaction between income distribution and urban public transport systems. To do so, a mixed methods approach is applied on two Latin American cities: Santiago (Chile) and Medellin (Colombia). The results provide the basis for a discussion on the role that formal and informal institutions play in defining the presence of different income groups within public transport networks.

7.2 Income distribution, transport and institutions

Although explicit accounts of income distribution as an input tend to be absent from transport studies, disposable income is central in the general understanding of how passenger travel dynamics operate. At a micro level, models tend to assume the existent of utility-calculator individuals who constantly make travel choices according to their needs, desires and available resources. Behavioural psychology, for instance, assumes that socio-economic factors determine how individuals will evaluate costs of different options, such as private and public transport (Collins and Chambers, 2005). In aggregate terms, it is often assumed that there will be higher income elasticity of travel demand among low-income groups (Polat, 2012). However, more recently, some studies have pointed to transport disadvantage and forced car ridership as causes of lower income elasticity among the poor (Mattioli, Wadud and Lucas, 2018).

Albalate and Bel (2010), who looked at the link between income inequality and both supply and demand for public transport, follow the same rationale. These authors hypothesise that

more unequal regions will have more supply and demand for public transport because more unequal income distributions will mean to have less people with ability to pay for private motorised travel. All these perspectives mentioned so far depart from a neoclassical view of how supply and demand operate in transport. A different perspective can come from institutional economics. For instance, a classic argument comes from Alesina et al (1999), who associate social polarisation to the weakening of funding of public goods. In chapter 3, I argued that, more than just a demand-based phenomenon, income distribution is linked to public transport provision because income shares are a proxy of power balances between the rich and the poor, and those balances shape transport regimes. This position adds up to the broader debate around commodification of social interactions and welfare state regimes proposed by Esping-Andersen (1990).

Furthermore, in recent years, some scholars have attempted to introduce institutional economics debates into transport studies (Rye et al, 2018; Canitez, 2019). Yet, as much valuable as these attempts are, they only partially reflect existing debates within institutional economics and political economy. Canitez (2019), for instance, notably attempts to provide a review of theoretical perspectives from institutional economics and to propose a set of applications in transport studies. However, the problem with the view by Canitez is that it only focuses on 'new institutional economics' (NIE), and dismisses what is called 'old institutional economics' (OIE) – associated by this author to John Commons, Thorstein Veblen and Daniel Bromley. Canitez consequently debates theoretical elements grounded on the works by Williamson (1981) on governance arrangements that diminish transition costs, and North (1990) on how institutional change influences economic performance.

Nonetheless, by this dismissal of OIE, Canitez discards an entire body of literature within economics that criticises NIE. This scholarship aims to continue the legacy of OIE instead. Chang (2002), for instance, provides a thorough analysis of post-war institutional approaches among mainstream economists, and highlights how incomplete they are in regard to four main problems: 'the definition of the free market; the definition and the implications of market failure; the market primacy assumption (namely the view that the market is logically and temporally prior to other institutions, including the state); and the analysis of politics' (Chang, 2002:557). Chang claims that conceptual downsides in economics are not able to be solved by just countering state-interventionist policies with anti-interventionism. Crucially, the problem requires developing an 'institutionalist political economy' to bring institutions and politics to its analytical core.

Criticisms by Chang exemplify what has been called 'heterodox economics' (Pike, 2004). Particularly after the 2009 financial crisis, this heterodox field has been enriched with new theoretical and empirical works, who build on ideas from other authors associated to OIE – a broader group that one pointed by Canitez (2019). New examples include building on Karl Polany's 'network and embeddedness' approach (Peck, 2013), applying it to real-life case studies that introduce the problem of space into the analytical effort (Cahill, 2019). Another recent work that accounts for the role of urban agglomerations in current capitalist development is the one by Goodfellow (2017), who applied Mushtaq Khan's (2010) political settlements approach to comparative analyses of sub-Saharan cities. In his firsts theoretical propositions, Khan departs from an explicit critique of NIE (Khan, 1995), similarly to what was later done by Chang (2002).

Two are the main downsides of the omission of OIE. First, NIE provides a limited understanding of informal institutions. Second, NIE neglects the problem of distribution of

benefits as a fundamental force shaping institutions. Interestingly, the political settlements approach focuses particularly on these two issues.

In regard to informal institutions, according to Khan (2010), there are three types of informal institutions. Firstly, there are patterns of behaviour that are based on internalisation of norms and values. Secondly, there are rules that require enforcement but are not written down, and therefore, are informally enforced by extra-state or intra-state actors. Thirdly, there are tacit institutions that emerge simply because of the need for coordination. According to Khan (2010), while NIE focuses on the first type of informal institutions, he proposes to focus on the second group, which are those that require enforcement and are so intrinsically rooted in balances of power. Similar critiques to those done by Khan to NIE could be done in regard to authors attempting to bring institutional economics into transport studies. Examples such as Rye et al (2018) and Canitez (2019) tend to focus on informal institutions derived from cultural values or ways of improve coordination outside formal rules, but not on more complex issues that might involve illegality, such as corruption or fare evasion.

In regard to the issue of distribution of benefits, Khan puts it in the centre of the political settlements approach. A political settlement 'is a combination of power and institutions that is mutually compatible and also sustainable in terms of economic and political viability' (Khan, 2010:4). In this context, 'the "rent-seeking" activities of powerful groups result in the creation of both formal and informal institutions', which 'sustain distributions of economic benefits for the participants in these institutional arrangements' (Khan, 2010:25). Distribution of benefits, including income, is therefore inherent to institutional arrangements, both formal and informal.

In this research, I build on the useful theoretical efforts by authors such as Canitez (2019), but expand them with discussions on empirical findings that come from observing income distribution within the case studies, and approaches that are closer to OIE. A particular emphasis is put on illegal informal institutions that have to be enforced by active omission of formal rules by intra state actors, and on formalisation of the role of informal actors in the context of conflict.

7.3 Case studies

This analysis uses the cities of Santiago in Chile and Medellín in Colombia as case studies. Chile and Colombia are among the most unequal countries in Latin America – the most unequal region in the world (Palma, 2011). Both are also part of the broad cultural inheritance of Catholic and Hispanic post-colonial norms and values (Khan, 2010). Household data on the 21 boroughs of Medellin (Alcaldia de Medellin, 2015) and the 37 of the Santiago Metropolitan Area (Ministerio de Desarrollo Social, 2017) show high levels of income inequality on both cities. While the Gini coefficient for total household income was 0.48 Santiago by 2015, it was 0.44 Medellin by 2017. Equivalent measures in other major cities around the world were 0.39 for Greater London, 0.33 for Barcelona, 0.42 for New York, and 0.32 as an average within the OECD (Barcelona Activa and Barcelona City Council, 2017). Figure 36 shows how similar income distribution curves are in both cities.

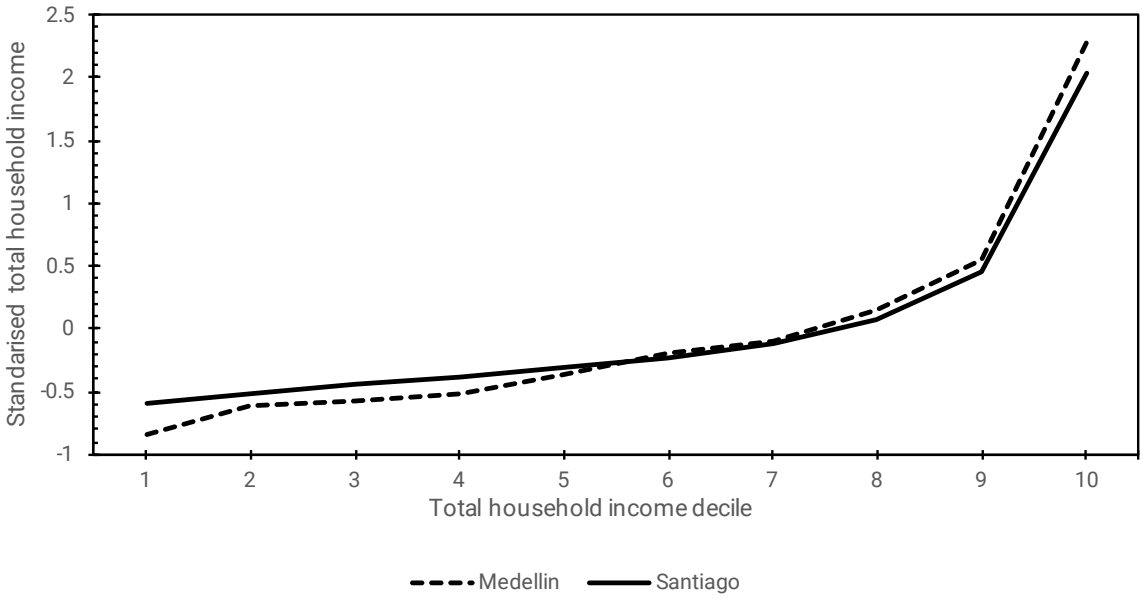

Figure 36. Comparison of standardised income curves in Medellin and Santiago

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

Furthermore, as shown in Figure 37, the same household surveys provide data on primary modes for work-related trips (see Section 7.4.2 for more details). In both cities, the public transport supply is based on a metro network and a fleet of different kind of buses and other smaller vehicles that are legally part of public transport (for instance, 'collective taxis' in Santiago). The share of public transport as primary mode for work-related trips is almost the same: 54.3 per cent in Medellin and 54.9 in Santiago. However, differences can be found regarding subsets of modes: Santiago has more workers using the metro network compared to Medellin. In turn, Medellin has a higher share of commuters using buses to get to their workplaces. This is expected to be related to the network supply: as shown in Table 33, the per capita area within 700 meters of distance from a metro station in Santiago triples the one in Medellin (see Figure 38 for a graphic comparison of both networks).

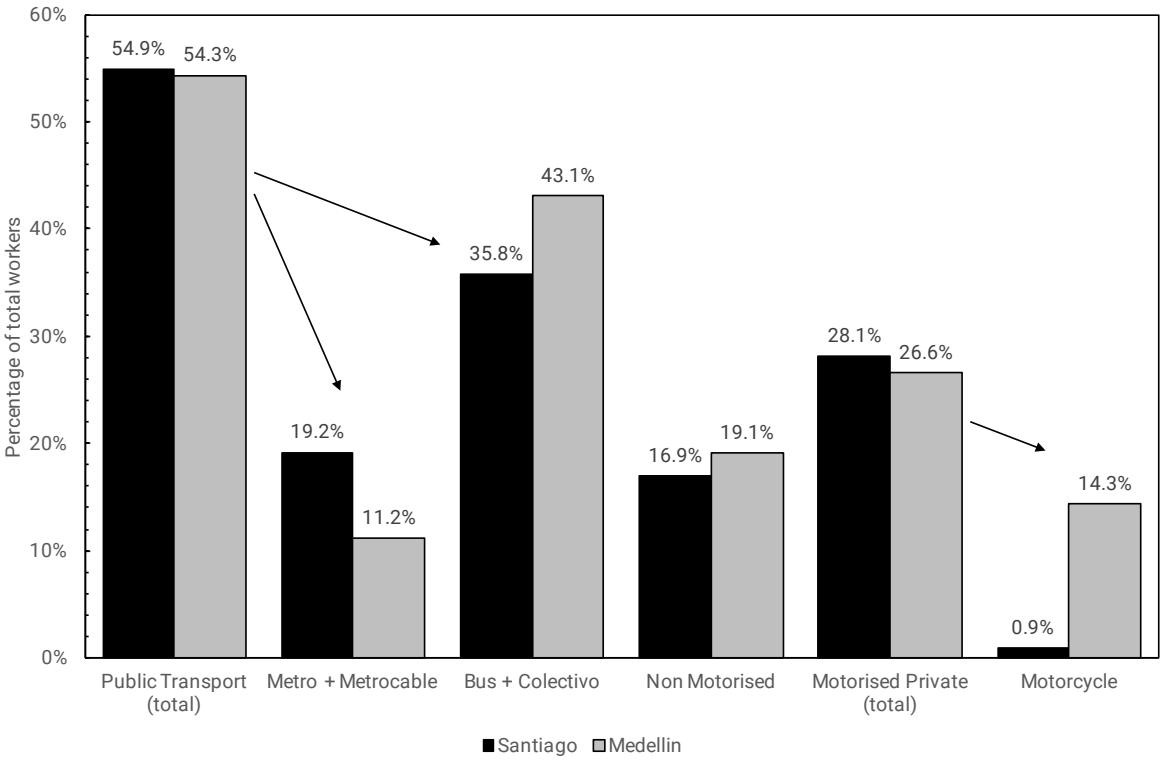

Figure 37. Primary mode for work-related trips in Santiago and Medellin.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

Metro networks have been part of the public transport supply in these two Latin American cities from a couple of decades ago. While in Santiago the first line was inaugurated in 1975 (Metro de Santiago, 2019), the metro started its operation in Medellin in 1995 (Metro de Medellin, 2019). A notable feature in Medellin is the expansion of the metro network into the steep slopes of the mountains that surround the central districts, by using cable cars (Dávila, 2012). Cable car lines, called *Metrocables*, have become icons of the city, starting their operation in 2004 and later following periodic expansions. Apart from the exceptional presence of the *Metrocable* in Medellin, both public networks work similarly, with an integrated flat fare to use a trunk and feeder system. In both cases, there are also some non-integrated bus lines connecting the periphery and the centre of the city.

Table 34. Relevant city characteristics

City	Population (millions)	Surface (sq. km)	Area within 700 meters of a metro network station	
			Km^2 Total	Mts^2 Per capita
Santiago	6.2	641	178.4	0.03
Medellin*	3.7	380	35.5	0.01

*Population and surface figures from Medellin correspond to the Area Metropolitana del Valle del Aburra, while the Comunas and Corregimientos only comprise 'Medellin Ciudad'.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

Finally, there are differences in the modal share of those work-related trips that are not part of the public transport network. Medellin has a higher share of non motorised trips (walk, bicycle, animal), and a lower share of private motorised trips (private vehicles, taxi, informal) than Santiago. Another feature in Medellin is the high use of motorcycles within private motorised trips. While the latter represent the main alternative for just 0.9 per cent of commuters in Santiago, the equivalent figure is 14.3 per cent in Medellin.

7.4 Material and methods

7.4.1 Methodology

The mixed-methods empirical approach is based on three methodologies, two of them quantitative and one qualitative. Firstly, a descriptive statistical analysis is provided in order to distinguish modal shares among the three groups recognised in the Palma proposition (Cobham et al, 2016). These groups are the 'bottom 40 per cent', comprising percentiles 1 to 40 of the total household income distribution, 'middle 50 per cent', which ranges from percentiles 41 to 90, and 'top 10 per cent', including percentiles 91 to 100. Additional analyses by deciles are provided for some variables.
Secondly, a binary logit regression model is used to run regressions on the samples provided by household surveys for each city. The objective is to analyse whether being part of one of the abovementioned income groups – bottom 40, middle 50 or top 10 per cent – is significantly linked to the probability of using a specific transport mode.

This type of analysis adds the possibility of controlling by relevant variables, which in this case are sex, age, accessibility to the metro network and time distance to the workplace. The outcome is a binary variable, *T*, accounting for the use of a specific mode to commute to work: that is, a value 1 if the worker declares it as their main mode or 0 if they do not. Considering the dichotomous nature of *T*, a logit model is used, as described by the formula $\Pr(T = 1|x) = G(x\beta) = \frac{\exp(x\beta)}{1+\exp(x\beta)} = \Lambda(x\beta)$. Here, $x\beta = \beta_1 + \beta_2 x_2 + \cdots + \beta_k x_k$, in which the intercept β_1, and factor variables plus their respective coefficients are contained. x_1 to x_k include sex, age, accessibility to the metro network and time distance to the workplace. Average marginal effects are calculated, as well as percentage of correctly predicted values by the model.

Thirdly, the qualitative part of this study is based on semi-structured interviews performed in Santiago and Medellín. Interviewees were high-level officials (cabinet ministers, heads of departments), public servants (specialised professionals from government teams), transport consultants, local community-leaders (community boards, local NGOs), managers from public transport companies, as well as workers and union leaders from the same companies. Fieldwork was conducted in both cities between March and May 2018. A total of 52 interviews were carried out: 20 in Santiago and 32 in Medellín. Distribution of interviewees among different roles is summarised in Table 34.

In the case of community leaders, as well as municipal level public servants in Santiago, a territorial selection criterion was applied. Since both cities are divided in boroughs, interviews targeted areas that included emblematic marginalised neighbourhoods in each city, plus adjacent zones with diversity of income groups. In the case of Santiago, the emblematic marginalised neighbourhoods were La Pincoya in Huechuraba and El Castillo in La Pintana; boroughs included were Huechuraba and Recoleta – in the North of the city –, plus La Pintana

and La Florida – in the South. In the case of Medellín, marginalised neighbourhoods were Zona Nor-Oriental and Comuna 13; boroughs included were Comunas 1-Popular, 2-Santa Cruz and 3-Manrique – in the East of the city –, as well as 13-San Javier, 12-La América and 14-Laureles-Estadio – in the West.

An interview schedule was utilised to organise semi-structured interviews. Depending on each interviewee, some topics were developed in more depth and extension. Interviews were conducted in Spanish, recorded in audio and transcribed for analysis. Quotations are translated to English by the author. A set of codes was preliminary stablished based on pilot interviews. These codes were confirmed after transcription and used for content analysis. Given the limited space of this paper, only a small number of representative quotes are reproduced in Section 7.5.3 in order to help to discuss main findings.

Table 35. Summary of interviews.

Type of interviewee	Medellín	Santiago	Total
Provision			
board member /managers	3	3	6
workers/union leaders	4	5	9
Constituency			
Community leaders	17	7	24
Policy			
high level authorities	2	4	6
public servants / consultants	6	1	7
Total	**28**	**22**	**52**
Gender			
female	16	3	19
male	16	17	33

7.4.2 Quantitative Data

Quantitative data for transport modes, household income and time-distance to the workplace comes from household surveys collected by governments in each city. In the case of Santiago, the survey is the Encuesta de Caracterización Socio-Económica Nacional in its 2017 version (Ministerio de Desarrollo Social, 2017). The analysis isolated data from 37 municipalities that are considered part of the Santiago Metropolitan Area. For Medellín, the survey utilised is the Encuesta de Calidad de Vida Urbana de Medellín in its 2015 version (Alcaldía de Medellín, 2015). The data includes the 16 boroughs that are part of the urban jurisdiction of the Alcaldía de Medellín, plus five semi-rural areas called *corregimientos*. Summary statistics for each city can be found in Tables 35 and 36.

Given that accessibility to metro stations should be a relevant factor for modal share within each public transport network, a variable of km^2 within 700 mts of distance to stations was calculated at borough level for both cities. This calculation was made using a Geographic Information Systems software, on the basis of shapefiles of borough limits that are publicly available in each city (Instituto Nacional de Estadísticas, 2019; Alcaldía de Medellin, 2019b), and locations of stations provided by OpenStreetMap. Figure 3 shows how the geometries of the buffer generated by the 700 mts distances from the stations and the borough boundaries interact in each city. Since both household surveys indicate the borough where every person lives, this value was later assigned according to place of residence.

Transport modes are measured by percentage of total workers. This limitation to work-related trips leaves outside other relevant type of trips. However, although the survey from Medellin included other trips, the one from Santiago only asks about the main mode to commute to work, and therefore I limited the analysis for the sake of comparability. However, acknowledging that this analysis leaves outside fundamental dynamics related to 'invisible work' and might have a gender bias (Díaz-Olvera et al, 2013), work-related travel is still useful to open a debate on relevant socio-economic phenomena, which might impact activities outside work. Total household income is measured by each local currency, and was later used to define deciles. Time-distance to the workplace was measured in 20-minute intervals from 20 to 100.

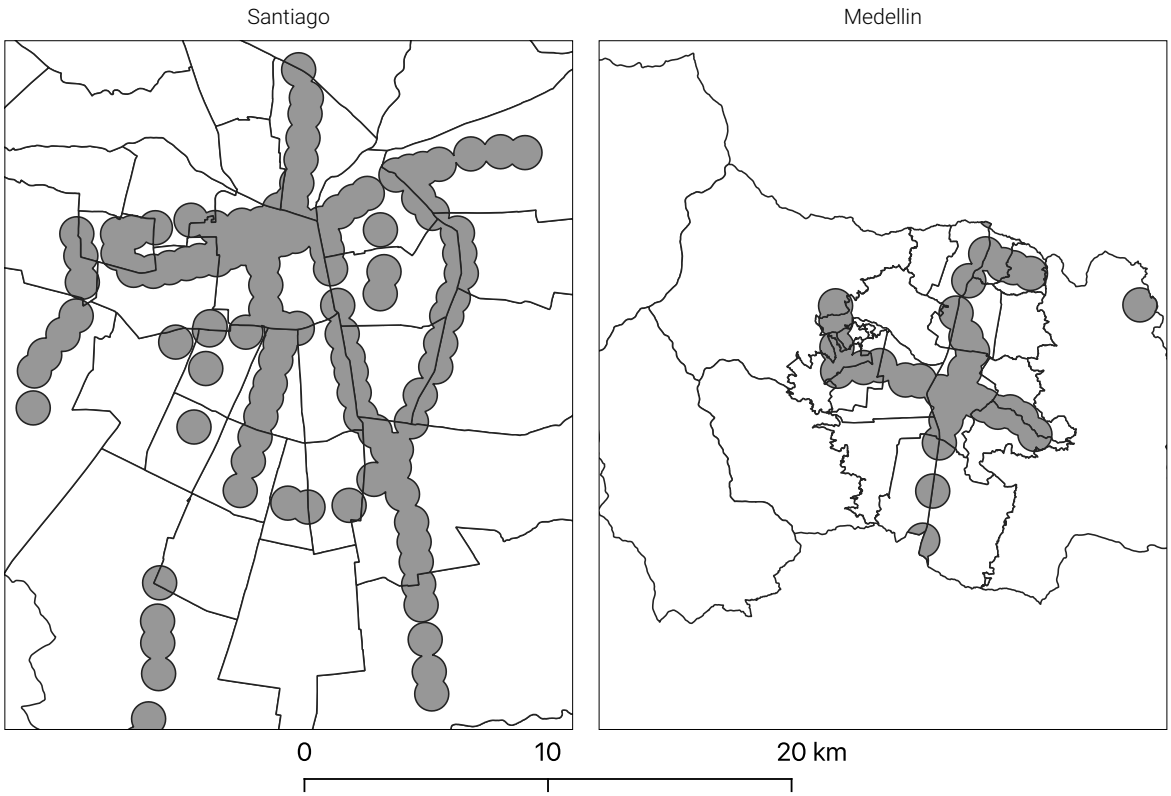

Figure 38. Geometric interaction between borough boundaries and buffers generated by 700 mts distance to Metro and Metrocable stations.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

Table 36. Summary Statistics for Santiago.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Metro + Metrotren as main mode	8,576	0.17	0.37	0.00	1.00
Buses + colectivo as main mode	8,576	0.32	0.47	0.00	1.00
top 10 income	8,576	0.11	0.32	0.00	1.00
mid 50 income	8,576	0.55	0.50	0.00	1.00
bottom 40 income	8,576	0.34	0.47	0.00	1.00
bottom 10 income	8,576	0.07	0.25	0.00	1.00
sex (1=men 0=women)	8,576	0.54	0.50	0.00	1.00
age	8,576	42.31	14.27	15.00	98.00
minutes to work	8,576	79.24	19.77	60.00	100.00
km^2 within 700 mts to metro station	8,576	7.55	6.02	0.00	19.04

Table 37. Summary Statistics for Medellin.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Metro + metrocable as main mode	12,993	0.11	0.32	0.00	1.00
Buses + colectivo as main mode	12,993	0.43	0.50	0.00	1.00
top 10 income	12,993	0.13	0.33	0.00	1.00
mid 50 income	12,993	0.55	0.50	0.00	1.00
bottom 40 income	12,993	0.33	0.47	0.00	1.00
bottom 10 income	12,993	0.09	0.29	0.00	1.00
sex (1=men 0=women)	12,993	0.56	0.50	0.00	1.00
age	12,993	38.92	13.44	5.00	99.00
minutes to work	12,765	39.90	19.28	20.00	100.00
km^2 within 700 mts to metro station	12,961	1.58	1.31	0.00	6.09

7.5 Results

7.5.1 Descriptive statistics

Figure 39 shows modal share of aggregate public transport, metro networks, and buses in both cities. Aggregate percentages illustrate how income distribution within public transport differs between the two cases: use of public transport is skewed toward lower income in Santiago compared to Medellin. Furthermore, while the middle 50 has almost the same participation in public transport in both cities, the top 10 group has lower ridership the Chilean city compared to the Colombian one. Disaggregated figures by mode (Figures 41 to 44) allow us to highlight that the explanation for the overrepresentation of the bottom 40 per cent poorest group in Santiago is higher use of buses.

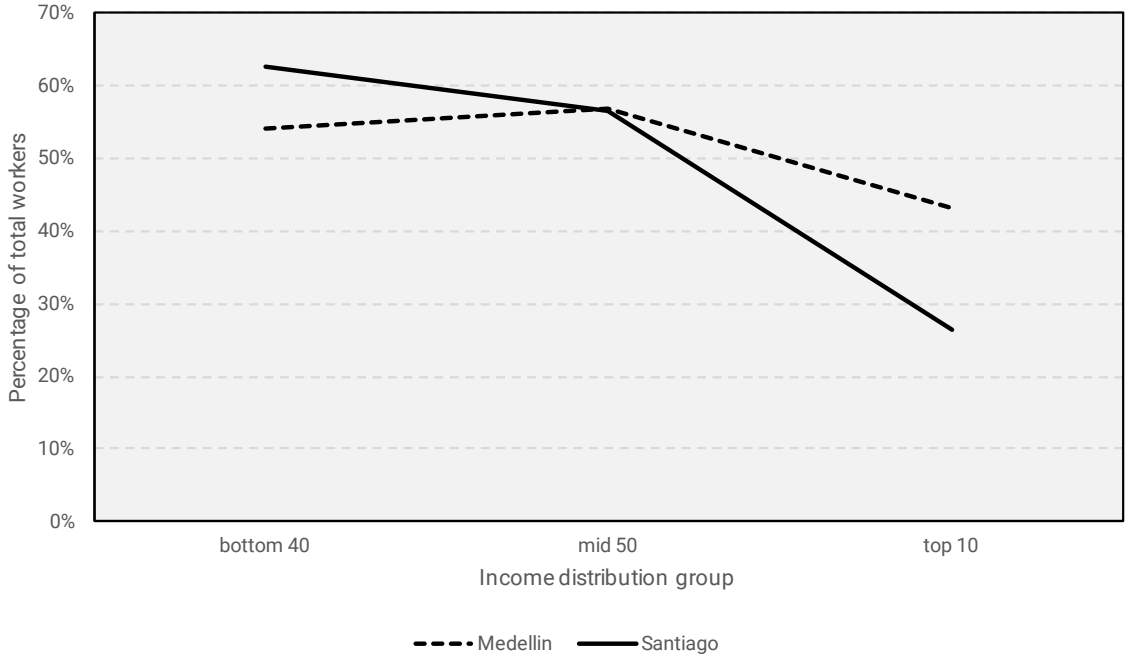

Figure 39. Share by income groups in aggregate public transport.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

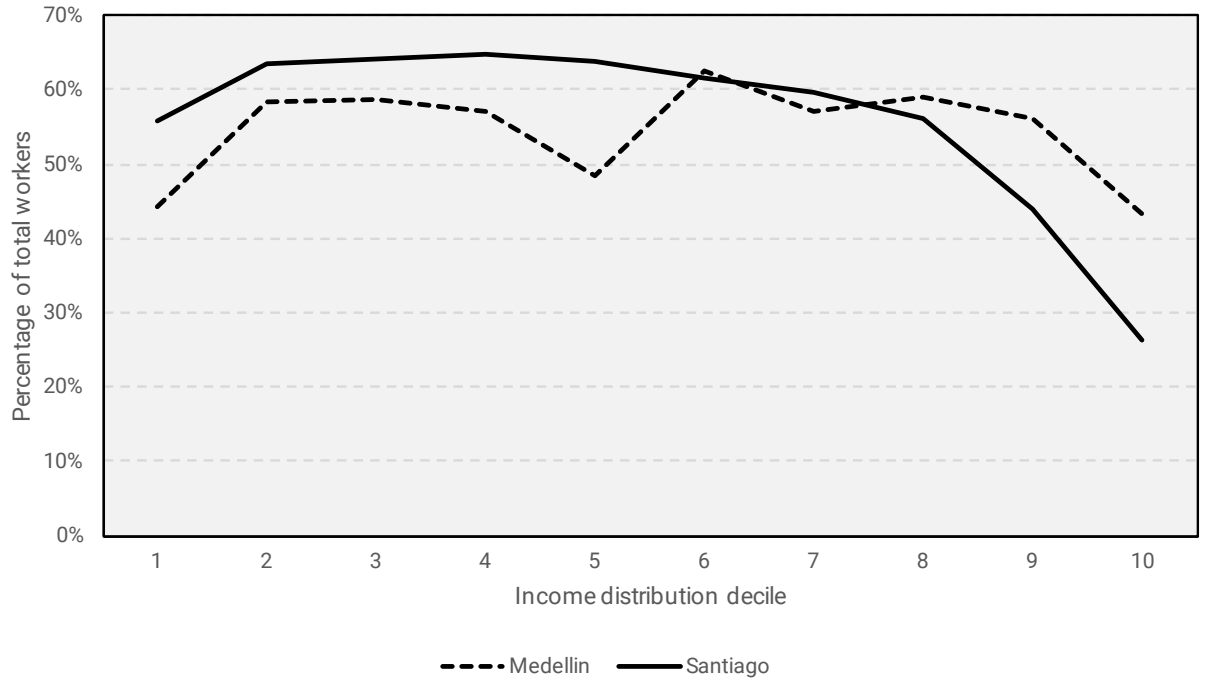

Figure 40. Share by income deciles in aggregate public transport.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

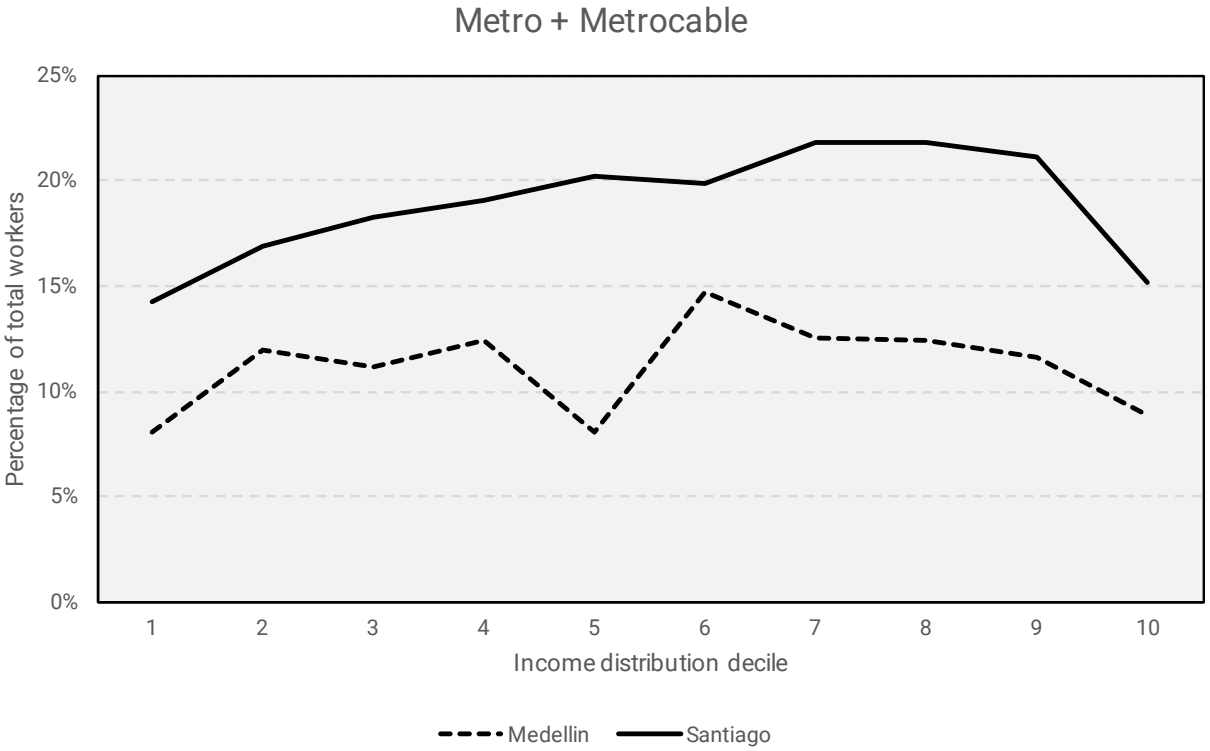

Figure 41. Share by income deciles in metro networks.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

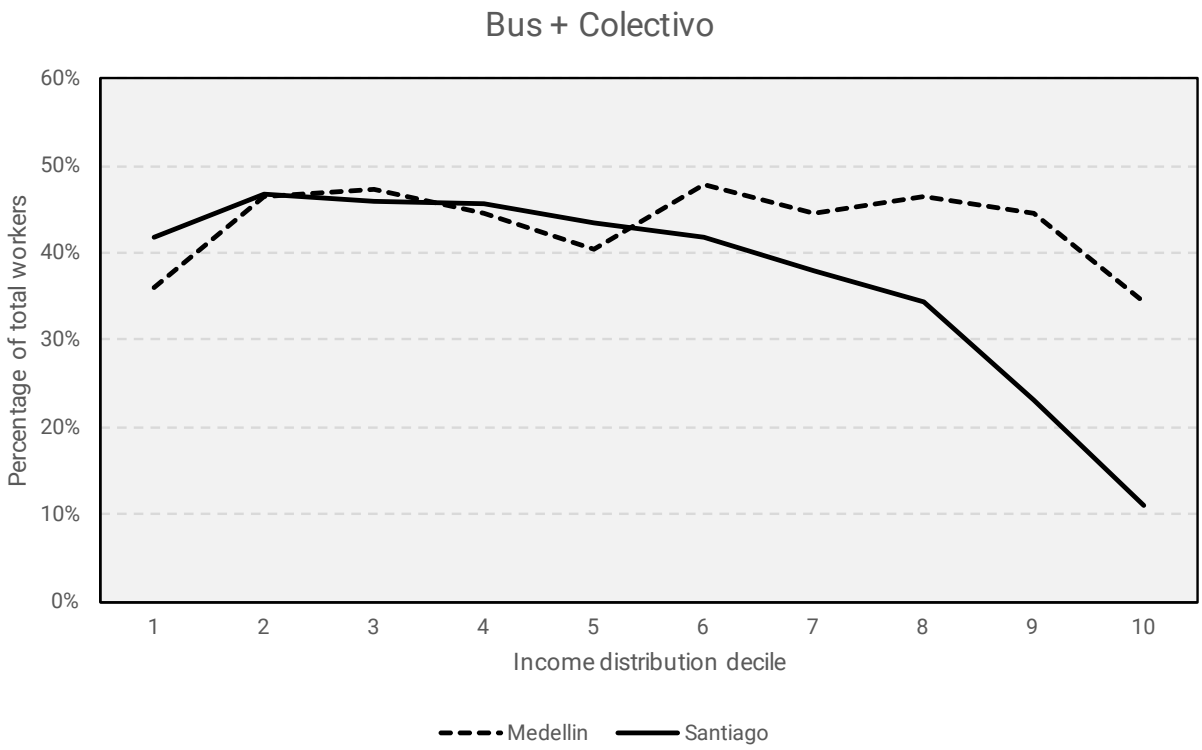

Figure 42. Share by income deciles in the bus fleet.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

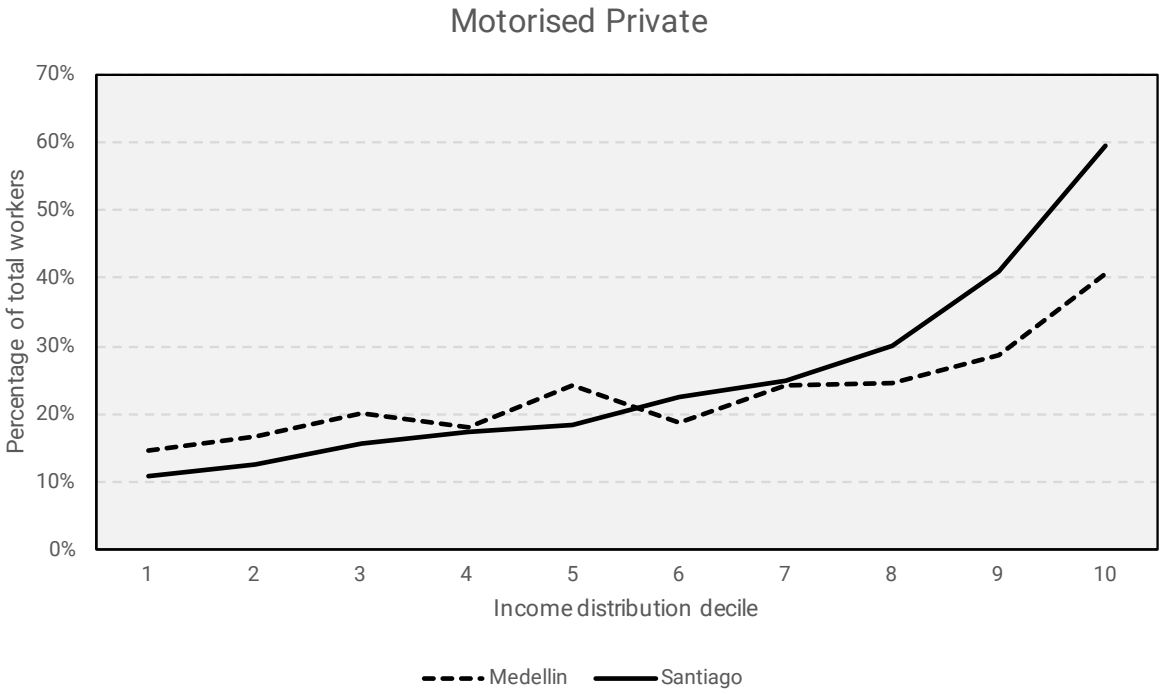

Figure 43. Share by income deciles in motorised private transport.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

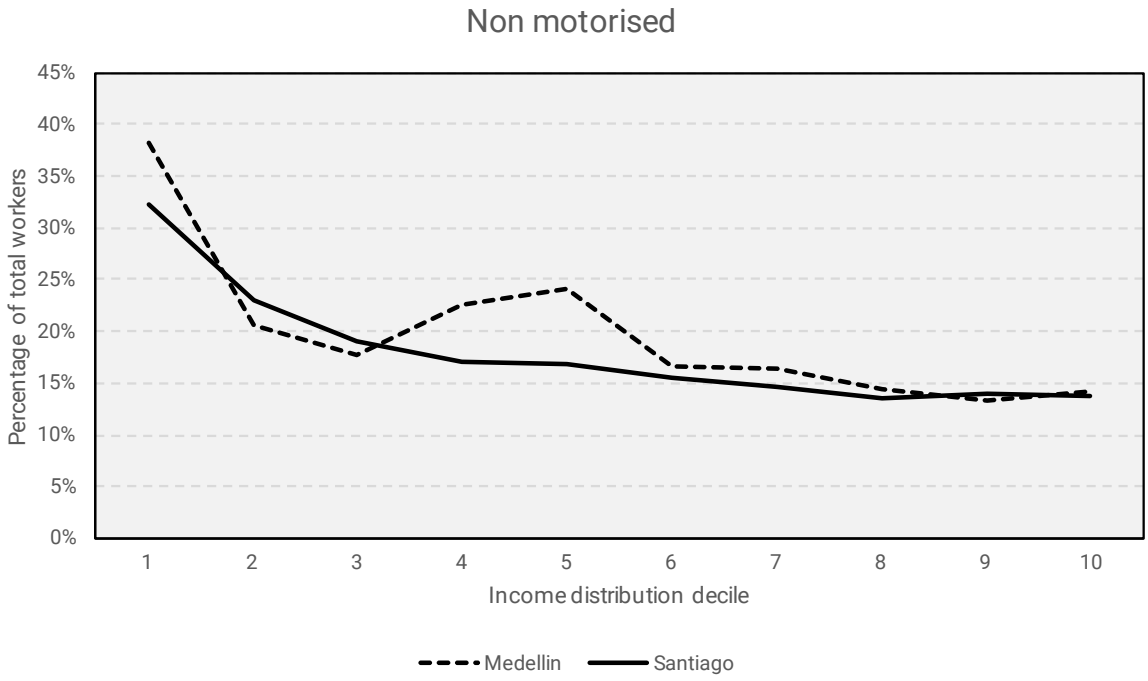

Figure 44. Share by income deciles in non motorised transport.

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

Moreover, a disaggregated account of income groups from Figure 40 shows that although there is an 'inverted U' shape in public transport commuters by decile in both cases, the slope of the tails is different in each city, and the curve moves to the left in Santiago compared to Medellin: in the former, the poor are more present and the rich are more absent in public transport than in the latter. As figure 41 illustrates, these divergences are not due to participation in the metro systems, but, as clearly seen in Figure 42, it is mostly due to a different use pattern of buses. On the one hand, the drop in use of buses in the poorest decile in Medellin is not as steep in Santiago. On the other hand, the continuous drop in use of buses from deciles 6 to 10 in Santiago does nor occur in Medellin, where a remarkably stable presence between 40 and 50 per cent can be observed between deciles 2 to 9, but similar drops to around 35 per cent can be seen in both deciles 1 and 10. Figures 43 and 44 show that the decrease in bus commuters between deciles 6 and 10 in Santiago is mirrored by an increase of use of private motorised vehicles. Conversely, the drop in bus commuters within the poorest decile in Medellin is matched with increases in both walking and use of private motorised vehicles.

Figures 45 and 46 allow us to complete the picture. They compare standardised values of commuter share for bus and metro systems within each city. The use of standardised values, also called standard scores or normal deviates, helps to compare how far from the mean are variations by decile in each mode. On the one hand, figure 10 shows clearly how the variance by deciles of shares within both metro and buses follows a similar path in Medellin. On the other hand, figure 11 shows how the metro network and buses follow almost opposite paths in Santiago. What these curves show is a metro network and bus fleet that has a similar presence of different income groups in Medellin, while, in contrast, presence of the poor is stronger in buses and weaker in the metro network in Santiago. This occurs in two similar contexts of integrated fares between metro and buses.

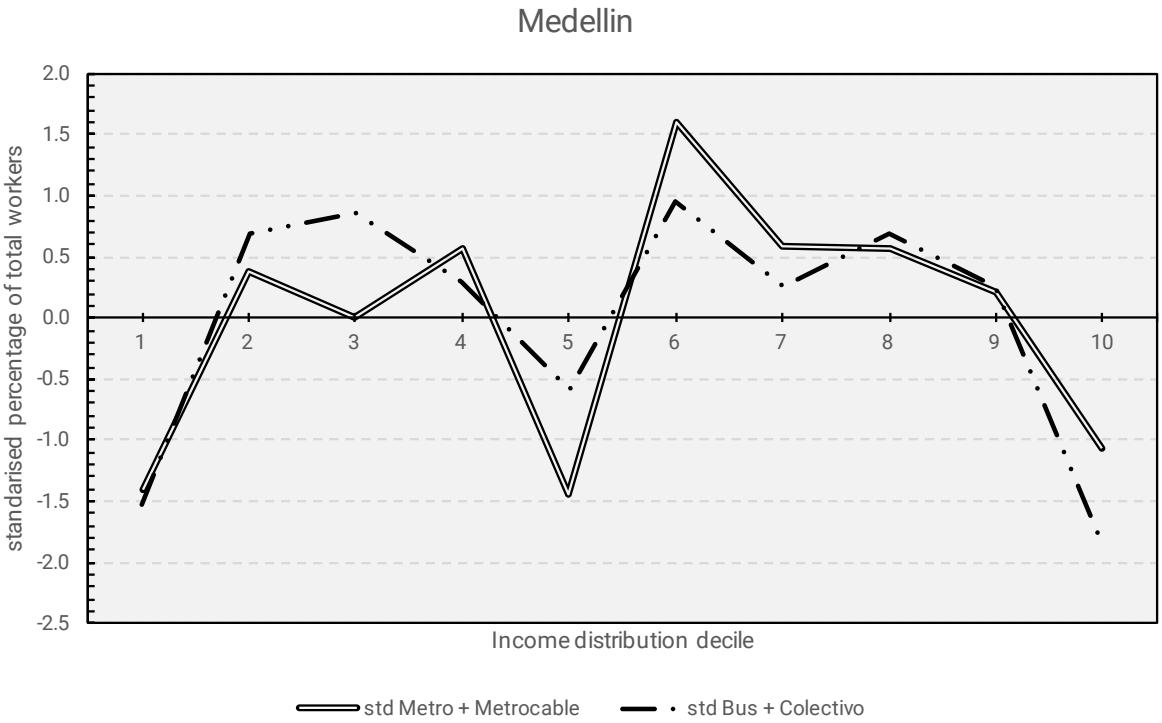

Figure 45. Standarised share by income deciles in metro and buses, Medellin

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

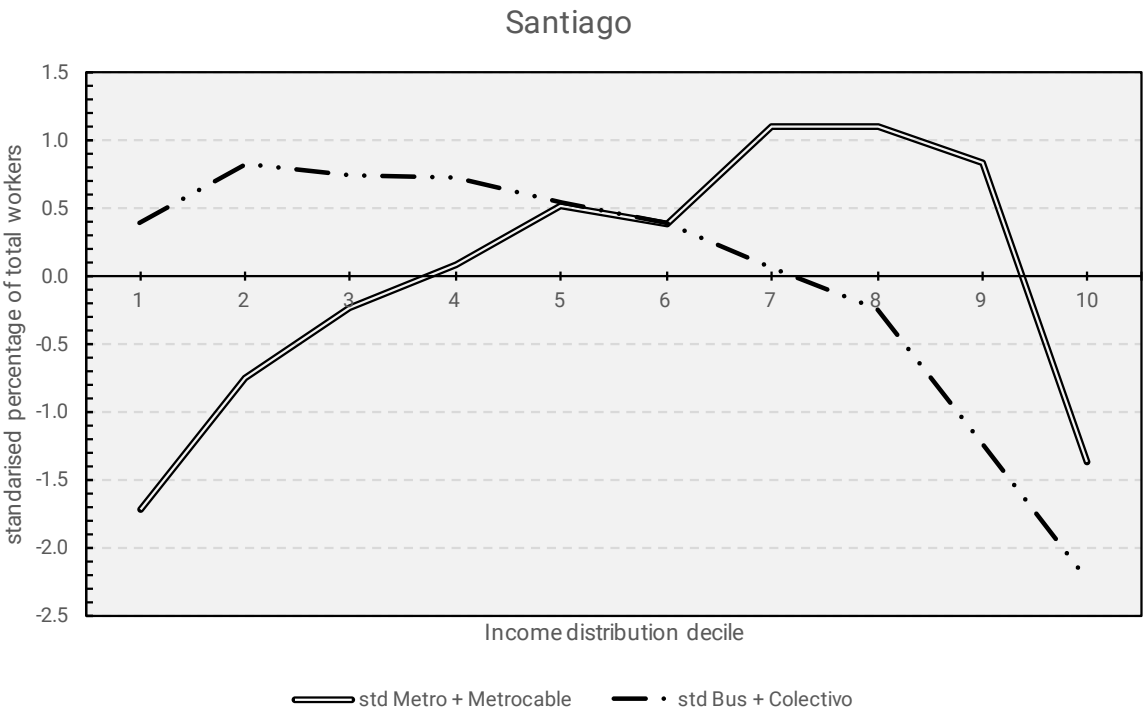

Figure 46. Standarised share by income deciles in metro and buses, Santiago

Source: The Author based on Ministerio de Desarrollo Social (2017) and Alcaldía de Medellín (2015).

7.5.2 Econometric model

I use logit regressions to observe likelihood of commuting on buses or metro among the three income groups from the Palma proposition, as well as in the bottom 10 per cent – as seen in the descriptive results, this group seems to behave differently from the rest 40 bottom percent, especially in Santiago. The models allow to observe these likelihoods after controlling for sex, age, distance to the workplace and accessibility of metro stations by borough of residence. Results are summarised in Table 37, showing marginal effects and significance by mode, city and income group.

In the case of the Metro, results are similar in sign and significance in both cities for the top 10, middle 50 and bottom 10 groups. Nevertheless, marginal effects tend to be higher in Santiago, meaning that differences in use of each mode for commuting to work between income groups are starker in the Chilean city. Yet, the biggest contrast is seen when observing the bottom 40 group. Being part of this group means to be significantly less likely to use the metro only in Santiago, but not in Medellin.

Contrasts are more remarkable in the case of buses. Being part of the top 10 group is associated to significant negative likelihood of using buses in both cities. However, the richest decile is three times less likely to use buses in Santiago than in Medellin. In contrast, the middle 50 is significantly and positively more likely to use buses in Medellin, but no significance is found for this group in Santiago. The opposite occurs in the bottom 40: being part of this group is significantly linked to higher likelihood of using buses in Santiago, but belonging to this group is not significant in Medellin. Finally, the most remarkable contrast is found in results for the bottom 10 group: although significance is high in both cities, the sign is the opposite. While likelihood of using buses is negative in Medellin, it is positive in Santiago.

Table 38. . Summary of logit regression results.

	Metro						Bus					
	Medellin			Santiago			Medellin			Santiago		
	dy/dx	Std. Err.	Sig.	dy/dx	Std. Err.	Sig.	dy/dx	Std. Err.	Sig.	dy/dx	Std. Err.	Sig.
top 10	**-0.022**	**(0.009)**	**	**-0.034**	**(0.012)**	***	**-0.104**	**(0.014)**	***	**-0.296**	**(0.023)**	***
Pseudo R^2	0.044			0.139			0.080			0.120		
Correctly classified	88.57%			82.96%			64.74%			71.35%		
middle 50	**0.012**	**(0.005)**	**	**0.025**	**(0.007)**	***	**0.038**	**(0.009)**	***	**-0.009**	**(0.010)**	
Pseudo R^2	0.043			0.139			0.078			0.100		
Correctly classified	88.57%			83.14%			64.52%			70.77%		
bottom 40	**-0.004**	**(0.006)**		**-0.015**	**(0.007)**	**	**0.008**	**(0.010)**		**0.100**	**(0.011)**	***
Pseudo R^2	0.043			0.138			0.077			0.108		
Correctly classified	88.57%			83.08%			63.30%			71.46%		
bottom 10	**-0.027**	**(0.010)**	***	**-0.047**	**(0.015)**	***	**-0.065**	**(0.017)**	***	**0.062**	**(0.020)**	***
Pseudo R^2	0.044			0.139			0.078			0.101		
Correctly classified	88.57%			83.02%			63.89%			71.01%		

dy/dx = average marginal effect
Observations / Medellin = 12,733 / Santiago = 8,576.
Control variables applied: sex, age, time-distance to workplace , km^2 within 700 mts to metro stations by borough of residence

*p-value ≤ 0.1; **p-value ≤ 0.05; ***p-value ≤ 0.01

Comparing the results within cities provides a similar result to what was observed using descriptive statistics. For instance, the significance and signs of each group for both metro and buses are similar in Medellin. In contrast, they only coincide in sign and significance for the top 10 group in Santiago, meaning that they tend to be absent from public transport – although much more strongly absent from buses than from the metro network –, but differ in signs and levels of significances in all the other groups.

Summarising, regression results show that what can be observed from the descriptive analysis holds after controlling for variables such as sex, age, distance to the workplace and accessibility of metro stations by borough of residence.

7.5.3 The role of formal and informal institutions: possibilities raised in interviews

The main finding from the quantitative analysis is that, although Santiago and Medellin have similar city-level income distributions and percentages of commuters using public transport as their main mode to get to work, income distribution within public transport is different. There are two main features. First, overall, the presence of different income groups within the public transport network is skewed towards the poor in Santiago compared to Medellin. The main difference has to do with a higher presence of the poorest of the poor in Santiago, and a less pronounced absence of the rich in Medellin. Second, the metro lines and the bus fleet compare to each other differently in the two cases regarding income groups. While both subsystems have similar income distributions in Medellin, the metro in Santiago is more used by middle and upper-middle income groups, whereas buses are strongly populated by the poor.

Are there institutional factors that can explain these differences? With institutional factors here I intend to go beyond those that can be embedded in the planning and decision-making process behind infrastructure investment. Obviously, supply of infrastructure and access to it is fundamental for the use of the metro networks, in a much more critical sense than buses, whose supply is more flexible. This is the reason why controls of time-distance and accessibility of metro stations by borough of residence were included in logit regressions.

Indeed, interviews allow us to focus in two main differences between public transport in Santiago and Medellin, both of which have to do with informal institutions, and can enrich the debate about institutions and transport. These are the role of fare evasion in Santiago, and a mixture between formalisation of informal providers in Medellin and attempts to use messages to promote certain behaviours in Medellin. Although the latter could be discussed under the light of existent institutionalist (Rye et al, 2018; Canitez, 2019) literature from transport studies, the former requires a wider theoretical framework that includes illegal institutions and distribution of benefits (Khan, 2010; Goodfellow, 2017).

Before going into detail, it is worth mentioning that the differences between cities shown by quantitative data is also supported by interviews. On the one hand, actors in Medellin see that socio economic groups are similarly represented in buses and the metro, with the exception of the richest people. As a union leader from Metro de Medellín told me, ‘the metro service in Medellín focuses on all income groups’. The same interviewee highlighted that the authorities were able to enforce a monopoly of mass transport in most areas of the city, in which people are forced to use integrated buses that work as feeders for metro lines and some BRTs. As a manager from a public transport company explained, ‘the metropolitan area has for 25 years had a concept of penetrating all social strata with the transport system’. All actors, however, recognise a very small participation among the rich. As a union leader puts it, the rich ‘do not use the mass system, precisely because it is massive’. A high ranked public official adds that ‘of course, the highest strata today do not want us to bring them metrocables and those sort of things’. However, there does not seem to be a perception of different participation of income groups when comparing buses and metro.

On the other hand, the difference between metro and buses is evident for all actors in Santiago: metro workers, bus drivers, metro managers, public officials and community leaders. While the metro is seen as socially mixed, buses are seen as a space in which the poor are more present than other groups. However, this socioeconomic differentiation between metro and buses in Santiago is accompanied by a particular role attributed to fare evasion in buses. Since its implementation in 2007, fare evasion has been considered by authorities as one of the main problems of Transantiago, the integrated public transport system (Ureta, 2014; Guarda et al, 2016; Troncoso and de Grange, 2017; Tamblay et al, 2017). A review of studies focusing on fare evasion, written by Delbosc and Currie (2018), stated that Santiago had the highest fare evasion in the world, 28 per cent of total trips, and that it is the case study more extensively covered by recent literature. In contrast, authorities from Medellin claim to have one of the lowest fare evasion rates in Colombia, reaching figures below one percent (El Tiempo, 2019).

A former Chilean cabinet minister explained it in a way that matches the quantitative data observed in Sections 7.5.1 and 7.5.2. 'If you look at the statistics in other countries, there is an inverted U curve, in the sense that when you have very low income you have fewer trips. Trips grow with income levels, but when you have too much income there are again fewer trips on public transport. Now, with evasion in Santiago, which makes transport to be almost free for many people, that does not necessarily happen that way. Not at least on buses. On the metro you have lower evasion, so you have to pay to travel. But on buses you can avoid paying: you evade'. A similar explanation was given by other actors, including managers from the Metro, which are not included here because of the limited available space.

As it becomes evident, there is an unresolved contradiction between years of official discourses attacking evasion as the main problem from Transantiago, and a recognition that, among the poorest of the poor, evasion enables trips that otherwise would be supressed. The 'public order' and 'social inclusion' dimensions of evasion are in constant tension in the voices of many interviewees. A community leader from *La Pincoya* explained it eloquently:

> 'every time *they* can *they* rise the fares… but buses are falling apart, drivers are exhausted, passengers are overwhelmed because of long trips in gigantic articulated buses where you can fit a bunch of people inside, and frequencies are low (…) I think that is the reason why nobody pays, what *they* have done is to punish people, charging fines, rising the fares even more, putting fences in the access of the buses… but that does not solve anything… people still doesn't pay'… *they* have included all types of turnstiles to control access… people already broke them. *They* try to use brute measures, punish people… instead of saying you know what, guys? We are going to improve the service, buses will be bright and shiny, and fares will be lower (…) or… you could still charge fines, but… at least improve the service!'

This leader was emphatic to point that 'they' are the elites: government authorities and private concessionaires. Part of the measures that authorities have implemented to control fare evasion, include the use of the police force to control buses. They stop buses in peak hours, when people is commuting to work. A tension that goes beyond transport operation becomes evident. People feel targeted and punished. As the same community leader told me, 'they use policemen to control us… I got a fine the other day! I was doing a short trip because of my job and I thought, why should I pay?'. He then explains: 'the policemen were proud of how many fines they passed… I told one of them "you have a lot", and he answered "yes, and it's just the morning. I have all day long" … so they even defy people… they were counting out loud how many fine tickets they had, and people around were sad enough already…'. He concludes that the attitude

among users ends up being far from collaborative: ‘we feel so punished, we are so overwhelmed… that the only thing we want is to destroy turnstiles… if the bus is falling apart, let’s make it even worse!’.

The perception of a divide between ‘us’ and ‘them’ is strongly present in the discourse regarding buses. This applies not only to users, but also to drivers. On the one hand, in the voice of another community leader, the perception is that ‘the system is fed by people with low or middle income, because we have no other alternatives for transport (…) in richer areas, is people from *here* that goes to work *there*… buses are also scarce in those neighbourhoods, because *they* know that people from *there* does not use buses… but who needs buses *there* are those who arrive to work… *they* do not provide a good service *there* either… because *they* know that the service is for *us*, for those from poorer areas’. On the other hand, bus drivers also complained that residents from rich areas do not only reject bus lines, but also the infrastructure that they need to work under basic conditions. An emblematic case is the resistance by rich municipalities, where bus lines end, to allow installation of sanitary services for the drivers. The latter claim to lack proper spaces for going to the toilet or eating, let alone have a proper rest between shifts.

Drivers and users feel similarly abused on buses. If fare evasion is a key problem of Transantiago, bus drivers are straight forward in saying that their job is to drive and not to risk their lives arguing with angry masses. As a union leader from Transantiago told me, measures planned by companies and authorities do not work: turnstiles are located in the first out of four doors. During peak hours, the stop is full with people trying to get to their work or home, and the turnstile delays boarding. ‘They open all the doors and get on the bus’. Drivers state that although they see paying fares as a civic obligation, they will not confront people because if they do so, the risk of being abused is high. As another union leader told me, ‘the drivers that bother are the ones that end in hospital’.

This risk of abuse does not keep drivers from sympathising with users. They share the socio economic explanation for evasion, which ‘is now part of the family budgets. A culture of evasion was generated. (…) The money that they would spend on fares… they need it… maybe levelling income, things would be different… but imagine a family of four people earning CLP 500,000 a month… if I can save CLP 70,000 per person… of course I won’t pay’. Other union leader concludes: ‘everybody has access to buses, because paying or not paying, people get on buses anyway’ (…) ‘if somebody pays, the rest will cheer… congratulations, you are the only one!’.

Given the conditions of the labour market, specially wages, the extension of the city, the location of housing for the poorest population in the most distant land, and concentration of jobs in richer areas (Rodriguez, 2007; Figueroa et al, 2017), different actors from Santiago see evasion as having a fundamental role in making working viable for the poorest of the poor. This is how fare evasion emerges as an informal institution that is a fundamental part of how Transantiago operates, as a mechanism which oddly equilibrates interests from different actors.

A very different relationship with informality can be seen in Medellin, one which has to do with the formalisation of informal bus providers, and with an active effort to promote behaviours associated with cultural values.

In Santiago, it was the capillary fabric in the periphery of the city which was most affected by the top-down ‘big bang’ of Transantiago, in 2007. Before that moment, a complex network of

316 lines was based on 119 operators, conformed by bus-owner associations, driver unions, and small companies (Díaz et al, 2004). Despite protests of the old operators, who responded with strikes and blockades (Díaz et al, 2004), the new system was later divided into seven business units, operated by large national and transnational companies (Directorio de Transporte de Santiago, 2018).

In Medellin, in contrast, recognition and formalisation of local informal providers enabled a special responsiveness to how local services should operate at the lowest scale. As a manager from a public transport provider in Medellín told me, they found a way to allow 'those people or companies that have a good knowledge of the territory to be those defining the routes'. Furthermore, this local openness has a role supporting the establishment of the rule of law in the city. The periphery of Medellin was one of the main stages of violence in the times of drug cartels, during the 1980s, 1990s and early 2000s (Dávila, 2012). Even today, attacks to buses are part of clashes between criminal gangs and public authorities. As a leader from a bus drivers' union told me 'if public transport arrived to a certain part of a borough, is because criminals allowed it. And if they don't allow the public service to reach a certain area, there is a reason for it'. The incorporation of informal transport providers, who are also local entrepreneurs, are part of a broader process of negotiation and power balancing which aims to increase the presence of legitimised activities over criminal organisations.

This legitimation strategy also includes the idea of extending the 'Metro Culture' from the metro to the buses. Managers from the transport system in Medellin see this culture as the main reason why evasion is almost inexistent (El Tiempo, 2019). As a manager from Metro told me, Cultura Metro 'is a civic behaviour which has been voluntarily adopted by citizens'. This includes a permanent reinforcement, via audio and visual messages that are constantly reaching users. As a community leader told me 'Cultura Metro works… it is about constant, constant messages… it is like a method of Neuro-Linguistic Programming… they are all day long telling you "don't drink water on the Metro", "don't eat on the metro", "keep the Metro clean" … you hear those messages all day long, everyday, until you start saying them by yourself… or you sing the songs they use in the advertisements'.

This is how two institutional aspects emerge in each city, both linked to informality and fare evasion. In the case of Santiago, it is the permanent role of fare evasion as an illegal institution that allows to balance tensions between different actors, and to make working possible for the poorest of the poor. In the case of Medellin, it is formalisation of formerly informal transport providers, and their incorporation into the core of 'Cultura Metro', what emerges as keys to both service quality and legitimisation of legal activities to confront criminal organisations in the outskirts of the city.

7.6 Discussion

As we can see, the relationship with illegality emerges as a relevant element in institutional analysis, in a way that can enrich theoretical approaches to institutions and transport (such as those by Rye et al, 2018, and Canitez, 2019). While fare evasion, an illegal doing, is a relevant informal institution in Transantiago, formalisation of previously informal transport providers is motivated by a broader strategy to reinforce rule of law against territorial control by criminal organisations in Medellin.

In practice, fare enforcement mechanisms are in the centre of the institutional differences between both cases, but they also point to a broader role of public transport in the social

contract. Fare evasion might 'open the door' of public transport to the poorest of the poor in Santiago, by letting them ride on buses. However, at the same time, part of what can be observed in Santiago is an acceptance of poor quality of bus services. It is worth asking whether the lower presence of the richest groups on buses in Santiago, compared to Medellin, has to do with fare evasion and tacit agreements on how buses operate. An inclusiveness which is achieved through an absence of 'rule of law' probably brings a reinforcement, among the rich, of the rejection of the kind of interactions to which they would be exposed on buses. They might use the metro, but not the buses. A strong notion of 'order' as part of the history of the metro system in Santiago has recently been discussed by transport historians (Castillo et al, 2017). It would be extremely difficult to assign a causal direction in this link between enforcement or lack of order, and presence or absence of the rich. They most likely reinforce each other in a complex and continuous interplay.

In contrast, the same income distribution of the metro lines and buses in Medellin is paired with an attempt to implement the same 'Cultura Metro' in both components of the integrated public transport system. 'Good behaviour' and collective vigilance are constantly reinforced by authorities in Medellin, explicitly attempting to reproduce conditions from the metro on the buses that are part of the integrated fare system. An analogue question emerges to the one inspired by fare evasion in Santiago: is this effort to reinforce an experience of civility and control on the buses something that at the same time excludes the poorest of the poor and attracts more workers from richer groups?

A hypothesis can be stablished on the basis of findings from this study. Although use of public transport among income groups tend to follow an inverted-U trend – that is to say, use increases among middle income groups but drops among the tails (as previously studied by Serebrisky et al, 2009) – there are institutional factors that can influence how much the poorest and richest ride on buses and metros. In the case of the poor, alleviation of the fare burden – which in Santiago occurs via evasion – can integrate more people. In the case of the rich, reinforcement of order, control and safety can persuade more people to use public transport instead of private motorised vehicles. In Santiago and Medellin, these options take place in the form of a trade-off between social order and inclusion. However, further research would be needed to establish whether this trade-off is real and unavoidable.

Finally, it is worth reflecting on the use of the Palma proposition (Cobham et al, 2016) and the groups observed by Palma (2011, 2014) as a departing point for the analysis. Firstly, it is clear that looking at income distribution within transport modes, beyond aggregate figures, provides insightful new perspectives on socio-technical systems such as public transport networks. Secondly, it is evident that income distribution does not only affect individual travel decisions, but is embedded in power balances and institutions that are part of these socio-technical systems. Thirdly, it seems that although using the segments discussed by Palma opens the debate about different groups – especially the richest and the poorest –, a more detailed look is required to understand dynamics happening on buses and metros. For instance, in this analysis, it is the bottom poorest decile, more than the aggregate bottom 40, which offers the most insightful findings, along with the richest decile. Nevertheless, it seems that a more relational view of socio-economic issues in transport, one which does not only look at the poor but also at the rich, can bring valuable new elements to the table.

7.7 Conclusions

The new emphasis on income inequality instead of just poverty, found in part of mainstream economics, can be a useful lens to approach transport systems. This research illustrates why a look into different income groups can illustrate relevant dynamics regarding how public transport operates. However, the link between income distribution and adoption of transport modes is not just a matter of consumer preferences or individual ability-to-pay. It is fundamentally mediated by institutions, which are rooted in balances of power.

The fields of institutional economics and political economy provide useful tools to incorporate institutions into the analysis of the link between income distribution and transport. However, efforts to integrate these tools in transport studies have so far been limited in their view on informal institutions. The political settlements approach is used here as a way to expand our analytical capacities for paying attention to illegal institutions and formalisation of informal transport providers.

Evidence found here can be used to hypothesise that there could be trade-offs between the presence of the poor and the rich in public transport. More research should be needed to understand how possible socio-economic integration is. Also, more case studies could help to refine these first observations, while, of course, much more complex and extensive data collection would be needed to arrive to conclusions that can be applicable to transport systems in general. However, this research provides novel elements that deserve attention in further studies on the link between income distribution and public transport.

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General Conclusions

This research included a thorough review of existent peer-reviewed literature, econometric modelling of aggregate country and borough level data, and a mixed-methods analysis of two specific cases. I provided evidence of the negative influence of income inequality on network technology adoption in regards to recycling, rail passenger transport and broadband internet. While the literature offers evidence of this link for broadband, results are novel in the cases of recycling and railway passenger transport. In these two latter cases, the income shares of specific groups within the bottom 40 per cent poorest population matter more than the overall income distribution.

Inequality can be a barrier for network technology adoption because of both demand-side and supply-side causal mechanisms. In the case of transport, the evidence suggests the idea that inequality is a proxy of power balances that determine institutional supply-side definitions of how transport regimes operate. In the case of recycling and broadband internet, demand-side or consumer-based explanations seem to be more plausible. In any case, be it because of supply-side decisions taken in favour of the rich, or because income distribution affecting aggregate ability-to-pay among consumers, inequality is a barrier for sustainable technology adoption within network industry sectors. Challenges regarding reduction of inequality and Climate Action, as included in the Sustainable Development Goals, need to be confronted in an integrated way.

Income generation also usually conditions individual or household level adoption of recycling, railway passenger transport and broadband internet, as well as differences in aggregates at a borough level within cities. However, the extent to which this relationship holds depends on institutional factors. The mixed-methods analysis of two specific cases allowed to discuss elements that should be considered when interrogating these institutional factors in the context of highly income-unequal cities.

In the case of recycling, for instance, case-studies from Santiago and Medellin, from the Global South, were complemented by a comparison of Barcelona and London, from the Global North. The four cases show that institutions can make recycling rates to depend on or to decouple from income. On the one hand, waste management funding regimes can be regressive, neutral or progressive in terms of income distribution. On the other hand, informal institutions such as corruption, as well as formalisation of waste pickers, can lead to different patterns of separate collection in cities. If demand-side causal mechanisms have to do with ability to pay for quality recyclable products, their influence on who ends up participating in recycling will be mediated by supply-side factors, which can be subject of policy decisions.

Furthermore, the analysis of railway passenger transport in Medellin and Santiago confirms a ‘inverted-U’ relationship between income generation and likelihood of ridership, as some of the theory predicts. However, the curve can be skewed according to institutional arrangements that are part of transport regimes in each city. Since metro systems are fare-integrated with bus fleets in the two cities, these institutional factors also affect how income determines adoption between both public transport sub-modes. The detailed account of these two cases provides illustrations of the role that informal institutions such as fare evasion in Santiago and effects of behavioural campaigns in Medellin can be playing in how the inverted-U skews towards the rich or the poor. Another element that is common to the transport and recycling sectors is the presence of policies to formalise informal providers, which in Medellin have been crucial to generate socially-mixed adoption of recycling and public transport.

Finally, although internet studies see adoption as an eminently demand-based phenomenon, according to which income tends to be linearly linked to connectedness, the case-studies provide elements to expect an influence of both local and informal institutions. Tax exemption policies and strong presence of local public service provision seem to lessen the influence of income generation on likelihood of adopting household broadband internet in Medellin. In turn, an informal enforcement of redlining by big telecommunication companies seems to disproportionally affect the 20 poorest percent of the population in Santiago, regardless of the ability and willingness to pay for broadband services among households.

Overall, the detailed case-studies provide elements that should be incorporated into an institutionalist political economy approach to network industries. On the one hand, a role of informal institutions can be found in the three analysed sectors. One fundamental conclusion is the usefulness of having a relational approach to informality, and of avoiding just paying attention to 'informality of the poor'. The examples of redlining in telecommunications, and corruption in waste management, should not be taken as isolated cases, but as informal institutions that are often structural parts of the functioning of each sector.

In this sense, institutionally produced network disadvantage should be considered as a phenomenon that is most likely present, in diverse forms, all across the globe. This means that formal and informal institutions are determining exclusion of segments of the population from adoption of network technologies. These institutions emerge from complex interactions between national political settlements and local service regimes within cities. However, although it is possible to observe many ways by which network disadvantage is induced by local institutional factors, intervening through policy and new political pacts is also proven to be possible in order to include new groups in the emerging dimensions of connectivity.

This institutionally produced network disadvantage is not neutral, in two ways. On the one hand, the evidence from this research shows that it tends to target specific groups within the bottom 40 per cent poorest population. This is shown both by the country level analysis of adoption of recycling and railway passenger transport, and by the case-studies. On the other hand, institutional factors driving network disadvantage are supported by political settlements that favour the rich. Existent formal and informal institutions are sustainable when they distribute benefits according to the balance of power. Particularly in the cases of redlining in telecommunications and corruption in waste management, informal institutions that marginalise the poor are implemented as ways to benefit the super rich trough securing profit rates and diminishing financial risks. In the case of transport, the virtual absence of the 10 richest per cent from public transport resonates with the correlation of income concentration by the same group and presence of private-oriented transport regimes, as shown by national-level data. Institutionally produced network disadvantage must be understood as a phenomenon that involves both the rich and the poor: network service regimes are a reflection of the balance of power between them.

Results from this research have the limitation of available OECD and World Bank quantitative data in Part I, and a lack of time to conduct additional interviews beyond the two case-study cities analysed in Part II. However, I believe they are robust enough to open new discussions, first, about the role if income inequality in adoption of sustainable technologies within network industry sectors, and second, to point to the importance of incorporating institutionalist political economy perspectives instead of purely neoclassical and demand-based modelling.

Opening the box of institutional factors means, of course, also allowing complexity to permeate all our analyses. I am deeply interested in continuing learning more about the role of formal and informal institutions as mediators between income inequality and network technology adoption. The elements that emerge from mixed-method case studies could be further analysed in broader samples if data were available. Although it might seem as a difficult enterprise, the increasing attention to institutions as a key for development, and a rebirth of political economy scholarship in recent years, make me feel hopeful about findings that could be made in the future.

Particularly in the Global South, imagining new futures requires to comprehend how interconnectedness is unfolding in cities and across the world. As explained in several parts of this thesis, the Sustainable Development Goals already include challenges that deeply involve network industries. I expect to have illustrated the importance of considering inequality as a fundamental problem for that sustainable development. Much effort remains to be spent in order to avoid the spread of a connectedness that reproduces, or even increases, existing inequalities.

Appendix: Relevant Definitions

Circular Economy

The Circular Economy is a term that is mostly used in environmental science and industrial ecology. It refers to an economic system that increases efficiency of resource use, by adopting production patterns that close the loop in terms of primary resources, manufacture, commercialisation, use and waste disposal. A fully closed loop would involve less consumption of natural resources, and fully recycle or re-use of materials, without incineration or landfill disposal of waste (see Ghisellini et al, 2016; Geissdoerfer et al, 2017).

Climate Action

Climate Action comes from the discussion in the fields of environmental policy and urban planning. It is usually named as Climate Action Plans that are generated in a country, a region or a city. It refers to some form of identifiable action that it is considered to produce an advance towards mitigation of the effects of the Climate Crisis, or reduction of greenhouse emissions (see Bassett and Shandas, 2010; Ribot, 2011).

Climate Crisis

Crimate Crisis has become a new term used to replace the previously extended notion of Climate Change. This evolution of the sense of urgency - to refer to the same phenomenon - has significant presence in the field of social environmental science and environmental studies, due to new evidence of the effects of planetary warming and the lack of effective policies to reduce temperature increase (see Crist, 2007; Archer and Rahmstorf, 2010).

Environmental Technologies

By environmental technologies, ecological economists refer to technologies that are associated to environmental policy (i.e. pollution abatement, recycling, emission reduction). Technology is named in this study in the context of adoption processes, which mean the introduction of a previously inexistent product or service into consumption by users (Magnani, 2000; Vona and Patriarca, 2011).

Sustainibility and sustainable change

Sustainability is understood here as a quality inherent to sustainable development, as first defined by Brundtland (1987): ‘sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs’. Sustainable change is thus significant change, predominantly in the form of technology adoption and policy, that entails a significant advance towards sustainability.

Sustainable network technologies

Sustainable network technologies refer to technologies that, when adopted, are considered as a significant advance towards sustainability in a given sector. The difference between sustainable

technology and environmental technology is that the former involves other dimensions of sustainability, and not just the environmental dimension. Sustainable network technologies are sustainable technologies that are adopted within the network industry sectors: telecommunications, transport, energy, water, waste. In this work, 'sustainable network technologies' are those technologies that, if adopted in the network industry sectors, involve progress in one of the Sustainable Development Goals (United Nations, 2016).

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