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How commuting influences urban economies and the environment:

A Commuting Satellite Account applied to the Lisbon Metropolitan Area

PhD Thesis in Sustainable Energy Systems, supervised by Professor Pedro Ramos and Professor Luis Cruz, submitted to the Department of Mechanical Engineering, Faculty of Sciences and Technology of the University of Coimbra

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UNIVERSIDADE DE COIMBRA

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PhD Thesis in *Sustainable Energy Systems*, University of Coimbra

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"If I came this far, it is by standing on the shoulders of giants."
Isaac Newton, adapted

"One's destination is never a place, but a new way of seeing things."
Henry Miller

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Abstract

The world is becoming more and more urbanized. The growth of megacities has been intrinsically linked with increasing sprawling that compels millions of workers to commute. Commuting has often been either neglected or simply viewed as a byproduct of the markets operating and individual choices. However, as a mass phenomenon, commuting has benefits and costs well beyond those supported by each individual, which further shape urban and regional economies.

This PhD dissertation sets out a proposal for an innovative Commuting Satellite Account (CSA). This framework integrates into a Multi-Regional Input-Output (MRIO) model five main elements that arise from commuting: (1) commuting flows are represented in a specific geographic and economic context; (2) commuting influences the regional distribution of income; (3) commuting affects household consumption structures; (4) commuting is intrinsically linked with the rental prices of housing and business premises; and, (5) commuting is a major cause of energy consumption and CO_2 emissions.

To assess commuting opportunity costs, the CSA extension to the MRIO framework is applied, as an illustrative example, to the Lisbon Metropolitan Area. Two hypothetical extreme scenarios are considered, both assuming that commuters change their status to non-commuters: one by considering the change of their place of residence to the municipality where they work; and the other one by assuming that the corresponding production activities are displaced to the suburbs. The CSA is also empirically tested in a more 'realistic' case, providing important insights into a scenario of commuting reduction resulting from a strategy of urban recentralization.

The comprehensive analysis of these applications indicates dichotomous, yet complementary, conclusions: commuting, by itself, induces significant economic, social and environmental costs, although commuting, as one of the many elements associated with the agglomeration phenomenon, is undoubtedly linked to increasing productivity and economic growth. To conclude, this work discusses the adoption of policy oriented recommendations, either through actual urban planning application, or by resorting to land-use and transport policy instruments, which might contribute to refrain sprawling in metropolitan regions and intervene to achieve the broader aims of economic growth, well-being and a more sustainable urban environment.

Keywords: Commuting, Environmental Impacts, Metropolitan Areas, Multi-Regional Input-Output, Satellite Account, Travel Patterns, Urban Policy, Urban Sprawling.

Resumo

O mundo está a ficar cada vez mais urbanizado. O crescimento de megacidades está intrinsecamente ligado à sua expansão territorial, obrigando milhões de trabalhadores a efetuarem deslocações pendulares. Esta atividade tem sido geralmente ignorada ou considerada apenas como um resultado do funcionamento do mercado e das escolhas dos indivíduos. No entanto, sendo um fenómeno generalizado, o volume diário de deslocações pendulares tem benefícios e custos que vão para além dos suportados pelos indivíduos, contribuindo para moldar as economias urbanas e regionais.

Esta Dissertação de Doutoramento propõe uma Conta Satélite de *Commuting* (CSC). Este elemento inovador é integrado num modelo Multi-Regional de Input-Output (MRIO), incorporando cinco componentes ligadas às deslocações pendulares: (1) os fluxos pendulares são representados num contexto geográfico e económico específico; (2) as deslocações pendulares influenciam a distribuição regional de rendimento; (3) as deslocações pendulares afetam a estrutura de consumo das famílias; (4) as deslocações pendulares estão intimamente relacionadas com o valor das rendas de habitação e de escritórios e outros edifícios usados pelas empresas; e, (5) as deslocações pendulares estão na origem de elevados níveis de consumo de energia e de emissões de CO_2.

Para estimar os custos de oportunidade das deslocações pendulares, aplica-se a CSC à Área Metropolitana de Lisboa. Para o efeito consideram-se dois cenários (extremos) hipotéticos, que apontam o fim das deslocações pendulares: um admite a alteração do local de residência dos trabalhadores para o município onde trabalham; o outro assume que uma parte da atividade produtiva é deslocada para a periferia, onde os trabalhadores residem. A CSC é também testada num exercício mais 'realista', permitindo avaliar potenciais impactos associados a situações em que as deslocações pendulares se reduzam como resultado da aplicação de uma estratégia de centralização urbana. A análise detalhada dos resultados deste trabalho aponta para conclusões dicotómicas, ainda que complementares: as deslocações pendulares, por si, induzem importantes custos económicos, sociais e ambientais; no entanto, as deslocações pendulares, enquanto elemento associado à aglomeração urbana, estão relacionadas com o aumento da produtividade e o crescimento económico. Para concluir, este trabalho discute a implementação de políticas de planeamento urbano e o uso de instrumentos de política do solo e de transportes. Estas soluções poderão contribuir para conter a dispersão territorial das cidades e concretizar objetivos de crescimento económico, bem-estar e de um melhor e mais sustentável ambiente urbano.

Palavras-chave: Contas Satélite; Deslocações Pendulares, Expansão Urbana; Impactos Ambientais; Multi-Regional Input-Output; Padrões de Mobilidade; Planeamento Urbano

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“Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world,
and all there ever will be to know
and understand.”

Albert Einstein, 1929

CHAPTER 1 – INTRODUCTION

1.1. Research Motivation

The world is becoming more and more urbanized. Nowadays, cities are the home of more than 50% of the world’s population. This number is expected to rise to 70% by 2050 (UN, 2014). Urbanization has several consequences that are the subject of strong debate, full of controversial and antagonistic opinions, about the (dis)advantages of this phenomenon. Despite such intense and passionate debate, it seems unquestionable that given the recent progress towards a borderless world economy, cities have been enhancing their importance as the basic units of economic systems (Fujita, 1999). Cities are engines of national and global growth, accounting for around 80% of global economic output. The world’s 150 largest metropolitan economies produce 41% of global GDP with only 14% of global population (Floater et al., 2014). The viability of megacities and large metropolitan areas has been intrinsically associated with the admirable technological and societal advances that allow humans to live together in confined buildings or territories[1] and cities to sprawl for several miles while still providing basic services (e.g. water,

[1] When the Chrysler Building was built in 1930 in New York, USA, it was the tallest building in the world at 319 meters. Now, there are 30 buildings in the world that are taller than the Chrysler Building.

electricity, waste collection). Indeed, this reality is only possible because of lower transportation costs, which allow people to travel larger distances within urban areas and commute longer distances daily between their home and work.

Commuting has often been "either neglected or typically seen as the market working just fine" (Ewing, 1997). In a more 'traditional' economic view, if commuting is seen as the cost of time and distance, then commuting is only an option if it is compensated by either a rewarding job or by additional welfare gained from a pleasant living environment. Accordingly, commuting is the consequence of an equilibrium state between the housing and labor market, in which individuals' utility (or well-being) is maximized given all of the combinations of alternatives in these two markets.[2] This conclusion, which is based on a more individualistic approach, is not consensual among economists and other social scientists, as they question the possibility of individuals making rationale choices associated with commuting (Hamilton and Röell, 1982; Stutzer and Frey, 2008).

Additionally, it is also possible to address the commuting phenomenon as a social and widespread activity with an influence that goes far beyond the strict analysis of each individual's choice and well-being. As with any mass phenomenon, the benefits and costs supported by each individual can be critically different from those supported by the society as a whole. Thus, commuting is a means of providing a vital input (workforce) into production activities and is simultaneously a mandatory routine for working households to secure their income. Indeed, it is indisputable that the growth of commuting has made a critical contribution to stretching urban areas' boundaries and to exacerbating energy consumption and greenhouse gas emissions. Furthermore, commuting plays a central role in regional and urban economies as it shapes the social, economic and environmental dimensions of metropolitan areas. In short, it requires the application of more holistic approaches.

This PhD dissertation addresses the topic of commuting by proposing a methodology suitable for assessing its multi-dimensional impacts. For this, a set of interactions are characterized by gathering and systematizing several statistical data and incorporating such information into a Multi-Regional Input-Output (MRIO) framework. This modeling

[2] The efficient allocation of resources has been studied, based on the conviction set forth by Wildasin (1987: 1136) that "migratory flows will arbitrage away any utility differentials among jurisdictions. Therefore, it is appropriate to impose equal utilities as a constraint at the outset, and to ask what allocation of resources will maximize the common level of utility for all households."

framework can accurately describe the interactions between industries and households located in specific regional contexts within metropolitan areas.

Then, an additional set of transformations is proposed to perform a more realistic assessment of commuting. These specific transformations, incorporated together, are the core of the proposed ‘Commuting Satellite Account’ (CSA). This is an extension of MRIO models that embrace five critical dimensions of commuting, namely:

(1) commuting flows are represented in a specific geographic and economic context;

(2) commuting influences the regional distribution of income;

(3) commuting affects household consumption structures;

(4) commuting is intrinsically linked with the rental prices of housing and business premises;

(5) commuting is a major cause of energy consumption and CO_2 emissions.

These dimensions are widely acknowledged in the literature but the design of a modeling framework capable of incorporating all of them within the economic context of a specific region is still missing from regional and urban economic studies. Indeed, the design of this model preceded the major goal and motivation of this work: assessing the multi-dimensional impacts of commuting in metropolitan areas through the application of the CSA framework in a real world case study.

Accordingly, this model is applied to the Lisbon Metropolitan Area (LMA), the most densely populated urban region in Portugal. Commuters are defined as all of the people living in one municipality and traveling daily to another municipality for the purpose of working, as employees or on their own account. One of the purposes of this work is to appraise the opportunity costs (or benefits) of commuting. For that, two ‘major’ scenarios are applied in the context of the CSA modeling framework. One consists of hypothetically relocating the commuters’ place of residence to the place where they work, while the other involves a hypothetical redistribution of the industries’ economic activity, according to the place where commuters live. Both scenarios involve commuting ceasing and represent the counterfactual to the current reality. This will allow for testing the hypothesis that the geographical distribution of people and human activities is not neutral and may induce a loss or a benefit that the society should consider. These scenarios are complemented by a more ‘realistic’ application concerning the return of a feasible quantity of commuters to live in the CBD. Accordingly, this set of contributions is expected to enlighten future academic works and decision makers with regard to the role of commuting in shaping urban economies.

For decades, commuting and urban expansion development have been systematically ignored in terms of oriented policy recommendations (Ewing, 1997; Carvalho, 2013). In many countries, including Portugal, urban planning has been focused essentially on municipal legislation with a lack of coordination and regulatory measures applied at more macro levels (e.g. metropolitan or regional level)[3]. This fact has contributed to the absence of coherent urban policies at the metropolitan level (e.g. concerning land-use regulations or transportation network planning) and promoted competition by attracting population between local governments. In Portugal, this fact is even more relevant as two of the main municipality revenues are associated with extensive land-use, namely the Municipal Tax over Real Estate (supported by house owners) and the cos ton licensing new buildings and constructions. So, the suburbia municipalities of the CBDs, which could already afford lower land costs, are also interested in attracting more and more inhabitants. Therefore, as described by Wyly et al. (1998), municipalities compete with each other in order to capture the largest amount of taxes.

All of this 'apparent neutrality' towards commuting, promoted by some governmental and political institutions, has contributed to a situation where commuting prevails and will probably continue to be more and more relevant in the future. Undoubtedly, a new perception of commuting can have a decisive role in supporting policy designed to accomplish the 11st Sustainable Development Goal of the UN 2030 Agenda, which calls upon world leaders to make cities and all "human settlements inclusive, safe, resilient, and sustainable" (UN, 2015). So, the proposed CSA framework is expected to be a decisive step towards a deeper understanding of this complex phenomenon.

This PhD dissertation was developed in the scope of the PhD program in Sustainable Energy Systems and the Energy for Sustainability initiative (Batterman et al., 2011). The work presented here is the result of a proficuous period in which the author of this dissertation participated in two research projects, and was author and co-author of seven articles in international journals, two articles in national journals, two book chapters, 32 papers published in Conference Proceedings and two awards.

[3] According to Newman and Thornley (1996: 53) "the municipalities (…) are the centers of regulatory planning power and once they have an approved municipal plan, which is a comprehensive plan for physical and socio-economic development and covers their whole area, they can prepare more detailed plans. There are the more detailed urban plans for parts of the area and also detailed layout plans, which involve the parishes".

This first section offers the 'foundations' that established the motivation for this PhD dissertation and addresses this particular 'societal challenge'. Following that, this chapter is devoted to the discussion of the most important works that have decisively contributed to establishing the motivation and methodology embraced in this work. Next, the chapter concludes by pinpointing the research gap(s) and presenting the structure of this PhD dissertation.

1.2. Commuting – a Multi-dimensional Phenomenon

Commuting has been identified as the activity performed by those people that periodically, as a rule on a daily basis, travel between their place of residence and workplace[4] and by doing this surpass the boundary of their residential community. In the scientific literature, the word commuting can be preceded by an adjective that can imply a more specific meaning (e.g., long distance commuting, green commuting, sustainable commuting).

The term "commute" etymologically derives from the Latin *commutare*, meaning "to often change, to change altogether" from *com* (intensive prefix) plus *mutare* "to change". According to Paumgarten (2007), in the 1840s the men who rode the railways each day from the newly established suburbs to work in the cities did so at a reduced rate by buying the so-called *commutation ticket*. Those people were the *commuted*. A few years later, linguistic evolution transformed the *commuted* into *commuters*. In New York, and in cities like Philadelphia, Boston and Chicago, railways (and the investment in transport networks) improved the desirability of the suburbs. So, by the time the automobile emerged a new *way of living* had already been established. It was with this kind of commuting that people became familiarized with, despite the number of "negative" effects.

The complementary effects of commuting have been well documented in the past. Writers such as John Cheever or Richard Yates included several passages in their novels portraying the life of typical American workers in New York and other metropolitan cities and their clipped conversations on the platform, the new airy houses as an aspiration of the American dream, the fraught encounters in moving cars, and the grooved route between city and country, each a terminus of both entrapment and escape (Tanenhaus,

[4] In this work commuting is limited to those that work; however in some circumstances commuting can also include a reference to students.

2015). After flourishing in the 19th and at the beginning of the 20th century, commuting has not stopped growing. The opinions and "emotional" positions regarding commuting are so vast and differentiated that ignoring commuting and its implications is no longer possible. Accordingly, urban planning, environmental issues and urban governance have become more and more challenging. Yet, a general agreement looks far from possible.

> *"Commuting, in the sense of using some form of transportation to separate one's places of work and rest, is – in theory at least – a rational exercise. It allows people, if not to have the best of both worlds, to achieve the best of all compromises: a rewarding job and a pleasant home. The travelling itself is the price that has to be paid to realize these two goals. It requires commuters to surrender their liberty to the operators of public transport, or to congestion on the roads, while they cross a kind of no man's land, whose interim stations or junctions are measures of their progress – no more – and which they'd probably never visit for their own sakes"* (Gately, 2014).

> "*Given the loss of personal well-being generally associated with commuting, the results suggest that other factors such as higher income or better housing may not fully compensate the individual commuter for the negative effects associated with travelling to work and that people may be making sub-optimal choices. This result is consistent with the findings of previous studies such as Stutzer and Frey (2008). This is potentially important information both for those who commute, particularly for an hour or more, and for their employers"* (Office for National Statistics - UK, 2014).

With such remarkable and profound roots in the daily life of every urban citizen, the references to scientific works with "commuting" as a keyword cross all areas of expertise from arts to economics or mathematics. From the scientific publications referenced in "*ScienceDirect*",[5] more than 300 have "commuting" as one of their keywords.[6] 40% of these articles were published in journals devoted to energy and environmental sciences, 20% to engineering, computer and decision sciences, 19% to economics and business and finance and 3% to arts and humanities. The remaining share (18%) belong to the other social and exact sciences (namely medical sciences). A quantitative analysis of the most common keywords associated with commuting shed light on the dimensions that more often go along with papers concerning studies on this topic, namely:

(1) the relevance of the geographical and territorial dimension where commuting actually happens (e.g., Central Business District, Urban, City, Rural, China, Hong Kong, Brussels);

[5] A webpage search engine that serves as a platform for access to nearly 2,500 academic journals and over 26,000 e-books.

[6] Searched in 15th March, 2016.

(2) activities, household types and complementary subjects associated with commuting (e.g., job, travel, household, student, worker, labor market, housing market);
(3) the different means of transportation used by commuters (e.g., bus, bicycle, automobile, public transport, accessibility);
(4) references to commuting externalities or other consequences (e.g., energy consumption, resource consumption, CO_2 emissions, physical activity);
(5) methodological solutions to addressing commuting issues (e.g., model, choice, urban economics, individual preferences; urban planning);

So, although Economics represents a small share of the scientific publications associated with commuting, a simple reading of the most related keywords highlights the potential relevance of the topic to this discipline. Moreover, as a topic that has such a rooted presence in people's daily lives, it also matches perfectly as a subject of study according to the definition of Economics proposed by Alfred Marshall, more than 120 years ago.

> *"Economics is a study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of wellbeing"* (Marshall, 1890).

This ambition of applying Economics to the study of what is important to mankind, together with the relevance of commuting, can be observed in the work of the Nobel Laureate Daniel Kahneman[7] together with Alan Krueger. In this study they performed a survey and asked the respondents to rate several activities according to how much they enjoyed them. Morning commuting was the least preferred activity; it was even less preferred than "working" (Kahneman and Krueger, 2006). The study also concluded that reducing the amount of time spent commuting was critical to improving the happiness of this population[8].

Another Nobel Laureate, Paul Krugman[9] has also written a vast amount of scientific literature in which commuting and urban concentration are an expression of intangible forces. Krugman (1996) considers that these two dimensions are in permanent tension

[7] Awarded with a Nobel Laureate in Economics in 2002.
[8] Sandow (2014) shows that the implications of commuting can be so intense that separation rates are 40% higher among long-distance commuting couples compared with non-commuting couples.
[9] Awarded with a Nobel Laureate in Economics in 2008.

due to centripetal and centrifugal forces (economies of scale, reduced transportation costs and labor mobility) that push the city together and commuting (and its consequences), which arises as the main diseconomy of a particular city. This new contribution from Krugman in particular contradicts the neoclassical urban systems theory, which considers that competition among city developers produces cities of optimal size in a perfect equilibrium.[10] Indeed, Krugman proves that the extent and direction of these forces are very sensitive to the internal and external reality of a given metropolitan area and surely need a more complex and realistic study.

So, despite the distinctive methods and objectives of the analysis, commuting has emerged as an important point in the works of these two Nobel Laureates. On the one hand, Kahneman showed how commuting can be critical in people's lives and, on the other, Krugman underlined a more structural and immaterial dimension of commuting that contributes to shaping the economies and the territory. Both works were important at an early stage of this work, as they contributed to establishing a more unambiguous motivation and ambition for this work.

Together with the works of Kahneman and Krueger (2006) and Krugman (1995; 1997; 1999[11]; 2001; and 2008), the works to be introduced in the next sub-sections have made a considerable contribution to the motivation and definition of the general ambition of this research work. Other works that were also quite important in the initial phase of this research work are more devoted to understanding the cause(s) of commuting: e.g., housing prices (Malpezzi, 1996; Cameron and Muellbauer; 1998), accessibility through public transit systems (Kawabata and Shen, 2007), education levels (Magrini and Lemistre, 2013), gender (Kwan and Kotsev, 2014) and ethnicity (Williams et al., 2014). In contrast, the option consisted of trying to address the consequences of commuting.

This section is divided into 5 sub-sections. The next sub-section is devoted to works that have studied the economic costs associated with urban sprawled regions. Next, sub-section 1.2.2. addresses the impact of commuting on interregional income distribution and household consumption expenditure. The following sub-section is dedicated to the relationship between commuting and housing costs. Next, sub-section 1.2.4. addresses the negative externalities of commuting, namely those associated with the environment and greenhouse gas emissions. Finally, the last sub-section explores the potential of

[10] Moreover, another important critic to neoclassical urban systems theory is its non-spatial nature. While describing the number and types of cities, nothing is said about their locations.

[11] Co-authored with Fujita and Mori.

Input-Output (I-O) and MRIO models to assess this kind of multi-dimensional approaches.

1.2.1. Commuting, Sprawling and Economic costs

In this sub-section, several studies relating urban forms with specific costs supported by society are addressed. These studies have the key characteristic of considering that commuting must be applied by models capable of linking geography and economics.

The discussion comprising the economic and environmental impacts of different urban forms had its first contribution in *The Costs of Sprawl* (RERC, 1974), which was a determinant in launching a debate that still persists. The goals established in this study were focused on addressing the question of how the distribution of human activities influences the economic costs supported by governments or other economic agents in the provision of different services (such as, e.g. recreation, schools, roads, street lighting, infrastructures and other several utilities). Their conclusion referred to the fact that sprawling had higher economic and environmental costs[12] than a more concentrated urban region. Other studies, however, published subsequently have contradicted this idea. Muller (1975) and Windsor (1979) argue that some sprawling benefits were not accessed in these works.[13] This intense debate has persisted with TCRP (1998) and Mandelker (1998) making important contributions to reinforcing the original conclusions of the RERC (1974) study.

Despite the different conclusions, an effort has been made to understand the overall impacts, which can vary accordingly with the geographical configuration of a given area. Gordon and Richardson (1997) identified 16 different costs associated with urban sprawling and organized them into 5 major areas: Transportation and Travel Costs, Public-Private Capital and Operating Costs, Land and Natural Preservation, Quality of Life and Social Effects. They did not conclude that there was any relation between the majority of these costs (except in the specific case of Transportation and Travel costs) and the different urban forms. Accordingly, Small and Gómez-Ibáñez (1997) and

[12] Namely the pollutants resulting from car use (measured in gallons per day), sewage effluent (liters per year) and water use (gallons per year) (RERC, 1974)

[13] It is important to note that the proper identification and quantification of the urban forms is not straightforward. E.g. Ewing et al. (2003) tried to identify the American cities in which the sprawl across the landscape far outpaces population growth. To measure this phenomenon these authors built complementary indexes, namely: a residential density index (in order to identify if a certain population is widely dispersed in a certain territory), a neighborhood-mix index (to identify if there existed a rigidly separation between homes, shops and workplaces), the strength of activity centers and downtowns and, finally, an index of accessibility to the street network.

Rietveld and Verhoef (1998) have underlined the contribution of a travel pattern based on car use to the increasing deterioration of cities' infrastructures, the underdevelopment of public transit systems, public space occupancy, physical barriers in city environments, accidents and congestion. Indeed, Small (1997) quantifies some of the costs associated with air pollution, health and congestion for the USA.

Using a more extensive approach, Camagni et al. (2002) defined different typologies of urban expansion (infilling, extension, linear development, sprawl and large-scale projects) and related these to the existence of different modal splits. The results addressed by this study reinforced the idea that higher costs are associated with low densities and sprawling development. This work was further improved by Travisi et al. (2010), who aimed to analyze the intricate relationship between urban sprawl and commuting, using a mobility impact index. In this particular case, the authors extended the study to seven major Italian urban areas and concluded that a structural organization of a city supported on low densities also ends up contributing to moving job opportunities from the CBD to peripheral areas in the suburbs and, therefore, continues to accentuate through a circular process, the incentives to abandon the CBDs and to increase commuting and other costs associated with sprawling. A recension of the different urban costs and other works that address similar conclusions is presented in the New Climate Economy Report (2014).

Other studies have adopted a different position in this debate (Cervero and Wu, 1997; Schwanen et al., 2003) and consider that the evolution of a polycentric spatial structure with employment decentralization could increase the probability of finding a more favorable spatial arrangement between jobs and the workers' housing location (Lin et al., 2015). This would positively contribute to reducing commuting.

However, this debate has definitely contributed to emphasizing the fact that metropolitan organization is not as straightforward as envisaged in the theoretical monocentric city presented by Alonso (1964), which was created on the basis of the neoclassical urban systems theory. In Alonso's model, jobs are located in what is often referred to as the CBD and only one-way commuting is observed from the suburban areas to the workplace. Indeed, due to the increasing complexity of urban regions, an industry located in the CBD that suffers a shock may use intermediate consumption produced in the 'rest of the country'. So, the effects of a change in employment should be partly felt in this region, and ultimately affect commuting in both regions (Ferreira et al., 2015a). Östh and Lindgren (2012) also highlight that GDP changes have important consequences for commuters' behaviour, differentially affecting rural and urban workers.

So, the background of the “concentration vs. decentralization” debate of urban regions (and, consequently, economic activities) was at the core of our decision to use a model capable of reflecting the interactions between the firms and households located within a certain geographical region. Moreover, Krugman (1995) underlines that commuting diseconomies are also dependent on the interdependencies established between agents within a certain region but they also relate to the degree of openness and the economic relations established with other countries.

To sum up, despite the absence of a consensual conclusion, most works presented in this sub-section have identified a relationship between different urban forms and corresponding specific costs. One of the major costs is associated with transportation and, more specifically, commuting. As most of these works concluded, more sprawled and less dense metropolitan areas lead to an increasing use of private transport and an increase in private and public expenditure on transportation services, and may exacerbate the externalities associated with commuting. However, the ultimate relevance of these costs is also dependent on the linkages established between the agents and the different regional economies.

1.2.2. Commuting, Income Distribution and Consumption Preferences

This sub-section is dedicated to providing an overview of several works that identify a particular consequence of sprawling and, more specifically, of commuting: labor-mobility of workers across regions implies the transference of income and induces particular patterns in households’ final consumption.

As commuting (and sprawling) exacerbate economic interdependencies, a significant part of households’ expenditure of those living in a certain region is dependent on the income generated in other regions (Aroca, 2001; Aroca and Atienza, 2011; Ferreira et al., 2014b). The debate on interregional income distribution implications in metropolitan areas was one of the first and most decisive contributions a few decades ago. Indeed, Mitchelson and Fisher (1987) identified the relevance of interregional income distribution from CBDs to the periphery, which is materialized through expenditure on land, housing, retail and service activities in the region where commuters live. Commuting, therefore, may be viewed as a basic or export industry of “people” attracting capital to nonmetropolitan areas and in turn generating multiplier effects (Lamb, 1975). Furthermore, Smith et al. (1981) and Shahidsaless et al. (1983) argue that the coefficients of in and out-commuting should also be used in the regressions to estimate the income multiplier effects in (small or open) regional economies.

More recently, Aroca (2011) addressed the particular case of long distance commuting in the Chilean mining industry (in the Antofagasta region). This work highlights the role of interregional commuting as a mechanism that leads to spillover effects of an economic activity to other regions. Indeed, an important share of the demand resulting from the income earned by Chilean miners arises in their places of residence and ultimately ends up benefitting these (remote) regions. Aroca (2011) concludes that approximately 16,000 workers in the Antofagasta mines that 'live' in the 'Rest of the Country' contribute to generating 38,000 indirect jobs in their original regions, as a result of indirect effects. These forms of commuting have been extensively described in regions specializing in extractive activities in several countries, such as Australia, Brazil, Chile (Aroca, 2011), Canada (Ryser et al., 2016), Sweden (Ejdemo and Söderholm, 2009) and Russia (Spies, 2009). Indeed, commuting is, in the particular case of extractive industries, explained by the imbalance in labor markets that oblige companies to seek workers from beyond the regions where they are located (Spies, 2009). Additionally, long-distance commuting can be motivated by a higher unemployment level or a lower income level (or even poverty) in the regions where workers live (Sharma and Chandrasekhar, 2016).

Moreover, as commuting activities usually imply the use of motorized vehicles, there are several products and services associated with (private or public) transportation that shape these households' final demand. Rapino et al. (2011) and Ferreira et al. (2014a) argue that commuters can exhibit a different typology of consumption structure from non-commuters. Indeed, concerning final household consumption, commuters are distinguished from non-commuters by the amount of income they spend on the commuting activity (e.g. fuel, parking, tolls) and by other commuting related products (e.g. motor vehicle insurances, car maintenance). Besides these more straightforward implications of commuting in the household consumption structure, the consumption of other products may also be influenced since there are other socio-economic-demographic characteristics that may differentiate commuters from non-commuters. For example Storper and Manville (2006) point out that the young and college-educated prefer to live in urban areas than rural ones. But the differences among consumption structures can also be influenced by a different supply (or availability) of 'amenities' Actually, non-commuters living in the CBD may easily access amenities such as a riverside, a shoreline or aesthetically beautiful architecture, diverse options for dining and cultural offerings (cinema, theatre and other entertainment). So, non-commuters living in the CBD have more opportunities to enjoy the external benefits of city living. In contrast, commuters living in the suburbs may find this lifestyle intolerable and suffocating (Twitchell, 1999).

Finally, the option for a specific household location, as a consequence of a certain commuting status, also reflect the fact that those households present a proper set of preferences regarding housing characteristics, e.g. in terms of space, quality or location (Brown and Moore, 1970; Hanushek and Quigley, 1978). More recently, with regard to new commuters in China, Day and Cervero (2010) considered that the commuting patterns option may reflect a higher preference for better environmental quality, less traffic and more modern and larger houses. Thus, as house expenditure is typically an important share of total household final consumption, this will also contribute to different typologies of consumption for commuter and non-commuter households.

To conclude, this set of scientific works highlight that commuting and housing location preferences are also associated with distinctive consumption patterns. Thus, these differences in final household consumption will also ultimately contribute to shaping regional economies, as they may benefit the local production of some products or induce the growth of interregional import products to satisfy specific demands.

1.2.3. Commuting and Real Estate Market

The relationship between commuting costs and the real estate market has been established since the early years of urban economics. Indeed, modern urban land use theory, which tries to explain the location of economic activities and land-rents, is essentially a revival of von Thünen's theory (1826) of agricultural land use. Currently, it is considered that the problem of location choice in a certain metropolitan area depends on three basic factors: accessibility, space and environmental amenities (Fujita, 1989). Accessibility is mainly associated with both the monetary and time costs of travel-to-work journeys. In the context of the housing market, space is typically understood as the size and quality of the house itself. Finally, environmental amenities include natural features and neighborhood characteristics. Thus, with preferences depending on these three features, in theory individuals have to admit the existence of trade-offs among them.

The earlier answer to this location preference problem addressed the trade-offs between accessibility and space. This simple theoretical exercise, first proposed by Alonso (1964), is ‘commonly’ referred to as the “monocentric city hypothesis”. It rests on certain assumptions, such as: it considers that the city is monocentric (a single center locating all job opportunities); it has a radial transport system without congestion; people travel only between their residence and work place; and, all land parcels are identical (without different proximities of public goods or the influence of externalities).[14] In such a simple model, and considering a household subject to a budget constraint and therefore looking to maximize its utility, an equilibrium will be established between the price of land (and its use) and transportation cost. So, housing prices are expected to be higher near the center and significantly less costly on the periphery (where the commuting costs are higher).

The monocentric city model has been subject to several extensions, but the critical idea of the established trade-offs (in the metropolitan areas) between commuting and housing/renting prices has been maintained. Actually, most of the urban economic analysis has departed from this simple theoretical framework. Beckman (1973) incorporated different household structures into the model, distinguishing working and dependent members in the household. The conclusion was that the more dependents a household has, the farther from the CBD its equilibrium location will be. Another important extension was developed by Muth (1969), who considered that the housing service is produced by the housing industry and depends on the relation between land and capital. Many of the patterns uncovered by these theoretical frameworks are consistent with those observed in large cities in the United States (Fujita, 1989).

Kulish et al. (2011) have identified the relative importance of population density in housing price increases. Observing the reality of Australian municipalities, a clear tendency towards higher values for land located near the CBD was found. Moreover, in 2010, the average land value for the five suburbs within 4 kilometers of the CBD was around 16 times the average value for the six suburbs that are at least 50 kilometers from the CBD. Similar conclusions were reached by Bhattacharjee et al. (2012), who showed that prices increase with access to the city center, although some variations may be found across the different submarkets. In the CBD of Aveiro (Portugal) or suburban areas close to the city, the negative value attached to poor access to the city centre is highly significant. Likewise, Koster and Rouwendal (2013) showed that agglomeration has a considerable effect on rents in mixed areas (balance with residential and non-residential spaces) and proximity to important business areas also leads to higher rents in residential

[14] In Alonso's work, the utility function was more complex and the disutility of commuting was also considered. However, this made the preference estimations more difficult and this additional feature was abandoned in many later works (Fujita, 1989).

areas. Tse and Chan (2003) also concluded that commuting time has a negative effect on property values in Hong Kong.

De Bruyne and Hive (2013), studying the housing and urban density of Flanders, considered that the distance to the capital city and, the decrease in housing density, had the largest effect on housing prices. However, this work reveals another important finding: the travel time by (private) car only influences the housing price in the more provincial clusters, while the travel time by public transportation appears to affect mostly commuters who travel to the CBD (in the capital city). Indeed, in accordance with other relevant works (Ahlfeldt, 2011; Rietvelt and Bruisma, 2012; Bocarejo et al., 2013; Mattingly and Morrissey, 2014), De Bruyne and Hive (2013) demonstrate that households do not care too much about distance but are more concerned with the time (and monetary costs) involved in commuting to work.

But cities have evolved and nowadays they are far from being seen as monocentric as they used to be (Angel and Blei, 2016). The suburbs and periphery growth have also contributed to locating several jobs that are no longer fully concentrated in the CBD. On the other hand, transport networks have developed and "approximated" the suburbs to the CBDs, at least in terms of time expenditure on commuting trips. The increase in analytical observations and data sets has also allowed for testing the realism of these theoretical constructions with regard to what happens in different metropolitan areas. Furthermore, worldwide empirical observations have also contributed to uncovering a large number of externalities and other kinds of "market failures" that can distort this 'often' verified correlation between housing prices and commuting patterns:

(1) the nearby location of several amenities, e.g. parks (Cho et al., 2006; Morancho, 2013), street illumination (Robert, 2008); schools or colleges (Haurin and Brasington, 1996; Kane et al., 2006; Chin and Foong, 2006);
(2) congestion externalities (Arnott and MacKinnon, 1978; Anas and Kim, 1996; Malpezzi et al., 1998);
(3) differentiated tax policies (Raymond, 1998; Weida, 2009; Eom et al., 2014);
(4) racial segregation (Bajari and Khan, 2005; Boustan, 2013; Bayer et al., 2014).

To sum up, commuting flows also influence the real estate market, as housing/rental prices are intrinsically linked to the travel costs that households have to bear in their daily travel to the workplace. More recent studies have also demonstrated that this relationship is often not so straightforward, being influenced by other features, thus alerting us to the importance of applying more realistic models to study such interactions.

1.2.4. Commuting, Energy Consumption and CO_2 emissions

This sub-section is dedicated to the approaches exploring the negative externalities that may arise from extensive commuting activities. It is clear in the literature that if a certain region allows/favors commuting this will have important effects in terms of energy consumption and CO_2 emissions (among other externalities). Newman and Kenworthy (1989) wrote one of the most relevant works concerning the analysis of the impact of urban density on energy consumption. Their analysis of 32 major cities revealed a negative correlation between urban density and annual gasoline use *per capita*. Accordingly, the authors argue that high priority should be given to policies that promote the planning and development of more compact cities. The argument is that planning with the goal of promoting high density has two main objectives: first, reducing trip length and total mobility by concentrating residential, employment and services areas (Cervero, 1988); and, second, changing the modal split to reduce the share of private car use in relation to public transportation, walking and cycling (Barrett, 1996).

More recently, Muñiz and Galindo (2005) analyzed commuting in 163 municipalities of the Barcelona Metropolitan region and concluded that those living on the periphery (and travelling to the center) have a higher tendency to spend more on energy and exacerbate the ecological footprint of commuting (than those living in the center, who usually do not own a private car). Naess has added other relevant contributions on the relation between travel patterns and energy consumption by studying several metropolitan areas (e.g. Oslo - Naess et al., 1995, Copenhagen - Naess, 2005, London - Naess, 2006 and Hangzhou - Naess, 2010). Indeed, in this latter work, Naess (2010: 25) highlights that *"accommodating growth in the building stock by means of densification instead of outward expansion is preferable from an energy and environmental point of view"*. Boussauw and Witlox (2009) also underline that in home-to-work travel, the home-workplace distance is, to a very large extent, a determinant of the energy performance of the commuting system.

In contrast, some authors argue that too much emphasis is being put on density, while other variables are more important. For example, Modarres (2013) concludes that space and density matter, but "who lives where" is equally (and in some cases more) important. Furthermore, urban transportation and energy consumption patterns are not divorced from social geography. Permana et al. (2008) highlight that controlled commercial-residential mixed areas near the city center present the lowest energy consumption. On the other hand, unplanned peri-urban areas are undesirable zones in terms of energy consumption. Accordingly, both works converge to argue for the possibility of decentralizing jobs from the city center, as the shift to less energy-consuming modes of transportation could be more adequate in terms of energy consumption reduction.

Other works have placed an emphasis on other aspects more related to urban transportation policies and technological advances. Barata et al. (2011) point out the relevance of parking policies and other transport demand management policies that can determinately contribute to reducing private car use and improving the efficiency of public transportation systems. Complementarily, Frade et al. (2011) and Correia and Antunes (2012) consider that the introduction of electrical vehicles and car-sharing promoting policies, respectively, may contribute to a relevant reduction in energy consumption and to reducing the costs supported by commuters.

To sum up, the debate on the importance of commuting flows and urban concentration/dispersion for energy consumption and CO_2 emissions is still ongoing. It should be noted that one important feature is still missing from these energy-related works. The background indirect of interdependencies among economic agents and households that can be affected by or dependent on the commuting activity has been understudied. Actually, these works, while making a relevant contribution to studying an additional dimension of commuting, are also limiting its analysis to the direct environmental effects of commuting.

1.2.5. Commuting and Input-Output models: overcoming research gaps

The works presented in the previous sub-sections have unquestionably contributed to shedding light on a number of distinct commuting impacts (e.g. demography, the economy, energy consumption, and CO_2 emissions). So, the use of a comprehensive framework, capable of integrating several dimensions, while embedding a background suitable to describe the miscellaneous interdependencies established between industries and households in a metropolitan region, was a major aspiration for this research project. In this context, Input-Output emerged as the best methodological option to fulfill these requirements, although the need to incorporate several extensions and additional flows to the framework was identified.

First applied by Leontief (1936; 1941) I-O analysis is a well-known tool used to study the impacts on economies. This type of model describes the interrelationships between several economic sectors within a certain geographical area (Miller and Blair, 2009). I-O models offer a method to properly integrate these economic interdependencies, especially if they are extended to deal with both energy and environmental issues (Cruz et al., 2005; Hilgemberg and Guilhoto, 2006; Miller and Blair, 2009). These models can be performed in order to present the results in terms of direct impacts, but they also allow for pinpointing the indirect and induced impacts of a (real or simulated) shock. For example, if the automobile industry increases its production, the energy consumed or the production of car components is expected to increase to satisfy the new demand for inputs (indirect effects). Moreover, as production expands, households income also increases, leading to a subsequent increase in households consumption (induced effects). This capability of this modeling framework is critical to represent the dialectic relation between commuting and the economy: economic shocks affect commuting patterns and changes in commuting patterns may also affect the economy.

Ferreira et al. (2014a) developed the first approach to studying the impacts of inter-municipality commuting in the Portuguese economy. I-O modelling was used to simulate a change in consumption patterns for a hypothetical scenario where commuters become non-commuters. The approach followed was based on an I-O table, following a 'rectangular' structure with 431 products and 125 sectors, at domestic flows and basic prices, for the year 2007 (INE, 2011a). This model framework can be considered a step forward as it allows for the estimation of how a change in households final consumption structure, motivated by changes in commuting patterns, can have impacts on GVA, Employment, energy requirements and the corresponding CO_2 emissions. However, this model considers only the Portuguese economy as a whole and therefore many effects of commuting remain absent from the analysis. So, particular attention was given to MRIO models that extend the scope of the I-O framework by incorporating the interactions between industries (and households) in different regions. The potential of these approaches goes far beyond the single region (country) model effects as it allows for a more detailed allocation of the flows and impacts associated with regional structural changes and the identification of regional spillover effects (Leontief, 1986; Hewings and Jensen, 1986; Miller and Blair, 2009). The other side of the coin is that MRIO models are much more data demanding. This is one of the reasons why there have been limited efforts to apply models capable of considering sectoral and spatial interdependence features in the context of metropolitan economies (Hewings et al., 2001).

It is relevant to note that some contributions have already been advanced, namely through the integration of regional income distribution due to the commuting phenomenon in I-O frameworks (Madden and Batey, 1983; Oosterhaven and Folmer, 1985). This endogenous regional distribution of income was then applied in the more demanding context of MRIO models by Madsen and Jensen-Butler (2005) – in a modelling framework designed for the Danish economy – and by Aroca and Atienza (2011) - regarding the interregional effects of Chilean miners' long distance commuting (among others). Additionally, the models derived for the Chicago Metropolitan Area also incorporate the regional distribution of income embedded in an MRIO framework. Hewings et al. (2001) used journey-to-work data to derive the value added coefficients associated with different income groups by county and concluded that one of the greatest sources of interdependency variation among regions is commuting (whether the focus is on production, employment, or income). Later, Sonis and Hewings (2003) suggested an innovative mechanism that uses the estimation of Miyazawa interrelational multipliers in an income consumption distribution framework associated with the theory of central place hierarchies. More recently, Hewings and Parr (2007) specifically analyzed the interdependencies in a metropolitan region and highlighted two important aspects: the role of labor mobility and the relevance of different consumption expenditure patterns in metropolitan areas.

So, MRIO models seem suitable for including the already mentioned characteristics of commuting. Additionally, more sophisticated I-O and MRIO models have also been applied to differentiate the final consumption of distinct household groups. For example, Blackwell (1978) proposes a tripartite division into current, new and unemployed local residents. Distinguishing between household groups is also explored in some detail by Madden and Batey (1983). Miller and Blair (2009: 75) list several early works that include disaggregation of the final consumption of households in different groups. Blundell and Stoker (2005) extensively discussed the benefits of disaggregating household final consumption, while more recently, Kim et al. (2015) argue that the disaggregation of households' final demand is even more suited in the context of an aging population, increasing mobility or widening income inequality.

Finally, there are several examples of MRIO models being applied to assess the impacts of shocks in terms of energy and the environment.[15] A landmark work by Wiedmann et al. (2006) applied an MRIO modeling framework to assess the direct,

[15] Moreover, several I-O models were applied in the study of environmental impacts (detailed surveys of environmental I-O models, with many references, including theoretical extensions and applications are provided in Proops et al., 1993; Cruz et al., 2005 and Miller and Blair, 2009).

indirect and induced effects and concluded that different socioeconomic groups can produce significantly different ecological footprints associated with distinct consumption patterns. Following this work, Druckman and Jackson (2009), departing from an MRIO framework, derived a socio-economically disaggregated model to assign the responsibility for CO_2 emissions to different household groups. Thus, MRIO modeling has been accepted as suitable for accurately assessing how changes in household consumption and in the economy may affect the environment.

Finally, in the scope of regional and urban economics several other types of methodologies have been applied to address the commuting impacts in a given geographical region but for different purposes than those assumed in this research project. Many of these works depart from I-O or MRIO as background information. UrbanSim (Waddell et al., 2000) and RELU-TRAN (Anas and Liu, 2007) are examples of sophisticated and advanced models designed to address emerging needs to better coordinate transportation and land use planning. The first major design difference is that these models work under the hypothesis that land-use responds to changes in the transportation sector but the economic interdependencies are treated as purely exogenous (Waddell et al., 2000) or in a more aggregated way (Anas and Liu, 2007). Through the application of several equilibrium hypothesis, the impact of exogenous shocks can be estimated in terms of land-use, the labor-market, commuting flows and the real estate market. According to Anas (2013), the RELU-TRAN model has already been applied to examine the impact of an increase in the price of gasoline or in congestion tolls in the location preferences of households. Considering this set of variables as endogenous would certainly demand higher availability of data and/or the assumption of additional hypothesis concerning the relations and elasticities affecting the different sets of dimensions coexisting in a metropolitan area.

Also applying a much more demanding data framework, Almeida et al. (2010) introduced a new proposal to study the links between transportation networks and regional economies. Using a model based on spatial computable general equilibrium (CGE) techniques, these authors conclude that if the transport infrastructure improvement links are concentrated among richer Brazilian regions, there is an increase in regional income inequalities. This technique was extended by Haddad and Teixeira (2015) to integrate Geographical Information Systems related to floods and firm locations with the goal of evaluating the economic impacts of floods in the city of São Paulo, Brazil. Finally, more recent work developed by Haddad et al. (2015) applied a CGE model to assess the economic impacts of the existing underground metro infrastructure. To do this, in their work, the authors simply remove the subway from the transport network, which affects labor-productivity (mainly due to increased commuting times), and they conclude that the economic impacts of the São Paulo underground go far beyond this metropolitan region.

These works approached the study of urban areas by combining the economic dimension with other dimensions (e.g. geography, demography and environment). The motivation behind these models, inspired in the regional economics tradition, is to pursue a more comprehensive specification of the economic relations in a certain territory. While their potential is still far from completely explored, with adequate transformations they definitely make an inspiring contribution to the model presented in this research work.

1.3. Research Gap(s) and Dissertation Structure

This section concludes the first chapter. So, the research gap(s) uncovered in the last section are explored and the structure followed in this manuscript is presented.

As explored in the previous section, the debate concerning commuting impacts is ongoing. First, there are deep disagreements regarding the costs and benefits of the different urban forms with different works reaching distinct conclusions. Additionally, the role of commuting in the regional distribution of income and in influencing households consumption typologies has had a more peripheral place in the literature. Next, the increased complexity of urban forms and the evolution towards more polycentric metropolitan regions leads to several cases where neoclassical urban theory is contradicted and the relation between commuting and housing prices becomes fuzzy. Finally, the contribution of commuting to increasing energy consumption and CO_2 emissions is currently a hot topic, and many inspirational contributions are being advanced, although most are directing their efforts at an exclusive analysis of the direct environmental effects.

All of these interactions and intricate relationships clarify that commuting takes place in a singular region with a unique orography, an inimitable transport network and modal split, some irreplaceable production factors, a distinctive interdependency between its own industries and households and other regions' economic agents, and its very own cultural and idiosyncratic society. So, the research gap that this PhD dissertation proposes to address consists of the design of a comprehensive multi-dimensional framework and its consequent application to the Lisbon Metropolitan Area, a region very intensive in commuting flows, which will allow for the simultaneous evaluation of the different commuting impacts. This approach to the Portuguese most important urban center can be in the future applied in other geographical regions and shed some light in the commuting impact in those areas.

It is undeniable that a change in commuting intensities and patterns can affect regional income distribution, households consumption structure, the economy, employment, real estate rental activity and the environment. It is also true that a change in one of these dimensions can stimulate a second or a third (and so on) order effect in the other ones, since these variables are all dialectically (and endogenously) dependent.

It is important to note that the derivation of an economic model (even the most sophisticated one) always comprises a simplification of the reality. Concerning this research work, a realistic achievement is that the proposed "Commuting Satellite Account" (CSA) can contribute to influencing future academic works and decision makers, while inspiring them to construct a better future.

To accomplish the proposed goal, this monography is organized into 5 chapters. Chapter 2 begins by briefly presenting the Lisbon Metropolitan Area (LMA), highlighting some demographic and economic indicators. Thus, international and interregional trade within the LMA and between the LMA and the 'Rest of the Country' is explored. Finally, commuting activity in Portugal is characterized, with a particular focus on the LMA and its municipalities.

Following that, Chapter 3 is specifically devoted to the methodology used in the development of the MRIO framework applied to the LMA. It starts by presenting an overview of the characteristics and procedures applied to format the I-O data at national level. Next, the process of regionalizing the I-O tables, first in the context of bi-regional I-O models, and then the methods applied to derive a tri-regional I-O model to the LMA are addressed.

Chapter 4 starts by synthetizing the 'most traditional' frame of multi-regional model structures. Then, the proposed elements to be incorporated into a CSA are derived and its theoretical structure is presented. This involves three particular features: (1) the regional distribution of labor income; (2) the consumption structures of commuter and non-commuter households; and, (3) the specific treatment given to real estate rental activities. Next, all of these CSA components are integrated together with an energy and environmental account. Then, two 'extreme' scenarios are applied in order to assess the opportunity costs of commuting in the particular case of the Lisbon Metropolitan Area.

Finally, two additional applications, illustrative of the potential of this modelling framework, are presented.

Chapter 5 addresses the main conclusions of this CSA application in a real world circumstance and addresses some policy recommendations that emerge from the results obtained. Finally, the text concludes by shedding some light on future research paths that arise from this research work.

“There are roughly three New Yorks. There is, first, the New York of the man or woman who was
born here, who takes the city for granted and accepts its size and
its turbulence as natural and inevitable. Second, there is the New York
of the commuter — the city that is devoured by locusts
each day and spat out each night.
Third, there is the New York of the person who was born somewhere
else and came to New York in quest of something.
...Commuters give the city its tidal restlessness;
natives give it solidity and continuity;
but the settlers give it passion. ”

E. B. White, 1949

CHAPTER 2 - THE LISBON METROPOLITAN AREA: ECONOMIC ACTIVITY AND THE COMMUTING PHENOMENON

2.1. Introduction

Commuting assumes different characteristics and even distinct degrees of importance according to each geographical space. Commuting does not happen independently of the geographic, demographic or economic characteristics of a given region. The agglomeration of people and human activities, and, as a consequence, of economic agents, trade, production and consumption makes an important contribution to exacerbating commuting. Furthermore, commuting is also a key component that sustains urban expansion. Research into transportation, and investment in transport networks and road infrastructures, mean that, nowadays it is normal for someone to travel more than 100 kilometers every day. At the beginning of the 20th century this could imply, for an average person, almost a day of traveling depending of the orography and other circumstances.

So, this dialectic relationship between commuting, geographical space and human activities leads to the necessity of exploring commuting, taking into account these different dimensions. In other words, an adequate understanding of commuting activity implies a profound knowledge of the regions where commuting happens. Accordingly, this chapter begins (section 2.2.) by briefly presenting the Lisbon Metropolitan Area (LMA), and highlighting some demographic and economic indicators. In sub-section 2.3., the international and interregional trade within the LMA and between the LMA and the 'Rest of the Country' is explored. Finally, sub-section 2.4. aims to describe the commuting activity in Portugal, with a particular focus on the LMA and its municipalities.

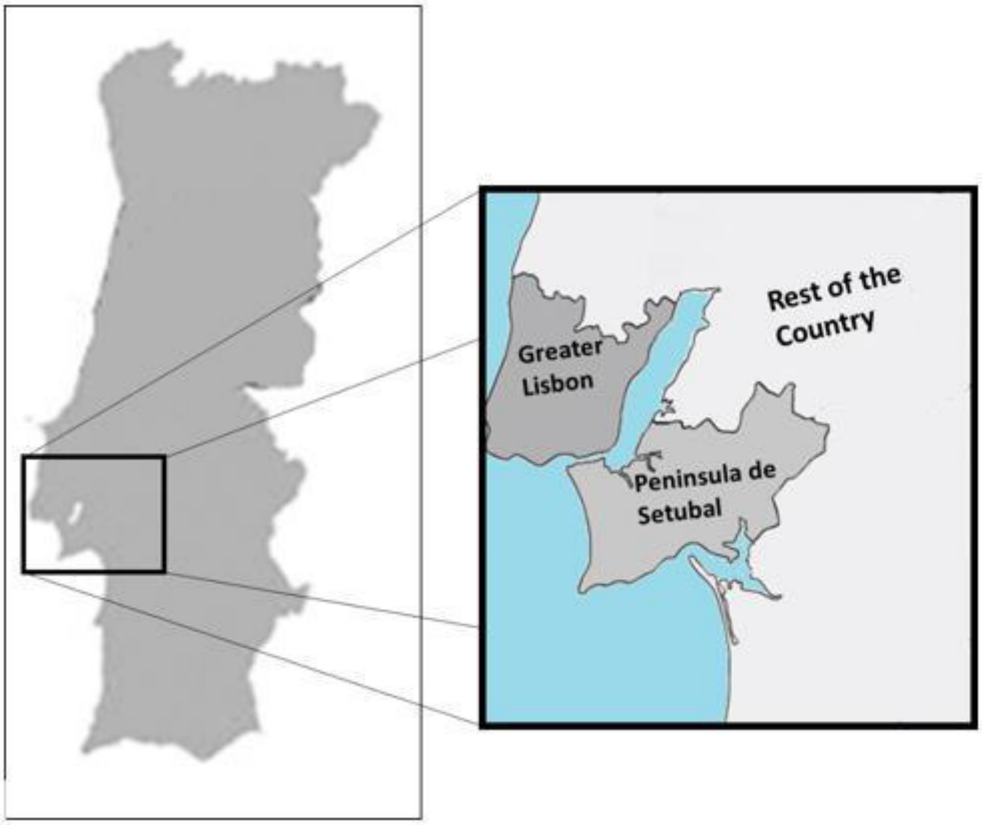
2.2. The Lisbon Metropolitan Area

The LMA is a NUT II region comprising two NUTS III regions[16] (Greater Lisbon and Peninsula de Setubal). Although this region is considered as a single metropolitan area, it is a "peculiar" case because the two NUTS III regions are separated by a physical barrier: the Tagus River. Indeed, there are only two bridges crossing this barrier.[17] In spite of this, there are intensive flows of people and goods traveling over this natural barrier with more than 135,000 vehicles traveling across the bridges every day, more than 65,000 passengers crossing the river by boat (INE, 2011b) and more than 40,000 passengers crossing the river by train (Fertagus, 2012). Figure 1 places the Lisbon Metropolitan Area in the Portuguese Mainland Territory and presents an enlarged image of this region.

[16] This work follows the 2002 geographical distribution of Portuguese NUTS III regions. More recently, the National Statistical Institute has implemented the "2013 NUTS III" geographical distribution. In this new version, the LMA NUT II region comprises only one NUT III region. This obviously leads to a decrease in the disaggregation level and would increase the potential for losing relevant information. Additionally, the data released for the 2013 NUTS III map is only available for recent years while older data is still missing. So, for both of these reasons our option consisted of continuing to use the previous version of the geographical distribution. The other reason was that the Multi-Regional Input-Output model developed in this work benefits from data that is still only available for the year 2010.

[17] In 2009, the idea of building a third bridge was launched by the Portuguese Government but this project has been postponed.

Figure 1: Map of Portugal and Lisbon Metropolitan Area



In 2011,[18] the Lisbon Metropolitan Area accounted for 26% of the Portuguese population and represented 38% of Portuguese Gross Domestic Product, 29% of National Employment and 42% of the commuters in the Portuguese territory. Observing the two NUTS III that comprise this NUT II region, Greater Lisbon NUT III region concentrates most of the economic activity of the LMA (85%), and, consequently, so is most of the employment (82%). However, as a relatively small share of the overall population (71%) is concentrated in this region, the GDPpc is significantly higher in Greater Lisbon than in the Peninsula de Setubal. As will be proved in the next sections and chapters, this result hides the role of commuters that live in the Peninsula de Setubal and work in the Greater Lisbon region.

According to the Portuguese Regional Accounts (INE, 2012b), the NUTS II Lisbon Metropolitan Area is the region with the highest Gross Value Added (GVA) and has a

[18] As will be explained in this work, the proposed economic model departs from the information available for 2010. Additionally, many of the data presented in this chapter and the following one are based on the information in the 2011 Portuguese Census. So, in the interest of coherence the analysis performed throughout this chapter relates to 2010 or 2011 depending on the information availability.

particular economic structure when compared with other Portuguese regions. In Table 1, the GVA by regions and by industries is presented disaggregated by 10 economic sectors.

Table 1: Share of Gross Value Added by industries in each Portuguese NUTS II region (2010)

	Norte	Cen-tro	**LMA**	Alen-tejo	Al-garve	Aço-res	Ma-deira	Extra regio	Por-tugal (10^6 €)
Agriculture, forestry and fishing	1.6%	3.4%	0.4%	8.9%	3.1%	8.1%	2.1%	0.0%	3,463
Industry, energy, water supply and sewerage	23.9%	23.5%	9.7%	21.8%	5.6%	8.3%	6.9%	0.0%	26,594
Construction	6.9%	6.4%	4.5%	5.3%	7.1%	6.0%	8.1%	0.0%	9,226
Wholesale and retail trade, repair of motor vehicles; transportation, storage; accommodation and food services	21.1%	22.5%	22.6%	21.4%	33.9%	24.6%	31.5%	0.0%	36,095
Information and communication	2.3%	1.4%	6.6%	1.1%	1.6%	1.8%	1.9%	0.0%	5,739
Financial and insurance	4.8%	3.5%	10.8%	3.0%	3.7%	3.7%	3.7%	0.0%	10,424
Real estate	10.5%	11.0%	10.0%	10.1%	15.8%	11.1%	9.7%	0.0%	16,795
Professional, scientific and technical; administrative and support services	5.9%	4.0%	10.7%	3.5%	5.6%	3.6%	4.6%	0.0%	11,244
Public administration and defense; compulsory social security; education; human health and social work	20.1%	21.9%	21.5%	22.7%	19.9%	29.8%	28.9%	100%	34,254
Arts; entertainment; repair of household goods and other services	2.7%	2.4%	3.2%	2.3%	3.6%	3.0%	2.6%	0.0%	4,491
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	
10^6 €	44,729	29,603	59,517	10,380	6,634	3,374	3,915	173	158,326

Source: Portuguese Regional Accounts (INE, 2012b)

Table 1 highlights the fact that most of the economic activity in the Lisbon Metropolitan Area is concentrated in the production of services (more than 85%) while in the Portuguese case this value is less than 75%. This fact uncovers the different specializations between this region and the Rest of the Country. The estimation of simple location quotients (Delgado and Godinho, 2011) is an important tool to understand the specific characteristics of each region's economic activity and its respective specialization pattern. Table 2 presents the location quotients based on the GVA for each Portuguese NUTS II region by industry.

Table 2: Location quotients by Portuguese NUTS II region and by industries (2010)

	Norte	Cen-tro	**LMA**	Alen-tejo	Al-garve	Açores	Madeira	Ext.-regio
Agriculture, forestry and fishing	0.8	1.6	0.2	4.1	1.4	3.7	1	
Industry, energy, water supply and sewerage	1.4	1.4	0.6	1.3	0.3	0.5	0.4	
Construction	1.2	1.1	0.8	0.9	1.2	1	1.4	
Wholesale and retail trade, repair of motor vehicles; transportation, storage; accommodation and food services	0.9	1	1	0.9	1.5	1.1	1.4	
Information and communication	0.6	0.4	1.8	0.3	0.4	0.5	0.5	
Financial and insurance	0.7	0.5	1.6	0.5	0.6	0.6	0.6	
Real estate	1	1	0.9	1	1.5	1	0.9	
Professional, scientific and technical; administrative and support services	0.8	0.6	1.5	0.5	0.8	0.5	0.7	
Public administration and defense; compulsory social security; education; human health and social work	0.9	1	1	1.1	0.9	1.4	1.3	4.6
Arts; entertainment; repair of household goods and other services	1	0.8	1.1	0.8	1.3	1.1	0.9	

Source: Own estimations

Table 2 reinforces the idea that the most relevant activities in the Lisbon Metropolitan Area are those associated with the service sector, namely Information and Communication Activities, Financial and Insurance Activities, Consultancy, Scientific and Technical Activities, and Administrative and Support Service Activities. In contrast, the Agriculture and Construction location quotients in the Lisbon Metropolitan Area are the lowest among the Portuguese regions.

However, the economic activity is not homogeneously distributed among the two NUTS III comprising the Lisbon Metropolitan Area. Table 3 presents the top five and bottom five location quotients of industries (based on the GVA) among the two NUTS III regions using more disaggregated data.

Table 3: Top 5 and bottom 5 location quotients of industries among the two NUTS III regions in the Lisbon Metropolitan Area (2010)

Greater Lisbon

Top 5		Bottom 5	
Manufacture of basic pharmaceutical products and pharmaceutical preparations	**2.3**	Manufacture of textiles, wearing and leather products	**0.1**
Publishing and radio and television activities	**2.3**	Manufacture of motor vehicles, parts and accessories for vehicles and other transportation equipment	**0.1**
Computer programming, consultancy and related activities	**2.2**	Agriculture, farming of animals, hunting and forestry	**0.1**
Financial and insurance activities	**2.0**	Mining and quarrying	**0.1**
Advertising, other consultancy, scientific and technical activities	**1.9**	Manufacture of basic metals and fabricated metal products, except machinery	**0.3**

Peninsula de Setubal

Top 5		Bottom 5	
Manufacture of motor vehicles, parts and accessories for motor vehicles and other transportation equipment	**5.3**	Manufacture of coke, refined petroleum products and fuels briquettes	**0.0**
Manufacture of computer, communication equipment. electronic and optical products	**3.7**	Manufacture of textiles, wearing and leather products	**0.1**
Water collection, treatment and distribution; sewerage. waste management	**2.2**	Manufacture of basic pharmaceutical products and pharmaceutical preparations	**0.2**
Manufacture of wood and of products of wood and cork, except furniture;	**2.1**	Manufacture of electrical equipment	**0.2**
Manufacture of furniture and repair, and installation of machinery and equipment	**1.6**	Publishing and radio and television activities	**0.3**

Source: Own estimations

Table 3 identifies the industries that are relatively more/less specialized in the two NUTS III regions when compared with the Portuguese economy. Greater Lisbon is more specialized in industries associated with service activities. In contrast, the production of some manufactured, agriculture and mining products is residual. In contrast, the Peninsula de Setubal is more specialized in the manufacture of several industrial products, in particular motor vehicles, and parts and accessories for motor vehicles (namely, due to one important plant, belonging to the Volkswagen group, located in the municipality of Palmela, which directly employs more than 3,500 workers).

Other important distinctive feature of the two NUTS III regions is the different average sizes of the establishments in the municipalities located in the different regions. Lisbon and Oeiras (in Greater Lisbon) and Palmela (in the Peninsula de Setubal) have a higher number of average workers per establishment (above 4). On the contrary, many municipalities of the Peninsula de Setubal have less than 2.3 workers per establishment.

The distinct distribution of the Gross Value Added and Employment for the two NUTS III regions and the different sectors is responsible for the important economic differences between the two regions. But another important phenomenon is much more relevant to the economy of both regions and most of the time this is neglected. As already stated, the GDPpc is significantly higher in the Greater Lisbon region (more than 28,000 euros per year) than in the Peninsula de Setubal (around 13,000 euros per year). However, labor-productivity is only 22% higher in Greater Lisbon than in the Peninsula de Setubal. So, an additional explanation is needed.

Indeed, the most important difference is the employment ratio, as defined by the OECD (2005), since the relation between employment and the working age population is 76.0% in the Greater Lisbon region and 46.4% in the Peninsula de Setubal. However, the proportion of the resident population that are employed out of the total working age population is 66.5% in the Greater Lisbon and 63.3% in the Peninsula de Setubal, respectively. This comparison explicitly shows that an important share of the Peninsula de Setubal workers out-commute every day in order to work in the Greater Lisbon region. As will be shown in sub-section 2.4., almost a third of the workers living in the Peninsula de Setubal actually work outside this region, mainly in Greater Lisbon. So, commuting is also a factor that contributes to the disparity of the GDPpc between the two regions.

To sum up, much of the GDP and income generated by industries located in the Greater Lisbon region is regionally distributed through commuting activities benefitting, for example, those who live in the Peninsula de Setubal. From a different perspective, households living in the Peninsula de Setubal region (and even, in other neighboring regions) directly earn an important share of their income due to their labor activity in the Greater Lisbon region. In this thesis, this relevant role of commuting in the regional distribution of income is discussed.

2.3. Results of the International and Interregional Trade Estimations

This section presents a summary of the results of the international and interregional trade estimations to the LMA. It is important to clarify that these estimations are a by-product of this research work and that the methodology applied to estimate these indicators is explained in detail in Chapter 3. However, these results are relevant to understanding the specialization of each region and to analysing the (inter)dependency between the NUTS III comprising the Lisbon Metropolitan Area and the 'Rest of the Country'.

The starting point for this more detailed analysis is a description of the overall trade balance of the Greater Lisbon and Peninsula de Setubal regions.[19]

Table 4: Trade Balance of Greater Lisbon and Peninsula de Setubal (2010)

	Greater Lisbon		Peninsula de Setubal	
	10^6 euros	% GDP	10^6 euros	% GDP
International Exports	10 173	18.5	4 514	48.6
Interregional Exports	23 767	43.2	5 001	53.8
Non-residents in Portugal consumption	1 068	1.9	70	0.8
Total Exports	**35 008**	**63.6**	**9 585**	**103.2**
International Imports	15 771	28.7	4 521	48.7
Interregional Imports	15 435	28.1	7 948	85.6
Consumption of Residents outside the National Territory	4 33	0.8	160	1.7
Total Imports	**31 639**	**57.5**	**12 629**	**136.0**
Net Exports	**3 369**	**6.1**	**- 3 044**	**-32.8**

Source: Own estimations

Table 4 shows that the overall dimension of interregional trade is far more important than international trade for both regions. This result is justified by the relevance of the Greater Lisbon area in terms of interregional trade. Actually, despite the fact that this area has a large deficit in terms of international trade, a large surplus is estimated in terms of interregional trade. In contrast, the Peninsula de Setubal region presents a major deficit in terms of interregional trade. The most important products in terms of the responsibility for these trade flows are presented in Table 5.

[19] It is important to state that the international and interregional imports and exports regionalized and presented in the next Tables are confined to the ones that were estimated while deriving our MRIO model (Intermediate Consumption, Household Consumption and non-residents in Portugal consumption). In the particular case of other final demand components, considered in the exogenous part of the model, such an estimation was not performed. This process is deeply explored in sub-section 3.3..

Table 5: Most important products (ranked by Net-Exports volume (10^6 €)) in Greater Lisbon and Peninsula de Setubal (2010)

Greater Lisbon	**Inter-regional Exports**	**Inter-national Exports**	**Non-residents in Portugal Cons**	**Inter-region Imp.**	**Inter-nationa l Imp.**	**Net Exp.**
Wholesale trade (include commission trade), except of motor vehicles and motorcycles	2,509.3	175.0	47.5	0.0	0.0	2,731.8
Passenger air Transport	349.7	1,398.7	0.4	3.6	196.7	1,543.1
Other monetary intermediation	1,590.8	109.8	0.0	0.0	175.4	1,484.7
Gas; distribution of gaseous fuels through mains; trade of gas through mains	1,386.2	0.2	0.0	107.3	0.1	1,057.0
Other credit granting	1,025.2	54.5	0.0	0.0	22.2	1,053.2
Peninsula de Setubal						
Motor vehicles passengers cars	31.0	1, 331.5	0.0	0.7	227.3	1,134.3
Motor vehicles for freight transport	2.9	334.3	0.0	0.1	10.8	326.4
Pulp	73.2	243.5	0.0	26.4	16.8	273.5
Other products of wood; cork industry products	74.2	168.4	0.0	58.2	9.3	175.1
Television and radio receivers and similar consumer goods	25.3	227.8	0.0	12.5	87.0	153.6

Source: Own estimations

Table 5 reveals that in Greater Lisbon the most relevant product production, in terms of Net exports, is associated with trade activities and bank services. The first most important activity results from the location of many warehouses and the concentration of the wholesale trade service production in the Greater Lisbon region. Passenger air transport is the second most important activity, mainly due to the location of the most important national airport in this region. The manufacture and provision of gas is also an important activity, which is explained by the location of the headquarters of the most important gas distribution company in the municipality of Lisbon (the maintenance of the gas network is not included in this product, but instead is considered as a primary product of another industry – Gas Transport via pipeline). Indeed, the results obtained for the Greater Lisbon interregional trade point reveal the importance of these headquarters effects in the volumes of interregional exports to the 'Rest of the Country' (and to the Peninsula de Setubal region as well). The services provided in these headquarters, being fundamental for the company's nationwide operations, are accounted as exports from the headquarters location to other regions. On the other hand, the Peninsula de Setubal region is more specialized in manufacturing products, mainly products that have as their destination the international market (e.g. passenger cars and freight transport vehicles, pulp).

One important component that contributes to the overall trade balance of both regions is non-residents in Portugal's consumption. This item captures mostly the tourist consumption of the products produced in each of these regions. It is possible to observe that this value is more significant in the Greater Lisbon region in comparison with the Peninsula de Setubal. Table 6 represents the number of nights spent by non-residents in hotel establishments located in each of the regions.

Table 6: Nights spent in hotel establishments (10^3) by non-residents in Portugal by region (2010)

	Total number of nights	Regional Share
Portugal	23,608	100%
Greater Lisbon	5,717	24.2%
Peninsula de Setubal	280	1.2%

Source: Statistical Yearbook of the Lisbon Region (INE, 2011c)

Table 6 shows that the Greater Lisbon region is significant in terms of national tourism[20] while in the Peninsula de Setubal tourism activity is residual, regarding its relative importance in terms of the total number of foreign tourists in Portugal. This also contributes to an increase in the total net exports in the Greater Lisbon region and represents almost 2% of the GDP of this region.

Notwithstanding this, as already mentioned, interregional trade is the most important item in the trade balance of both regions. So, to gain a better understanding of the linkages between industries in the different regions, in the Portuguese economy, as well as the relative importance of the industries located in the Greater Lisbon region, Table 7 presents the products with the most relevant interregional net-exports (with their origin in this NUTS III region).

[20] Greater Lisbon is the 2nd NUT III region with more nights spent in hotel establishments by non-residents in Portugal. The most important NUT III is the Algarve.

Table 7: 10 most important products produced in Greater Lisbon in terms of Interregional Net-Exports (2010)

	Net Interregional Exports (10^6 euros)
Wholesale trade (include commission trade), except of motor vehicles and motorcycles	2,509.3
Other monetary intermediation	1,590.8
Gas; distribution of gaseous fuels through mains; trade of gas through mains	1,278.2
Insurance and Reinsurance	1,094.7
Other credit granting	1,025.2
Wireless telecommunication service	937.3
Human health services	919.8
Head offices activities and services; management consultancy services	378.6
Advertising and Media representation	356.3
Passenger air Transport	346.1

Source: Own estimations

Table 7 confirms the services' relative importance in the interregional trade between Greater Lisbon and other regions, as a result of most of these products being consumed nationwide, although the headquarters are located in the Greater Lisbon area. As it was referred, this headquarters effect is easily observed in the financial services, in the communication activities and even in the Distribution of Gas. However, the most important product in terms of interregional trade results from the existence of many warehouses and establishments that belong to the wholesale trade industry and, consequently, the concentration of this activity in Greater Lisbon (almost 50% of Portuguese production). This means that when economic agents buy products and support wholesale trade margins (despite this trade occurring in or outside the Greater Lisbon region), there is a relevant possibility that Greater Lisbon benefits from positive spill-over effects. Next, the same analysis is presented for the Peninsula de Setubal.

Table 8: 10 most important products produced in Peninsula de Setubal in terms of Interregional Net-Exports (2010)

	Net Interregional Exports (10^6 euros)
Oils and fats	91.0
Metal structures and parts of structures	69.6
Basic iron and Steel and Ferro-alloys	65.2
Services of repair, maintenance and installation of machinery and equipment	47.4
Pulp	46.8
Processed and preserved meat and meat products	46.0
Services of renting of other machinery, equipment and tangible goods	42.4
Non-alcoholic beverages	33.2
Cement	32.9
Motor vehicles	30.3

Source: Own estimations

In Table 8, the products with the most relevant interregional net-exports in the Peninsula de Setubal are presented. Once again, the importance of manufacturing in this region is highlighted. Motor vehicles are less important here than in Table 5 since most of the supply satisfies demand from abroad. Otherwise, other processed food products assume some importance in terms of interregional net-exports such as oils and fats, processed meat and other meat products and non-alcoholic beverages. The other products that are among the 10 most important products in terms of net-exports are products that are mostly produced to satisfy intermediate consumption by other industries (namely, ‘basic iron and steel’, ‘metal structures’, ‘services of repair, maintenance and installation of machinery and equipment’ and ‘services of renting of other machinery, equipment and tangible goods’).

Table 9 presents the interregional trade of these three Portuguese regions, divided according to an aggregation of the results in the three main economic sectors. This table reinforces the picture of the main types of products that each region imports from and exports to other regions.

Table 9: Overall Interregional Gross and Net exports (10^6 € and % of regional GDP) from Greater Lisbon, Peninsula de Setubal and Rest of the Country (2010)

Products	Greater Lisbon				Peninsula de Setubal				Rest of the Country			
	Gross Exports		Net Exports		Gross Exp.		Net Exports		Gross Exp.		Net Exports	
	10^6 €	%	10^6 €	%	10^6 €	%	10^6 €	%	10^6 €	%	10^6 €	%
Primary	103	0	- 910	- 2	167	2	- 206	- 2	1,273	1	1,116	1
Secondary	7,117	12	- 1,785	- 3	2,673	27	- 596	- 6	10,623	10	2,382	2
Tertiary	16,548	29	11,026	19	2,160	21	- 2,146	- 21	5,127	5	- 8,881	- 8
TOTAL	23,767	41	8,332	15	5,001	50	- 2,948	- 29	17,023	15	- 5,385	- 5

Source: Own estimations

From these figures on interregional trade, one can see that although the Greater Lisbon region has a trade balance surplus regarding the services produced, it faces a deficit regarding primary goods as well as secondary products (namely some manufacturing and electricity production). However, as observed previously, the surplus observed for tertiary products overcomes the deficit obtained in primary and secondary products. In contrast, the Rest of the Country is the region that mostly exports products associated with the Primary and Secondary sectors. Despite this, the overall trade balance of the Peninsula de Setubal presents a large deficit that accounts for almost 30% of its GDP.

These deficits only account for the interregional trade of products, but they can be offset by other flows. However, as it is possible to observe in Table 4 this is not compensated for either by international trade or by non-residents in Portugal's consumption. So, once again, commuting arises as the most suitable explanation for the counterpart for this huge deficit.[21] Indeed, due to commuting, thousands of households that live in the Peninsula de Setubal have their monthly salaries paid by the industries located in the Greater Lisbon region and "transport" that money to the Peninsula de Setubal region, financing the acquisition of goods and services in this region (which in many cases have also been imported from other regions or abroad).

2.4. Commuting activity in Portugal and in the LMA

The analysis of the commuting data among the Portuguese regions allows us to understand the peculiarity of this phenomenon in the LMA. Every decade, the most relevant data regarding commuting in Portugal is released in the Portuguese Population Census Publication, produced by the National Statistical Institute (INE). According to the

[21] Other common explanations found in the literature are not applicable to the Peninsula de Setubal region: e.g. a significant amount of government transfers, social security payments, and immigrants' money transfers to their region of origin.

2011 Census, there were about 4,361,187 Portuguese workers with different commuting patterns. Table 10 represents the distribution of commuting patterns among Portuguese workers. Commuting students are excluded from these numbers and from the analysis in this research project.

Table 10: Commuting Patterns among Portuguese employed resident population (2011)

Commuting patterns of Portuguese workers	Nº	%
Work and live in the same municipality	2,860,521	65.6%
Work at home	152,291	3.5%
Work and live in the same "freguesia"	1,242,977	28.5%
Work in a different "freguesia"	1,465,253	33.6%
Work in another municipality	1,429,867	32.8%
Live in Portugal and work in Spain	69,309	1.6%
TOTAL	4,361,187	100%

Source: 2011 Portuguese Census (INE, 2012c)

According to Table 10, most Portuguese workers (more than 65%) live in the same municipality in which they work, while an important share (around 33%) commutes daily to other municipalities in order to work. A residual share of less than 2% of Portuguese workers stated that they commute to Spain in order to work.[22] Out of those who work and live in the same municipality, 5% affirmed that they work at home, 43% stated that they work within the same "freguesia" (a small administrative area that, in some situations, may be translated as a parish) and 52% indicated that they have to travel to another "freguesia". As already mentioned, for the purposes of this work only those that live and work in a different municipality are considered as commuters, so in the next sub-sections and chapters the remaining analysis will focus on commuting between municipalities and not on movements within or between "freguesias".

Compared with the 2001 Portuguese Census (INE, 2003), the number of commuters slightly declined in absolute terms (less 20.000). However, the same happened with total employment such that the share of workers that traveled daily to other municipalities to work increased by more than 2%. This comparison demonstrates that commuting is a "steady" phenomenon in the Portuguese territory that has arisen and become relatively more important in the last decades.

The Portuguese workers who commute are not distributed homogenously throughout the Portuguese territory. Table 11 demonstrates the relationship between commuter and

[22] Those workers are excluded from the remaining analysis since the goal of this work is focused on the commuting phenomenon in the LMA and this region has no border with Spain.

non-commuter workers (to different municipalities), by place of residence, in the Portuguese NUT III regions. Remark that a significant part of these commuters, commute within the NUTS III where they inhabit, as they live and work in different municipalities. Indeed, only a small share of workers commute to a different NUTS III. The dichotomy of commuting "within" and "between" NUTS III persists all over this work.

Table 11: Distribution of commuters and non-commuters, by place of residence, among the Portuguese NUTS III regions (2011)

		Non-commuters		Commuters	
	Workers	Nº	%	Nº	%
Portugal	4,290,388	2,860,521	67.2%	1,429,867	32.8%
Minho-Lima	88,240	69,686	79.0%	18,554	21.0%
Cávado	172,626	133,042	77.1%	39,584	22.9%
Ave	214,168	159,745	74.6%	54,423	25.4%
Grande Porto	523,950	296,335	56.6%	227,615	43.4%
Tâmega	208,769	148,693	71.2%	60,076	28.8%
Entre Douro e Vouga	118,650	82,825	69.8%	35,825	30.2%
Douro	72,502	59,000	81.4%	13,502	18.6%
Alto Trás-os-Montes	67,065	58,694	87.5%	8,371	12.5%
Baixo Vouga	166,449	114,005	68.5%	52,444	31.5%
Baixo Mondego	137,150	98,554	71.9%	38,596	28.1%
Pinhal Litoral	111,517	86,426	77.5%	25,091	22.5%
Pinhal Interior Norte	47,904	33,118	69.1%	14,786	30.9%
Dão-Lafões	102,344	78,835	77.0%	23,509	23.0%
Pinhal Interior Sul	13,211	10,738	81.3%	2,473	18.7%
Serra da Estrela	14,559	11,498	79.0%	3,061	21.0%
Beira Interior Norte	37,122	31,257	84.2%	5,865	15.8%
Beira Interior Sul	27,594	24,344	88.2%	3,250	11.8%
Cova da Beira	32,333	26,407	81.7%	5,926	18.3%
Oeste	150,007	105,527	70.3%	44,480	29.7%
Médio Tejo	85,330	59,966	70.3%	25,364	29.7%
Grande Lisboa (Greater Lisbon)	888,557	484,396	54.5%	404,161	45.5%
Península de Setubal	321,263	155,365	48.4%	165,898	51.6%
Alentejo Litoral	38,654	31,614	81.8%	7,040	18.2%
Alto Alentejo	47,557	34,854	73.3%	12,703	26.7%
Alentejo Central	77,239	53,854	69.7%	23,385	30.3%
Baixo Alentejo	52,100	38,409	73.7%	13,691	26.3%
Lezíria do Tejo	91,196	67,362	73.9%	23,834	26.1%
Algarve	184,381	142,595	77.3%	41,786	22.7%
R. A. Açores	101,808	86,947	85.4%	14,861	14.6%
R. A. Madeira	107,637	76,430	71.0%	31,207	29.0%

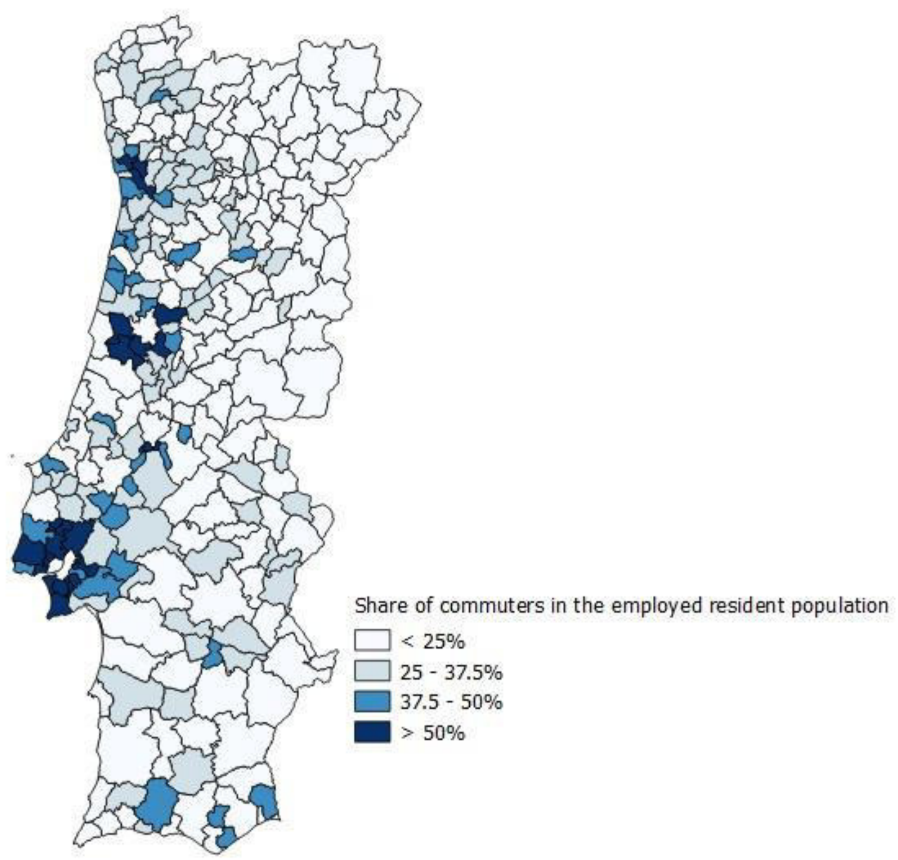
Source: Own calculations based on 2011 Portuguese Census

As Table 11 highlights, there are only 3 NUT III regions where commuting is more intensive than the Portuguese average - Peninsula de Setubal, Greater Lisbon and Grande

Porto. These regions account for more than 55% of Portuguese commuters, and the Lisbon Metropolitan Area is the place of residence for more than 40% of Portuguese commuters.

Figure 2, which depicts the proportion of commuters in the employed resident population, at the municipal level, allows us to geographically identify the municipalities of residence where the commuting flows are more intensive in the Portuguese mainland territory.

Figure 2: Share of commuters in the employed resident population, by municipality (2011)



Once more, Figure 2 highlights the relevance of the Lisbon Metropolitan Area, although it is possible to see that in some municipalities of the Oporto Metropolitan Area and in the Coimbra region there also exists a relevant intensity of commuting. In the rest of the municipalities, the relative number of commuters in each municipality is less relevant (i.e., in most of the municipalities there are less of 15 commuters per 100 employed inhabitants).

The commuting activities happen mainly among neighboring municipalities located within the same administrative region. In Portugal, an average of 11.5% of workers travel daily to other NUT III regions while 32.8% travel to a different municipality. However, there are commuting activities among some Portuguese NUTS III regions, namely affecting the Greater Lisbon region. Table 12 presents the top 5 most intensive interactions between different NUT III regions of workers by place of residence.

Table 12: Share of workers, by place of residence, which commute to other NUT III region (2011)

Place of Residence NUT III	Working Place NUT III	% of working residents travelling between the 2 NUTS III
Peninsula de Setubal	Greater Lisbon	30.8%
Pinhal Interior Norte	Baixo Mondego	15.7%
Oeste	Greater Lisbon	12.9%
Leziria do Tejo	Greater Lisbon	11.2%
Tâmega	Grande Porto	9.2%

Source: Own calculations (based on 2011 Portuguese Census)

Table 12 highlights the critical capacity of the Greater Lisbon region to attract workers that live in other regions. Indeed, Greater Lisbon can attract more than 10% of workers living in the regions of Peninsula de Setubal, Oeste and Leziria do Tejo. Once more, the analysis of the commuting data underlines the relevance of commuting between the Greater Lisbon region and its surroundings (particularly the Peninsula de Setubal region). However, despite the importance of the Greater Lisbon NUTS III region as an important employment center for the population of the neighboring regions, commuting is relatively more relevant among the workers who live within this region.

The description of the commuting flows proves the relevance of this activity in the Lisbon Metropolitan Area. Table 13 details the origin-destiny of Portuguese workers with a special focus on those who work or live within the Lisbon Metropolitan area, comprising the two NUTS III regions.

Table 13: Portuguese workers origin-destiny matrix (2011)

Workplace / Residence Location	Same municipality *(non-commuters)*	Other municipalities *(commuters)*		
		Greater Lisbon	Peninsula Setubal	Rest of the Country
Greater Lisbon	484,396	370,776	13,633	13,044
Peninsula Setubal	155,365	98,762	60,521	4,048
Rest of the Country	2,220,760	36,138	3,855	829,090

Source: Own calculations (based on 2011 Portuguese Census)

According to Table 13, around 45% of those who work and live in the Lisbon Metropolitan area are commuters. Among those living in the Greater Lisbon NUT III region, 55% are non-commuters, 42% travel between municipalities located within the Greater Lisbon NUT III region and 3% travel to the Peninsula de Setubal or to the Rest of the Country to work. In the Peninsula de Setubal, 48% of its employed or self-employed inhabitants are non-commuters, 19% travel between municipalities located within the Peninsula de Setubal NUT III region and more than 30% travel to the Greater Lisbon NUT III region in order to work. So, in the case of Greater Lisbon, the commuting flows are more intense among the municipalities located within the NUT III region. However, the commuting of Peninsula de Setubal residents to work in Greater Lisbon corresponds to a high share of total employed inhabitants in that region and represents the most intensive commuting flow concerning the Portuguese NUTS III regions.

Indeed, among the Portuguese municipalities, those located in the Lisbon Metropolitan Area rank among those with a higher relative share of commuters, well above the Portuguese average number of commuters. Table 14 presents some indicators regarding commuting among the Lisbon Metropolitan Area municipalities.

Table 14: LMA demographic indicators, employment and share of commuters by municipality (2011)

Municipality	Total Population (1)	Employed population living in the municipality (2)	Employed persons working in the municipality (3)	Out-commuters as % of employed population (4)	Workers in the municipality / Employed population (3) / (2)
Amadora	175,558	72,995	51,817	64%	71%
Cascais	205,117	88,656	67,995	45%	77%
Lisboa	545,245	226,622	531,214	17%	234%
Loures	205,577	89,056	68,638	57%	77%
Mafra	76,749	35,603	25,630	44%	72%
Odivelas	143,755	66,107	32,998	65%	50%
Oeiras	172,063	75,820	84,914	56%	112%
Sintra	377,249	168,447	108,673	52%	65%
Vila Fr. Xira	136,510	64,943	42,420	54%	65%
Alcochete	17,565	7,928	7,042	59%	89%
Almada	173,298	70,012	54,293	51%	78%
Barreiro	79,042	30,544	20,800	57%	68%
Moita	66,311	25,439	12,806	63%	50%
Montijo	51,308	22,637	18,486	48%	82%
Palmela	62,549	26,410	27,371	48%	104%
Seixal	157,981	67,887	36,205	60%	53%
Sesimbra	49,183	21,570	13,164	50%	61%
Setúbal	120,791	48,711	45,999	31%	94%
TOTAL	**2,815,851**	**1,209,387**	**1,250,465**		**103%**

Source: Own calculations (based on 2011 Portuguese Census)

Table 14 reinforces the commuting relevance in the Lisbon Metropolitan Area. Indeed, only the Lisbon and Setubal municipalities reveal a relatively small share of commuters among their inhabitants. Odivelas, Amadora and Moita have the most intense outgoing commuting activity regarding their employed resident population, with more than 60% of their resident workers traveling to other municipalities in order to work. In contrast, only 2 municipalities have a lower share of commuters than the Portuguese average (Lisbon and Setubal). In the case of Setubal, this is because this municipality was the head of a former administrative territorial division (Distrito) and therefore some relatively important services are still located there, which refrain the outgoing commuting flows. This is also the reason for the small difference, in Setubal municipality, between employment positions and the employed population living in this municipality. Other municipalities, as Oeiras or Palmela, also have more employment positions than the working population living in the municipality. There are various reasons for this. Due to its geographical proximity to Lisbon, Oeiras has become an important employment center with many firms opting to locate their headquarters in this specific municipality. Furthermore, Palmela is capable of attracting an important share of workers from the neighboring municipalities since one of the most important Portuguese manufacturing plants is located there (Autoeuropa, dedicated to the manufacturing of cars and other vehicles). Figure 3 illustrates, using Geographical Information Systems, the most important commuting flows in the Lisbon Metropolitan Area. Red border defines the Greater Lisbon NUTIII region and blue border defines the Peninsula de Setubal region.

Figure 3: Commuting flows in the Lisbon Metropolitan Area (2011)

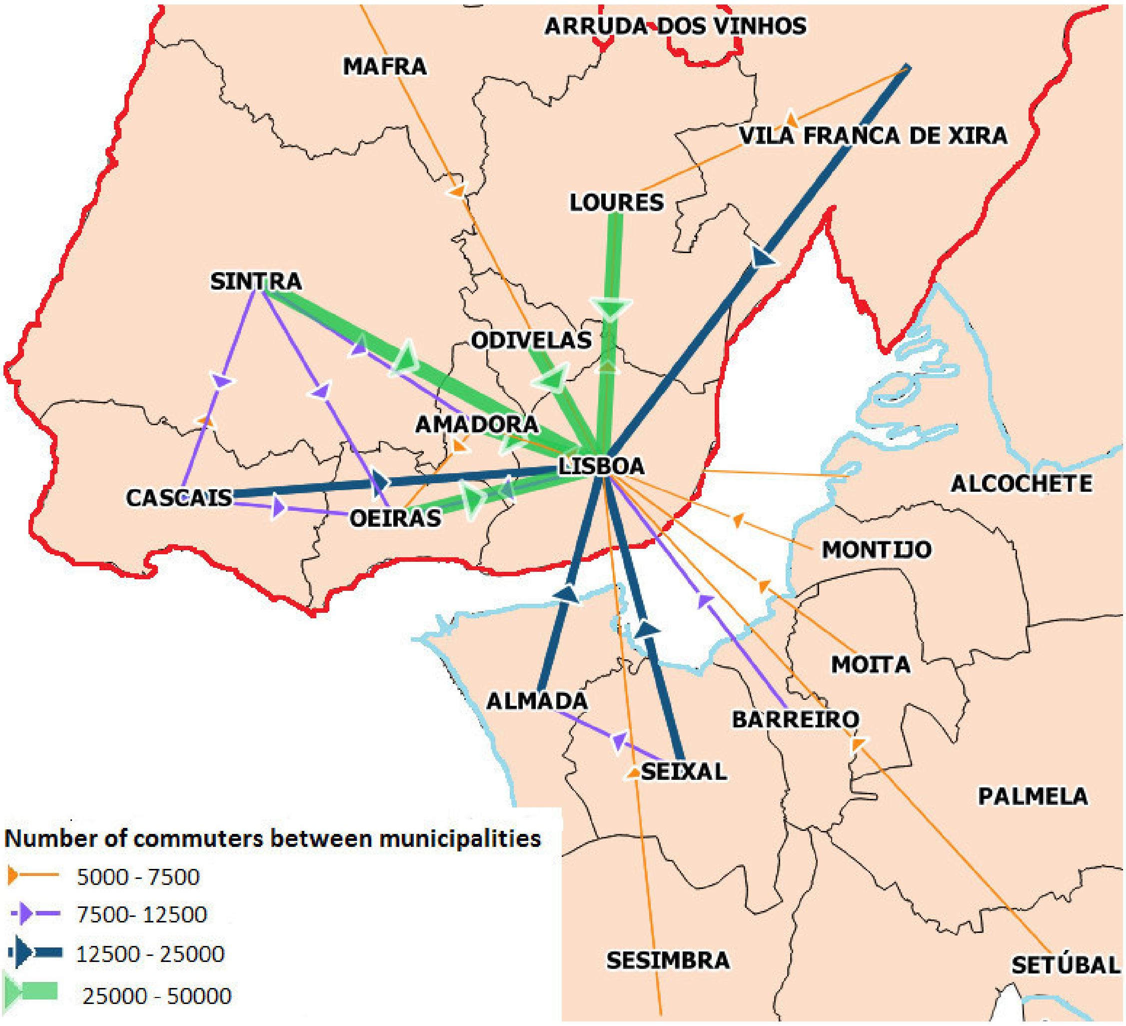
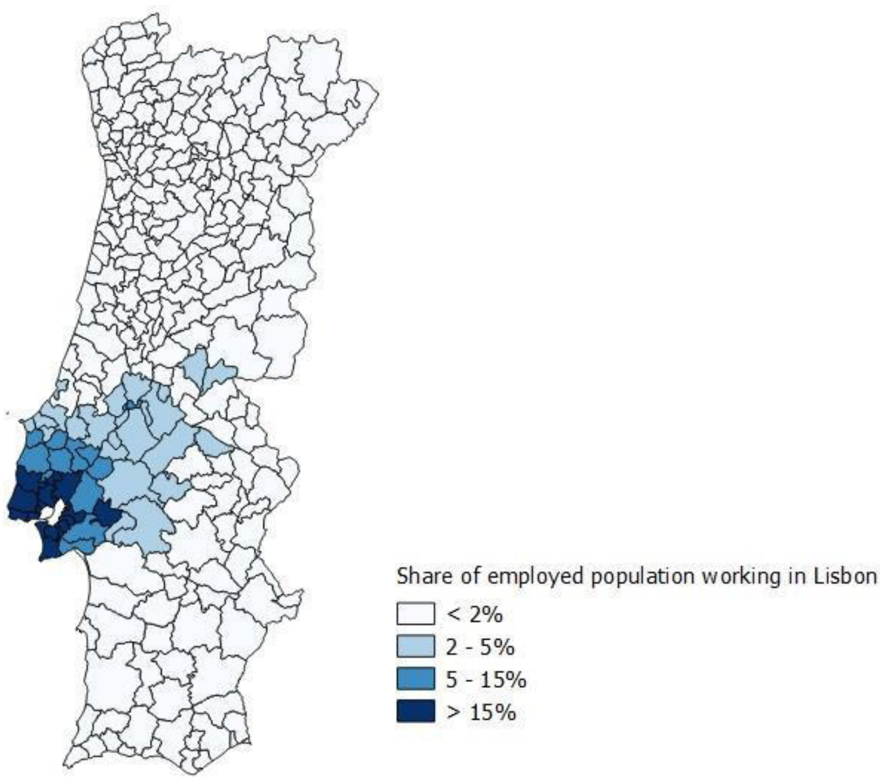


Figure 3 demonstrates the central importance of the Lisbon municipality (with several incoming flows of more than 25 thousand people) while also highlights the existence of some important flows of commuting between other municipalities. But, despite these second-order central places, the case of the Lisbon municipality, the Portuguese Capital, is the most paradigmatic one in Portugal. It is the most important employment center in

Portugal and is the municipality that attracts more workers from different municipalities (in absolute terms and relatively when compared with the number of inhabitants). The attraction capacity is higher amongst the municipalities adjacent to this municipality but its influence extends far beyond its borders. Figure 4 demonstrates the share of the working population that live in a different municipality but work in the Lisbon municipality.

Figure 4: Share of employed population working in the municipality of Lisbon, by place of residence (2011)



According to Figure 4, there is a significant number of municipalities in which more than 15% of their working population travel to the Lisbon municipality in order to work. Most of these municipalities are located in the Greater Lisbon region. Odivelas is the municipality from which the most workers travel daily to the Lisbon municipality (more than 40%). In most of the Lisbon Metropolitan Area municipalities the value is above 30%, including some municipalities located in the Peninsula de Setubal (Almada, Barreiro, and Seixal).

Since commuters travel between different municipalities, they also have to deal with different journeys (in distance and time). A commuter who travels daily between Sintra and Lisbon bears a different "cost" than a commuter who travels between Palmela and Lisbon. Thus, longer trips have higher externality impacts associated with commuting. So, combining the commuter origin-destiny matrix (Table 13) with the distance of each journey (Ferreira et al., 2012), the total amount of kilometers travelled is estimated. This allows us to estimate a new dimension of the commuting phenomenon within a region. Table 15 presents the results of the kilometers travelled by commuters within, coming into or going out of the Lisbon Metropolitan Area.

Table 15: Number of kilometers (10^3) travelled by commuters per day by the LMA workers/residents (2011)

Residence \ Workplace	Greater Lisbon	Peninsula Setubal	Rest of the Country
Greater Lisbon	17,128	1,031	1,757
Peninsula Setubal	5,848	2,529	794
Rest of the Country	5,076	683	-----

Source: Own calculations

As Table 15 demonstrates, commuters in this region travel almost 35 million kilometers every day.[23] Commuters who work in Greater Lisbon are the most important share in terms of travelled-distance (more than 80%). Specifically, those who work and live in the Greater Lisbon region are responsible for almost 50% of the total kilometers travelled. The average distance (combining going and coming back from work) travelled by commuters is also different according to the distinct travel-to-work journey patterns.[24] Table 16 represents the Lisbon Metropolitan Area commuters' average travel distance per day.

Table 16: Daily average kilometers (10^3) traveled by commuters working or living in the LMA (2011)

Residence \ Workplace	Greater Lisbon	Peninsula Setubal	Rest of the Country
Greater Lisbon	46.2	75.6	135.0
Peninsula Setubal	59.2	41.8	158.0
Rest of the Country	140.5	157.1	-----

Source: Own calculations

[23] Based on the 2001 Portuguese Census and on the distance between Portuguese municipalities, Ferreira et al. (2014a) estimated that 59% of the kilometers traveled by inter-municipality commuters correspond to trips made inside the Portuguese metropolitan areas of Lisbon and Oporto, confirming the relevance of these regions to commuting activity in Portugal.

[24] According to Ferreira et al. (2014a), in 2001 Portuguese commuters travelled an average distance of approximately 56 km per day. In 2011, this value increased to an average distance of 64 km per day.

According to Table 16, despite the fact that a large number of commuters are concentrated in the Greater Lisbon region, those who travel from/to the Rest of the Country have to bear longer distances in their commuting activity. Those who travel between Greater Lisbon and the Peninsula de Setubal also account for a larger number of kilometers than those that just travel within the NUTS III regions.

These results highlight the relevance of the commuting process within and between the Greater Lisbon and Peninsula de Setubal regions. Additionally, they also show that despite the important commuting flows among and between these NUTS III regions the commuting activity related to the LMA also affects residents and jobs in other neighboring regions.

Another important conclusion that can be drawn from a more detailed observation of the 2011 Portuguese Census comprises the heterogeneity associated with commuting intensity by different industries located in different regions. To offer an illustrative representation concerning the residential location of the Greater Lisbon and Peninsula de Setubal workers by industry, in Table 17a and 17b, are presented the top 3 industries attracting more (and less) commuters from the other regions included in the model (as well as the corresponding average values).

Table 17a: Industries attracting more and less commuters in Greater Lisbon according with the place of residence of the workers

% of Full-Time Equivalent (FTE) jobs satisfied by workers that live in	**the same municipality where they work**	**Total Share of commuters**	**other municipalities within GL**	**PS**	**RC**
Top 3 industries attracting more commuters					
Water Transport	29%	71%	39%	25%	7%
Air Transport	29%	71%	49%	15%	7%
Computer programming, consultancy and related activities	32%	68%	48%	16%	4%
Average Values	**49%**	**51%**	**37%**	**10%**	**4%**
Top 3 industries attracting less commuters					
Fishing and aquaculture	64%	36%	22%	10%	4%
Manufacture of basic metals	65%	35%	26%	6%	3%
Agriculture, farming of animals, hunting and related service activities	74%	26%	14%	3%	9%

Source: Own calculations

Table 17b: Industries attracting more and less commuters in Peninsula de Setubal according with the place of residence of the workers

% of Full-Time Equivalent (FTE) jobs satisfied by workers that live in	**the same municipality where they work**	**Total Share of commuters**	**other municipalities within PS**	**GL**	**RC**
Top 3 industries attracting more commuters					
Manufacture of motor vehicles, parts and accessories for motor vehicles	32%	68%	61%	5%	2%
Services of renting of other machinery, equipment and tangible goods	44%	56%	27%	18%	11%
Scientific research and development	44%	56%	20%	37%	2%
Average Values	**67%**	**33%**	**26%**	**6%**	**2%**
Top 3 industries attracting less commuters					
Food and beverage service activities	83%	17%	15%	2%	1%
Activities of households as employers of domestic personnel	88%	12%	10%	2%	1%
Fishing and aquaculture	93%	7%	5%	1%	2%

Source: Own calculations

According to Table 17a, 71% of "Water Transport" industry workers in Greater Lisbon are commuters. The industry attracting less commuters among its workforce is "Agriculture, farming of animals, hunting and related service activities" (for which about ¾ of the workers live in their workplace municipality, i.e. do not commute). In average terms, 37% of Greater Lisbon workers commute to municipalities located within the region, 10% live in the Peninsula de Setubal region and 4% live in the Rest of the Country region. Additionally, Table 17b also highlights significant commuting 'attractiveness' differences among the industries located in the Peninsula de Setubal region. In this specific case, the industry with relatively more commuters in its workforce is the "Manufacture of motor vehicles, parts and accessories for motor vehicles" industry (of which 68% of the workers are commuters). In contrast, the "Fishing and aquaculture" industry only embodies 7% of commuters among its workforce.

Commuting is also not homogeneous in terms of the means of transport used in the journey to work (the modal split). Some workers may travel to their workplace on foot, while others may use public transportation or travel by car. In Portugal, and in the Lisbon Metropolitan area, most workers travel by car and the use of public transportation relatively low compared with other countries of the European Union (Eurostat, 2015). However, the modal split depends on the distance-travelled between the place of residence and the workplace. Table 18 represents the modal split in the Lisbon Metropolitan Area and in the Rest of the Country according to the different travel patterns.

Table 18: Modal split in Lisbon Metropolitan Area and in the Rest of Country according with the different travel patterns

Travel Pattern	Main Transportation Used					
	On Foot	Car	Public Transportation			Other
			Bus	Train / Subway	Boat	
	(%)	(%)	(%)	(%)	(%)	(%)
Lisbon Metropolitan Area						
Same freguesia	39.8%	47.5%	9.5%	1.5%	0.0%	1.7%
Other freguesia in the same municipality	5.8%	61.9%	19.3%	11.2%	0.0%	1.8%
Other municipality	0.7%	60.4%	15.2%	19.8%	2.6%	1.3%
TOTAL	**10.1%**	**58.4%**	**15.4%**	**13.4%**	**1.2%**	**1.5%**
Rest of the Country						
Same freguesia	36.2%	55.8%	3.7%	0.1%	0.0%	4.2%
Other freguesia in the same municipality	5.3%	81.2%	9.8%	0.8%	0.0%	2.8%
Other municipality	0.9%	81.3%	10.9%	5.3%	0.0%	1.6%
TOTAL	**14.9%**	**72.3%**	**10.1%**	**1.8%**	**0.0%**	**3.0%**

Source: 2011 Portuguese Census (INE, 2012c)

As Table 18 reveals, the non-use of motorized vehicles in journeys to work is almost exclusive to workers who live and work in the same freguesia and is residual among those who travel among municipalities (either in the Rest of the Country or in the Lisbon Metropolitan area) and is confined to people living and working near the municipalities border. In contrast, the use of cars is above average for those who work in a different freguesia (and municipality) from their place of residence and is relatively more important in Portugal than in the Lisbon Metropolitan Area. Compared with the Rest of the Country, the modal split in the Lisbon Metropolitan Area is mostly characterized by a higher use of public transportation, namely trains, the subway and boat transportation.[25] This happens mostly as a response to two important drivers: first, there are more costs associated with car use (e.g., congestion, higher parking prices, less accessibility to parking, tolls); second, in the LMA there is a more extensive (and functional) public transportation network with urban trains and different bus companies linking several municipalities. Lastly, one important point regarding the modal split is the use of more than one means of transportation. In the Rest of the Country, 12.2% said that they usually use more than one means of transportation when commuting to work. This value is

[25] Boat transportation in the Lisbon region concerns those crossing the Tagus River connecting the NUTS III regions. The remaining commuters in Portugal – in fact a residue - which use boat transportation for commuting purposes are located in the Azores – mainly between Faial and Pico Islands - or in the Aveiro municipality.

significantly higher in the Lisbon Metropolitan Area where almost 25% of the workers stated that they use more than one type of transportation. The number is also significantly higher among those who travel daily to another municipality (31%). The number of workers who use more than one means of transport reveal the importance of multi-modal passenger transportation in the Lisbon Metropolitan Area in comparison with the Rest of the Country.

Finally, commuting activity imposes a burden on commuters in terms of the time spent on their journey to work. Thus, the intense commuting observed in the Lisbon Metropolitan Area is also reflected in the average time spent by workers on their journey to work. According with 2011 Portuguese Census, Table 19 compares the average time spent by workers every day according with the type of transportation used.

Table 19: Average time spent (in minutes) on commuting by means of transport and by region of residence (2011)

	By car	By public transportation	Total
Lisbon Metropolitan Area	22.1	42.5	26.4
Greater Lisbon	21.8	40.7	25.8
Peninsula de Setubal	22.9	47.7	28.0
Portugal	18.0	34.3	20.0

Source: 2011 Portuguese Census (INE, 2012c)

Table 19 highlights that commuting is more time-consuming in the Lisbon Metropolitan Area in comparison with the Portugal average. Indeed, in average terms, a commuter in the Lisbon Metropolitan Area spends 32% more time than the average Portuguese commuter. This difference is smaller, but still relevant, when compared with public transportation commuters (23% more time consumed by Lisbon residents) and car users (more 22%).[26] Indeed, both NUTS III regions comprising the Lisbon Metropolitan Area have higher values of average commuting time duration among the 30 Portuguese NUTS III regions, independently of the travel mode used.

2.5. Final Comments

This chapter started by exploring some economic indicators regarding the LMA. It was possible to observe that the LMA region is a very 'open' region that produces several

[26] The higher gap for commuters as a whole, compared with the analysis by means of transport, mirrors a structure effect. The average time spent by an LMA commuter is basically higher, compared with the Portuguese average, because more people use public transportation and less use their own car.

services and manufactures products for the 'Rest of the Country' as well as others to be exported internationally. Using more disaggregated information, it was made clear that an important share of the manufacturing industries is located in the Peninsula de Setubal but almost all services (except those that must be locally provided) are located in the Greater Lisbon region (and, very likely in the Lisbon municipality and in its proximities). Many of these services' exports correspond to "headquarter services" provided by firms headquarters, located in this region, to the different establishments located sparsely all over the country. According to the National Accounts rules, this kind of service is considered to be an ancillary activity and so is allocated to the main scope of the firm.[27] That is to say, there is not accounted a specific industry to headquarters. For this reason, the headquarters services emerge as exports of wholesale trade, financial or insurance products, human health services, electricity distribution, gas distribution and provision, and so on.

As the LMA concentrates a thrilling agglomeration of people and jobs and an important variety of economic activities, this actually contributes to potentiating the existence of commuting, which, as was shown, assumes a relatively large proportion in this region when compared to the 'Rest of the Country'. This influences the intensity of commuting but also has other important consequences in terms of the modal split, number of kilometers travelled, time spent commuting and the different 'commuter attractiveness' of the industries located in the two regions.

[27] According to the UN (2008: 68), these types of activities are described as including the overseeing and managing of other units of the company or enterprise; undertaking the strategic or organizational planning and decision making role of the company or enterprise; and exercising operational control and manage the day-to-day operations of their related units. Moreover, such units are allocated to the non-financial corporations sector unless all or most of their subsidiaries are financial corporations, in which case they are treated by convention as financial auxiliaries in the financial corporations sector.

How will the cessation of war purchases ... affect the national
level of employment? How many new jobs will be
created by the consumers'demand for an additional
one million of passenger cars, how many of these jobs can be
expected to be located in the automobile industry itself, and how many
in other industries such as Steel and the Chemicals,
the Coal and the Petroleum industries?

W. Leontief, 1941

CHAPTER 3 – MULTI-REGIONAL INPUT-OUTPUT MODELS

3.1. Introduction

Multi-Regional Input-Output (MRIO) models represent a relevant advance regarding the former and most frequently applied single-region Input-Output (I-O) models. Indeed, MRIO models improve the recognition, in an operational way, of the interdependencies established between economic agents located in different regions (Miller and Blair, 2009: 76). As commuting prevails in urban areas, it also contributes to intensifying the interdependencies among industries and households located in different regions of a certain metropolitan region. Thus, an MRIO modeling framework may constitute a suitable approach to assessing the impacts that stem from this particular phenomenon. On the other hand, MRIO models usually demand a significant amount of data that is not directly available from National Statistical Offices.

This chapter is devoted to discussing the different steps in estimating the data that supported the development of the MRIO model applied to the Lisbon Metropolitan Area (LMA). This ongoing "journey", involving mainly researchers of the University of Coimbra, started in 2010. The author of this dissertation was privileged to participate from the very beginning of this challenge and actively contributed as a researcher in every step of this collective construction. . Indeed, the estimation of the first consistent set of I-O regional tables for all the NUTS III Portuguese regions, had its impulse in the scope of DEMOSPIN (Economically Sustainable DEMOgraphy - ReverSing the Decline in Peripheral RegIoNs), a research project funded by the Portuguese Foundation for Science and Technology (PTDC/CS-DEM/100530/2008). This project emerged for the purpose of bridging two scientific areas (economics and demography) and had the ambition of studying how the ageing process and the economic decline could be reversed in the Portuguese peripheral regions. For this purpose, 14 matrices were built, for 2007, one for each focus region. These were single-region models that described, with a relevant level of disaggregation (431 products and 125 industries), the intra-regional flows in each of these regions. One important limitation of single-region I-O models is that they fail to include the full specification of interregional trade. Their most important limitation therefore consists of ignoring trade linkages between regions. In fact, if for example, a region suffers a hypothetical shock, some of the inputs needed to 'deal with' the impact in production come from the remaining regions – spillover effects. The production in those regions may also need to import inputs from other regions (including the one that suffered the initial shock). These effects concern the concept of interregional feedback effects. These kinds of spatial linkages are precisely what distinguishes complete interregional from single-region models (Miller and Blair, 2009: 81)

This specific limitation of the derived regional I-O tables has been overcome, in the context of the following research project, EMSURE (Energy and Mobility for SUstainable Regions, framed under the Energy for Sustainability Initiative of the University of Coimbra and funded by MaisCentro – an operational program in the Portuguese Centro Region funded by the European Union - and the Portuguese Foundation for Science and Technology (CENTRO-07-0224-FEDER-002004). In this case, our specific research objective consisted of deriving a bi-regional model – for the Portuguese NUT II Centro Region and the 'Rest of the Country' – and compiling an extensive statistical database on economy, energy and environment with the aim of generating the required satellite accounts for the NUT II Centro Region. The same approach was also used for other geographic configurations of bi-regional type (e.g. Coast versus Interior of Portugal) addressing other specific purposes. Thus, together with the aim of fulfilling the EMSURE objectives, there was the ambition of compiling a broader database with the goal of amplifying the potential scope of our work. This was the origin of what is hereafter designated the MULTI2C database, a general flexible approach, developed mainly in the University of Coimbra, which allows for the construction of MRIO models for different geographic configurations and empirical applications (aimed at Portuguese regional economies).

Such a process implied different types of frameworks and several research issues were studied in the scope of DEMOSPIN and EMSURE (Barata et al., 2013; Ramos et al, 2013; Ramos et al., 2015). This chapter is specifically devoted to the methodology used in the development of the MRIO framework applied to the LMA. This application has a feature that makes it distinctive from other MULTI2C models: it abandons the bi-regional constraint and aims to build up a tri-regional model. Accordingly, this chapter provides an explanation of the methodology followed. The next section starts by presenting an overview of the characteristics and procedures applied to formatting the MULTI2C data at national level. Next, the process of regionalizing the I-O tables is addressed, namely exploring the interregional trade in the context of bi-regional I-O models. Finally, one of the main characteristic of this thesis frame is presented, namely by exploring the methods applied to derive a tri-regional I-O model for the LMA.

3.2. MULTI2C – Shaping a Portuguese National Matrix for Impact Assessment

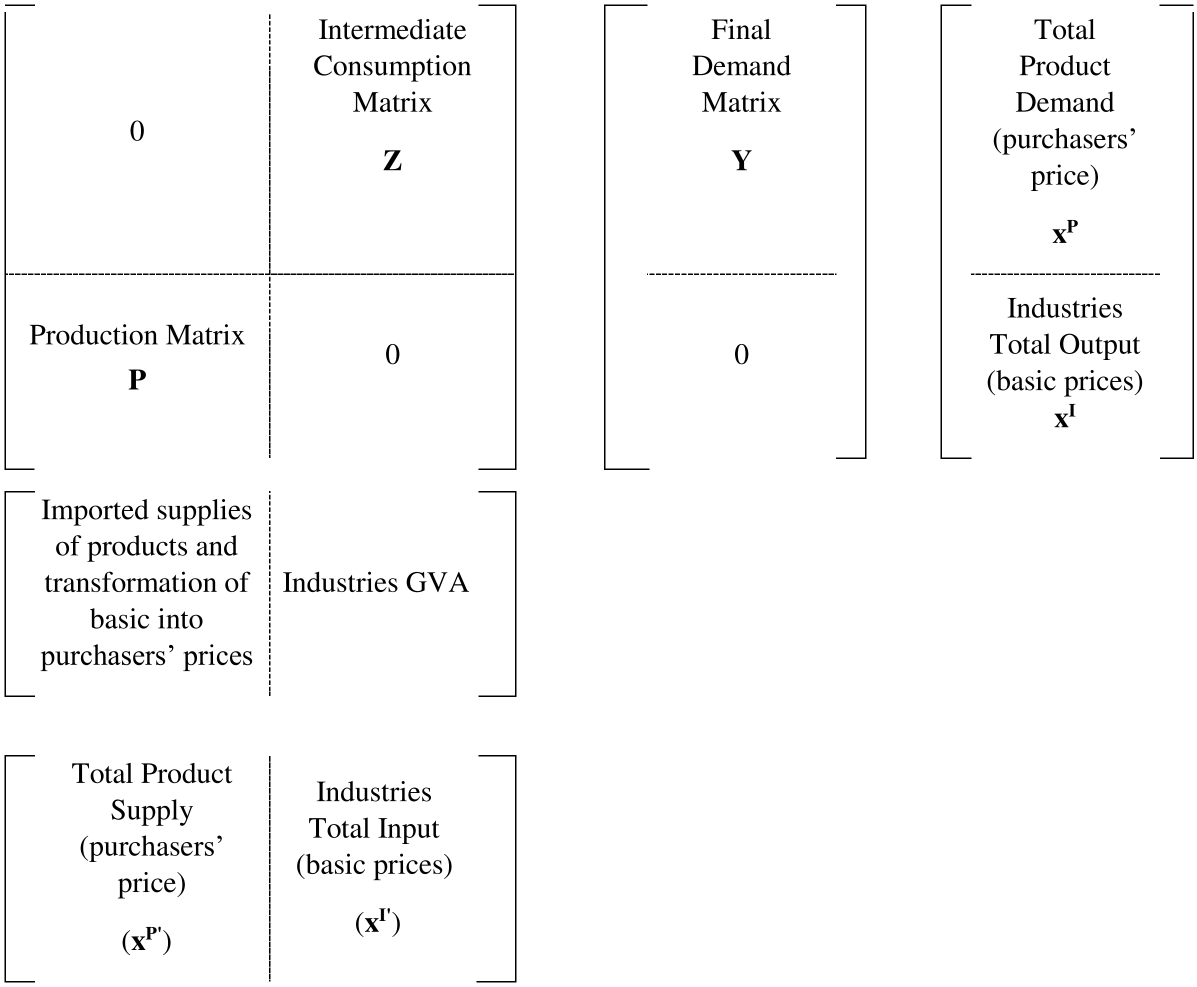
The starting point for deriving the information incorporated in the MULTI2C database (in its most recent version for the year 2010) was the National Accounts (ESA, 1995; base 2006) produced by the National Statistical Institute (INE). From this source, the following were specifically used:

- The Supply and Use Table (with one single column as the origin of the domestic product supplies and including basic information on the decomposition of the industries GVA);
- The Production Matrix - industries that produce the products as primary or secondary products;
- Employment – individuals and full-time equivalent workers by industry.

The Supply and Use Table and the Production matrix have a significant level of detail concerning both the number of products (431) and the number of industries (125) that produce and use them. This framework is also commonly designated as the ‘rectangular’ approach (or the “non-square” I-O frame). In this framework, two dimensions are simultaneously considered (products and industries): the Use table, which describes the consumption of products by the several industries, and the Production Matrix, which represents the distribution of the industries' output by product. According to the System of National Accounts (SNA) (UN, 2008: 18), the term product is a synonym of goods and services, which are always a result of production, either domestically or abroad, in a certain period of time. Additionally, an industry consists of a group of establishments engaged in the same, or similar, kinds of activity (UN, 2008: 87).

In the particular case of the Portuguese Supply and Use Table in its original form, the information that is available is at purchasers' prices and total flows. This means that the cells in the Intermediate Consumption and Final Demand Matrices also account for different Taxes and Subsidies (e.g., VAT and Other Taxes and Subsidies on Products) borne by the different flows. The trade and transport margins are also allocated to the traded and transported products not to their specific industries. On the other hand, those matrices also include the inputs supplied from abroad. The available data was assembled according to Figure 5.

Figure 5: National matrix at purchasers' prices and total flows



The Final Demand Matrix accounted for different product demand types that were not included in the Industries Intermediate Consumption. So, the Final Demand incorporates:

- Resident Households Final Consumption
- General Government Final Consumption
- Non-profit institutions serving Households Final Consumption
- Gross Fixed Capital Formation
- Changes in Inventories
- Acquisition less Disposables of Values
- Non-residents in Portugal final consumption
- International exports of goods and services

As the traditional goal of deriving Input-Output Databases consists of deriving models and applying them to an impact analysis, the use of total flows is a debatable issue. So, despite the fact that an I-O table at "total flows" reflects the total amount of inputs needed by domestic producers, some of the demand shocks measured by the model will be felt internationally (Miller and Blair, 2009: 30). The same concern arises regarding Taxes and Subsidies and the transformation from “purchaser prices” to “basic prices”. According to the UN (2008: 102), “purchaser prices” is the amount paid by the buyer for a unit of output less any taxes invoiced by the seller but deductible by the purchaser. It should be equal to the basic price plus non-deductible taxes on products less subsidies on products and it incorporates the transport costs and trade margins on products, which are not separately invoiced. Thus, the part of the monetary flows among industries, corresponding to taxes, subsidies, benefits, and trade and transportation margins is not set apart when the I-O matrix is at “purchaser prices”. Thus, a bunch of transformations were needed in order to better suit data to impact analysis applications.

Another important transformation was also performed in setting the national frame of the MULTI2C models. The original information provided by the Portuguese National Accounts Supply and Use Tables (INE, 2012a) only considered one aggregated industry describing the inputs and outputs of electricity production and distribution (“351 - Production, transmission, distribution and trade of electricity”). One of the first transformations made consisted of disaggregating this particular sector. There were three different reasons for choosing this option: first, the relevant differences between production and distribution technology (and consequently the respective use of inputs); second, the differences in the inputs used by the different technologies for producing electricity; and thirdly, the aim of simulating the different environmental impacts that could result from the use of different sources of electricity production. Therefore, the procedure consisted in splitting the total production and intermediate consumption of the National Accounts electrical sector by one industry of electricity distribution and 9 industries of electricity production according to the following sources: 1) wind; 2) geothermal; 3) hydro; 4) photovoltaic; 5) coal; 6) fuel oil; 7) natural gas; 8) diesel; and 9) cogeneration. Each of these “new industries” included in the model have a new (and specific) production technology and different Outputs, GVAs and Intermediate Consumption. The procedure applied in this partition is detailed in Ramos et al. (2015). At this point the model was extended, keeping its “rectangular format” and still comprising 431 products, but now having 134 industries (instead of the 125 considered in the National Accounts).

3.2.1. From purchaser to basic prices

The first step in transforming Figure 5, in order to get a more operative scheme, was to adapt it to basic prices. This specific treatment was performed in three different steps. First, the VAT included in each product specific use was estimated. Next, a similar estimation was made regarding the Other Taxes less Subsidies on products. Finally, the trade and transport margins were estimated and incorporated in a specific part of the framework and treated as the production of particular products in the economy.

To estimate the VAT affecting different product uses a VAT matrix was estimated departing from the information obtained from the National Statistical Institute.[28] Non-deductible VAT is supported by both industries and households; however households final consumption supports a VAT average tax rate that is much higher than that supported by industries. The idea is that households, as a rule, cannot deduct the VAT they bear, while the opposite happens for industries (which, as a rule – with a few exceptions – have the prerogative to deduct into the VAT they pay the one they bear in the inputs they buy). Therefore, the actual knowledge of the VAT matrix had an important role in improving the estimation quality. The value of each cell, in matrices **Z** and **Y** of Figure 5, was reduced by amount of the non-deductible VAT actually supported by each product in each use, generating new matrices expunged from VAT. The VAT supported by the industries in their purchases was dragged down to a row (below the Intermediate Consumption Matrix) to keep constant the Industries Total Input. A similar process was also applied in the case of the Final Demand Matrix, generating a new row detached from the former matrix (see Figure 6 ahead).

Next, a similar procedure was applied to expunge Other Taxes and Subsidies on Products from the Intermediate Consumption and Final Demand Matrices. The main difference was the lack of appropriate official information, capable of separating the taxes, less subsidies supported by each product, according to the different destinations. On the other hand, a deductibility mechanism of the VAT kind does not exist for these taxes, such that the exemption according to the destination is the exception and not the rule. So, a matrix of Other Taxes and Subsidies supported by products was estimated assuming the principle of an identical tax rate for each product consumption (with a few

[28] In fact, this information was only available to 2007 but it was updated to 2010.

exceptions, which were the same for all uses).[29] Once again, the cells of the Intermediate Consumption and Final Demand matrices were expunged from the estimated value and the corresponding value was added in the rows inserted below those matrices (see Figure 6).

The last transformation regarded the treatment of the Trade and Transportation Margins.[30] In National Accounts Supply and Use Tables, the total trade and transport margins columns always add up to zero. This happens because the margins' value is reallocated from the industries that generate them, to be incorporated in the purchasers' price of the products upon which they fall. Thus, while most of the products support the "payment" of these margins, there are other products (those included in Tables 20 and 21) that "benefit" from them. In the process of transforming the matrices to "basic prices" these margins are considered to be products of the industries that generate them: the trade and transportation services themselves. The amount of margins that are supported or benefit each of the products considered in the model was found from the National Accounts Supply and Use Table.

According to the level of disaggregation, the trade margins may be seen as four products of the typical trade industries, namely those depicted in Table 20.

Table 20: Products yielding to Trade margins

4501	Wholesale and retail trade services and repair of motor vehicles and motorcycles
4602	Wholesale trade services (include commission trade), except of motor vehicles and motorcycles
4701	Retail trade services, except of motor vehicles and motorcycles and except fuel in specialized stores
4702	Retail sale of automotive fuel in specialized stores

Each trade margin borne by the different products' destination was allocated specifically to each one of the products in Table 20.[31] At this point, the sum of the rows of the Intermediate Consumption plus Final Demand Matrix, associated with these four products, equals, at basic prices, the product production (at basic prices) declared in the

[29] In this distribution, it is considered that the uses associated with changes in inventories and international exports did not, as a rule, support taxes less subsidies. In the case of some specific financial and insurance related products, it was considered that exports also bear taxes, according to the study by Dias (2008).

[30] According to the UN (2008: 102) the margin represents the difference between the price paid by the final purchaser of a product after it has passed through the commercial and transportation chains and the basic price received by its producer.

[31] E.g., the product "Wholesale and retail trade and repair of motor vehicles and motorcycles" exclusively embedded the margins supported by products associated with vehicles and motorcycles. Additionally, the retail trade margins were mostly supported by household final consumption while the wholesale trade margins were divided by the Final and Intermediate uses.

Production Matrix. This rule also applies to the other products, since the total value of their consumption was now reduced according to the supported trade margins.

An identical procedure was applied to estimate and re-direct the incorporated value of the transportation margins in each product use. According to the National Accounts, the transportation margins are considered to proceed from the following products, presented in Table 21.

Table 21: Products yielding to Transportation margins

49012	Freight transport via railways
4903	Freight transport by road and removal services.
5003	Sea, coastal and inland freight water transport

At this point these trade and transportation margins are products by themselves and do not add up to the value of other products. The Intermediate Consumption matrix describes the interactions among products and industries in the Portuguese economy, at basic prices, as defined by the System of National Accounts (UN, 2008: 101): "the amount receivable by the producer from the purchasers for a unit of output. Thus, it should exclude any tax assessed on the output (i.e., taxes on products) and include any subsidies on the output that the producer receives. It also excludes any transport charges invoiced separately by the producer". Furthermore, as the SNA explicitly defines, if the product supports trade margins, it is also necessary to exclude this value from the basic prices (UN, 2008: 103). This transformation was also included. The Final Demand matrix is, likewise, at basic prices.

3.2.2. From total to domestic flows

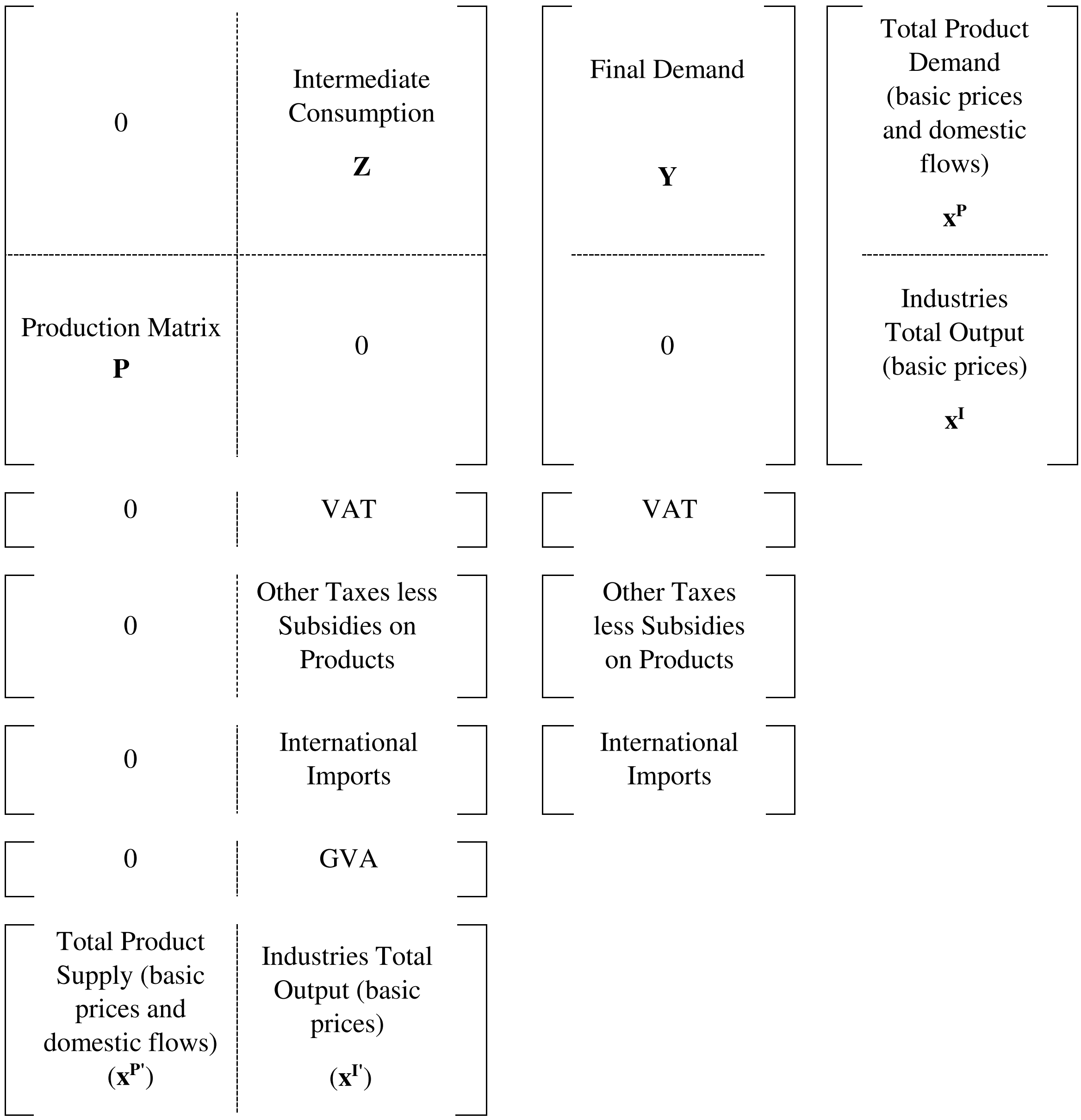
The next step consisted of "transforming" the Intermediate Consumption and Final Demand Matrices from total to domestic flows. This is fundamental in order that the database conforms to the impact analysis. An international import matrix was estimated, departing from the international imports by product from the Portuguese National Accounts. This was made considering the same propensity to import despite the use associated with each product (other industry or the different final demand components).[32]

[32] The exception was for international exports, where it was assumed that they were not fed by international imports, without any national transformation and added value (following Lahr, 2001). The exceptions were the (very rare) products in which the international imports account for, at least, more than 98% of the total supply. This is a reasonable assumption for a non-hub economy such as Portugal.

Using a procedure similar to that used for taxes less subsidies, international imports were dragged down from matrices **Z** and **Y** to row vectors in the bottom part of the table, as shown in Figure 6.

At this point, the National matrix had the design presented in Figure 6.

Figure 6: National matrix at "basic prices" and "domestic flows"



To sum up, international imports and taxes less subsidies on products were reallocated from the supply of the relevant products (or at least those in which their value is incorporated at the purchasers' price) to the industries or other destinations that bear them. Indeed, the rows for Taxes Less Subsidies and International Imports, in Figure 6, refer to the inputs bought by the industries, not to the value of their output. Instead, the Trade and

Transport Margins remain within matrix **Z**, namely in the rows concerning the trade and transport services. This set of matrices was considered adequate to perform an impact analysis in the Portuguese economy. Simultaneously, the whole scheme was considered suitable to proceed with the derivation of regional matrices for Portugal.

3.2.3. A 'Closed' I-O Model

I-O models can be classified into two distinct forms: 'open' or 'closed' models. 'Open' models consider that only the interdependencies among industries are endogenous to the model; 'Closed' models include other economic relations also assumed as endogenous. Miller and Blair (2009: 35) consider that, in the case of households, the "exogenous" categorization is not consistent with basic economic theory. So, as well as the inputs consumption by industries, there is also the use of primary factors by the same industries (labor, capital), from which income generation originates. Households earn income (at least in part) in payment for their labor inputs to production processes, and, as consumers, they spend their income in rather well patterned ways. Therefore, a modification in the amount of labor needed for production leads to a variation in the amount spent by households in response to their income change. This process of income generation, its distribution to households and its conversion in private consumption is to be made endogenous in 'closed' I-O models.

3.2.3.1. Households Consumption

One further important improvement, embraced by MULTI2C models, was made in order to incorporate more detail into the households consumption module, as has been highlighted by several works dedicated to I-O models and regional economics. Kim et al. (2015) take a critical view of most economic models that persist in aggregating all households into one 'representative' household sector. Therefore, it was assumed that households heterogeneity is an important concern, as much as in 2010, the Portuguese economy households consumer expenditure account for approximately 64% of national Gross Domestic Product.

In the MULTI2C approach, household final consumption is split into five different household types, according to the main source of income. This division distinguishes between those living mainly on: labor income, real estate rental income, other capital income, pensions and other social transfers. Those living mainly on labor income included both employees and self-employed workers. However, in the MULTI2C standard model, labor income earners are still not divided into commuters and non-commuters, which can be considered a further source of heterogeneity. This deserves a more in-depth examination in the next chapter of this thesis.

First, total consumption expenditure (at purchasers' prices and total flows) by each household type was estimated considering the (2010-2011 Households Budget Survey – HBS - sample) average expenditure by household type, weighted according to the number of households by main source of income (in the 2011 Portuguese Census). Then, each type of household consumption structure was derived from the information provided by the HBS.[33] Table 22 presents the consumption structures for the different household types, at national level, and their estimated total consumption expenditure.

Table 22: Household consumption structure by main source of income, at national level, at purchaser's prices and total flows.

	Labor	Real estate rental	Pensions	Other Capital	Other Social Transfers
Products of Agriculture, forestry and fishing	3.4%	3.7%	5.7%	3.7%	4.5%
Industry, energy, water supply and sewerage	49.1%	41.2%	48.0%	41.2%	50.4%
Construction	0.1%	0.3%	0.2%	0.3%	0.1%
Wholesale and retail trade services, repair of motor vehicles and motorcycles; transportation and storage; accommodation and food services	13.7%	14.1%	10.2%	14.1%	12.2%
Information and communication services	4.7%	4.5%	4.6%	4.5%	4.8%
Financial and insurance services	6.0%	5.2%	4.7%	5.2%	4.4%
Real estate services	10.2%	11.3%	12.9%	11.3%	13.4%
Professional, scientific and technical; administrative and support services	1.4%	3.0%	1.8%	3.0%	1.0%
Public administration and defense services; compulsory social security; education; human health and social work services	6.2%	9.2%	6.6%	9.2%	5.6%
Arts; entertainment; repair of household goods and other services	5.0%	7.5%	5.5%	7.5%	3.5%
Total consumption (10^6 €)	**64,888 (60%)**	**5,656 (5%)**	**30,613 (28%)**	**1,786 (2%)**	**5,355 (5%)**

Source: Own calculations

Table 22 confirms that there are important differences regarding the household types considered. For example, households living mainly on pensions and other social transfers spend relatively more on housing services or on agriculture products than the other household types. In contrast, households living mainly on labor income, income from real estate renting or capital income, spend relatively more on transport related products, and

[33] As the Households Budget Survey sample had a small representation of households living mainly on other capital income, it was assumed that this household type had the same consumption structure as those living mainly on income from real estate renting activities.

accommodation and food services. Although the consumption of what is identified as commuting related products is only addressed in the next chapter, one may note that important differences are also verified in the consumption of fuel and diesel products (which are included in the manufactured products in Table 22). Indeed, households living mainly on labor income spend almost 5% of their total expenditure on fuel or diesel, while the remaining households spend less than 3.5% on these specific products.

It should be noted that the estimation of the different household consumption structures was made at purchasers' prices and included imported goods and services. After this disaggregation of household types, consumption still had to be converted to basic prices and domestic flows, as described in the previous section.

A final procedure was applied concerning the consumption of "imputed rents". This product is produced entirely by the so-called "renting of own real estate" industry, which is more commonly referred as the "imputed rents activity"[34]. The SNA rules (UN, 2008: 99) suggest that the decision to produce services for own consumption is not influenced by and does not influence economic policy (in the short term) because the imputed values are not equivalent to monetary flows. So, the consumption of this product was separated from the household final consumption and excluded from the endogenous part of the model and included in the Other Final Demand.

3.2.3.2. Households income

One distinctive feature of the MULTI2C standard approach is that the closure of the model may be done, not for the total households final consumption but only for some distinctive groups of households, very often only for those that mainly live on labor income. The assumption behind this method is based on the idea that households mainly living on pensions or other social transfers do not suffer automatic variations in their income (and, therefore, in their consumption) due to changes in industry production (and, consequently, in the income distributed to households).

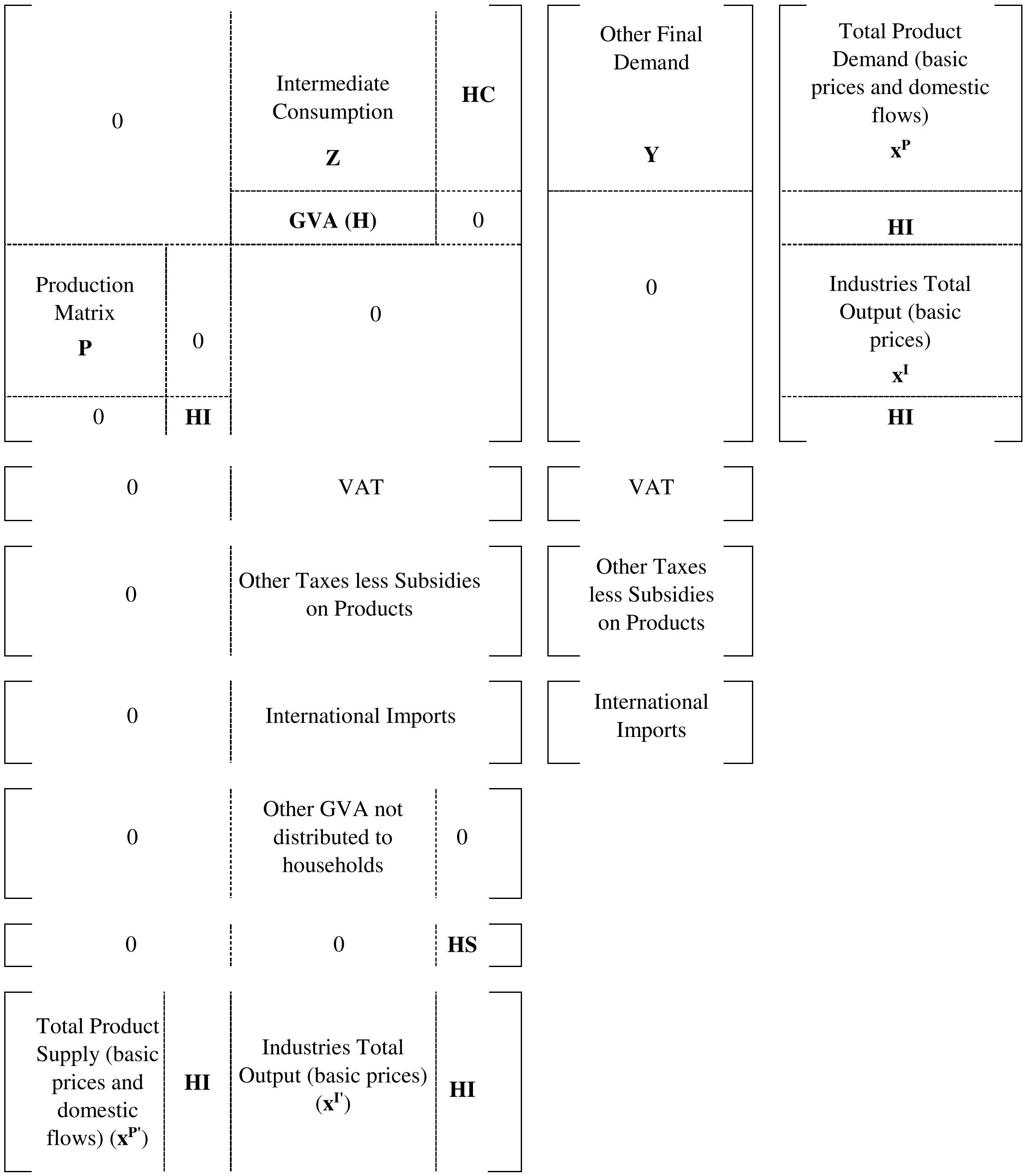
Thus, the estimation of the income share that is directly distributed by each industry to households (in particular to those mainly living from labor) was considered critical, and was deemed to be divided into two distinct parts: the compensation of employees and

[34] The SNA considers that "the production of housing services for their own final consumption by owner occupiers has always been included within the production boundary in national accounts, although it constitutes an exception to the general exclusion of own-account service production" and defines this production as "imputed rental services". So, the SNA specifies that an imputed rental on owner-occupied housing should be included in the production boundary and form part of household consumption (UN, 2008).

the mixed income that is the retribution of own-account workers. The information regarding the compensation of employees by industry was directly available from the National Accounts. However, the estimation of other income distributed to households that live mainly on labor income had to be performed in the MULTI2C construction (namely, the one associated with rewards for self-employment). This income contains an element of remuneration for work done by the self-employed, or other members of the household that cannot be identified separately from the return of the capital owner as an entrepreneur (UN, 2008: 132). Despite this small compensation for capital use, mixed income was assumed in the MULTI2C to be fully accrued to the compensation of employees to determine the total household labor income resulting from participation in the productive process. In the Portuguese National Accounts, only the aggregated mixed-income distributed to households is known. Thus, the value due by each industry was derived considering the share of own-account workers by industry weighted by the average employees' compensation by industry, which was deemed to be an indicator of all labor average compensations.

The mixed income reverting to households mainly living from labor income, in standard MULTI2C models, does not include other relevant income sources by households, namely the one that specifically results from the "renting of own or leased real estate". For owner-occupiers and those leasing dwellings all of the income generated accrues to the operating surplus. This operating surplus is not automatically distributed to households in standard MULTI2C models, and so even if it increases, it does not "fuel" household consumption (of those mainly living from labor income). The next chapter comes back to this point and uncovers some solutions to overcome this exclusion of the induced effects of (actual) real estate rents on private consumption. Closing the model to the household consumption of one (or more) group(s) of households would imply changes in the design of the matrix. In the specific case of closing the model to households living mainly on labor income would result in adding two more columns and rows to the national model (one in the supply matrix part, the other attached to the use matrix). These changes are presented in Figure 7.

Figure 7: Portuguese matrix, at "basic prices" and "domestic flows", and 'closed' to households mainly living from labor



Legend:

HC – Households consumption by endogenous type of domestic products, at basic prices

GVA(H) – GVA distributed to the households types considered as endogenous, by industries

HI – (Endogenous) households total income

HS – (Endogenous) households savings and transfers to other institutional sectors

After estimating the information considered to be essential, at the national level, the process of I-O regionalization began. This procedure is described in the next section.

3.3. MULTI2C – Deriving Regional Matrices

The MULTI2C database has been applied in various works (Ramos et al., 2013; Ferreira et al., 2014b; Parreiral et al., 2014; Ramos et al., 2015a; Ramos et al., 2015b; Cruz et al., 2015). Works stemming from the MULTI2C have used different geographical configurations, according to the issues/subjects addressed. Mostly, when applied in a regional setting, the MULTI2C approach adopts a bi-regional configuration (e.g. Interior-Coast, Centro Region-Rest of the Country - where both of the regions exhaust the Portuguese territory). These flexible geographical representations of the Portuguese economy are only possible because the information is disaggregated at a small scale level (NUTS III level). This sub-section addresses the process of estimating the relatively substantial set of information required for the 30 Portuguese NUTS III. This procedure is applied before the interregional trade estimation, whose description is postponed to section 3.4..

To advance in the derivation of the I-O Tables for the 30 territorial Portuguese NUT III regions (thereby exhausting the Portuguese economy)[35] several data had to be regionally estimated concerning products' and industries' production (domestic supply and demand), households' income and consumption and the uses associated with other final demand components.

3.3.1. Regional Products Supply

With regard to the supply or production matrix (**P**), the goal consisted of allocating the production of the 431 products to the 134 industries that produce them in each of the regions. At this stage, the information available consisted of the output by industry and per region available in the Portuguese Regional Accounts and the national production of each product. Thus, in a 'rectangular' type model, each industry can produce one or more products primarily, but often it can also produce a wider range of products as secondary

[35] In fact there are 31 NUTS III regions. An additional draft matrix of the "Extra-regio" was derived in order to exhaust the Portuguese economy, despite the fact that this does not represent an NUT III region located in the geographic Portuguese territory. According to the European System of National and Regional Accounts (EUROSTAT, 2010), the Portuguese extra-regio territory is made up of parts of the economic territory that consist of territorial enclaves (i.e. geographic territories situated in the rest of the world and used, under international treaties or agreements between states, by general government agencies of the country — embassies, consulates, military bases, scientific bases etc.).

production (i.e., the production of other industries' primary products). Primary production corresponds to the most important share of production by each industry. As secondary production is (significantly) less important, it was assumed that the secondary production structure was the same as the national one by industry, independent of the regional location.

The estimation of each primary product production for the Portuguese NUTS III regions was performed using several sources, with the goal of finding proper information to allow a realistic allocation of its product production among the national territory. The information was based on:

- The 2009 General Agricultural Census – for the 63 Agriculture Products[36]
- The 2010 National Forest Inventory – for the 11 Products of Forestry[37]
- The 2010 Gross Production of Electricity by type of production – for the electricity produced by production source.
- The 2011 Employment records of the Ministry of Labor and Social Security and the Portuguese Population Census – for the remaining 355 products.

The distribution of the different products throughout the Portuguese Territory that resulted from these different information sources was used to provide a first input to the estimated national distribution of production among the industries in the NUTS III regions. The final results concerning product production in each industry located in each region were obtained using the RAS[38] method, keeping constant the regional industries' output values (according to the Regional Accounts data) and the total products' national outputs (according to the National Accounts data).

An exception to this algorithm concerns electricity production and distribution. Indeed, information on production, GVA and Intermediate Consumption, at the regional level, was absent in the official Regional Accounts, for each of the ten sectors that were

[36] The most recent Agricultural Census is from the year 2009 (INE, 2011d).
[37] The Portuguese National Forest Inventory (ICFN, 2013) is a responsibility of the Nature Conservation and Forests Institute.
[38] According to Sargento (2002) this is a bi-proportional algorithm adjustment method applied with the goal of estimating a final matrix, departing from an initial matrix with relevant information and recalculating the distribution among the cells, keeping stable the total values of each row and each column. Miller and Blair (2009), who also address and describe this method, point to a newer reference: a special issue of Economic Systems Research (2004), on "Biproportional Techniques in Input–Output Analysis," and, most specifically, the article by the editors (Lahr and De Mesnard, 2004).

considered. Therefore, to estimate these indicators, the method consisted of using several data sources to split the national production by the different regions.[39]

3.3.2. Regional Intermediate Consumption

The estimation of domestic demand of intermediate products by region implies the adoption of more assumptions. In an I-O model, the columns with the total flows (domestic plus imported inputs) of the Intermediate Consumption matrix consist of each industry's production technology. To estimate the whole intermediate consumption associated with each industry, in each region, the information on Regional Accounts was used, namely the Output and the GVA, both by industry and by region.

Departing from such statistical information, the total Intermediate Consumption by industry and by region was estimated from the relation:

$$\text{Intermediate Consumption} = \text{Output} - \text{Gross Value Added} \qquad (1)$$

The specific demand for inputs by each industry (at the total flows level) was estimated assuming identical technology by industry for all of the regions, i.e. the Intermediate Consumption structure among the 431 products for each industry was kept stable. However, the distribution of the Output between Intermediate Consumption and Gross Value Added was different in different regions, as explained above, in accordance with the information of the Portuguese Regional Accounts. The decomposition of the total flows between the domestic and internationally imported shares proceeded from assuming the same partition in all regions, such that the gathering of regional matrices is consistent with the national one depicted in Figure 7. This allows for obtaining regional matrices to which regional inputs are nationally supplied. The determination of the regional origin of these products is explained in section 3.4., where the estimation of interregional trade is addressed.

An exception to the rule of identical technology by industry for all regions was the specific treatment of the refined petroleum industry. The adoption of this assumption hides the actual regional disparity of its input structure. Indeed, while there are two

[39] The Portuguese National Statistical Institute data (INE, 2015a, 2015b) to estimate total electricity production, as well as total electricity produced by cogeneration plants; information from the Statistical Department of the Ministry of Labor and Solidarity (GEP-MTSS, 2011) to estimate the number of workers concerning the distribution sector; the reports published by companies that manage thermoelectric power plants (EDP Produção 2011, 2012, 2013; Turbogás/Portugen, 2011; Tejo Energia/Pegop, 2011; EEM, 2008, 2011) to estimate the energy produced by non-renewable sources, in each region. See Ramos et al. (2015a) for a detailed description of the procedures regarding the 10 industries of electricity production and distribution regional production estimation.

refineries operating outside the Lisbon area (that consume the main specific inputs – raw petroleum and other raw materials - directly related to the production process of refined products), the production in the LMA region is confined to the headquarters contribution, and so only requires goods and services associated with management activities. Accordingly, it were assumed different production technologies for each region, based on the Regional Accounts' information (regarding compensations, Gross Value Added and production) and taking into account the actual location (and production) of the refineries in Portugal.

3.3.3. Regional Households Income and Consumption

As explained above, in the MULTI2C approach, household final consumption is split into five different household types, according to the main income source. This partition distinguishes between those living mainly on: labor income, real estate rental income, other capital income, pensions and other social transfers. Those living mainly on labor income included both employees and self-employed workers. So, at this stage the household consumption of the different household types was also regionalized for the 30 NUTS III.

The total household final consumption per region (at purchasers' prices and total flows) was estimated according to the "proportion of purchasing power" by geographic localization (INE, 2013a). Then, the consumption expenditure for each household type by region was estimated considering the average expenditure by household type weighted by the number of households by main income source (in the 2011 Portuguese Census), in each region. This procedure provided a first rough estimation, but the regional expenditure sum by each household type was not consistent (yet approximate) with the total national consumption for each household type. Therefore, the RAS method was applied and consistent values were estimated for final consumption by region and for the five household types.

Next, the Household Budget Survey provided different consumption structures for each household type[40] in each of the NUT III regions[41]. The RAS method was applied

[40] Similarly to the procedure adopted at national level, due to a small representation in the Household Budget Survey sample, the consumption structure of those living mainly on capital income was assumed to be similar to those living on the income from real-estate renting activities.

[41] The 2010-2011 Household Budget Survey regional disaggregation is statistically significant only at the NUT II level. Accordingly, it was assumed that in those NUTS II comprising several NUTS III regions, the households consumption structure at the NUTS III level was identical for each household type.

once again to ensure that the regional households' consumption by products were consistent with the former estimation of national consumption by products, and the total regional consumption by household type and by region. However, the process described above was conducted using purchasers' prices and total flows, such that the subsequent transformation to "basic prices" and "national domestic flows" was only performed in a second step. The VAT, the Other Taxes and Subsidies supported by products and the International Imports associated with the final household consumption by region were estimated keeping stable the total values obtained at the national level. Please remark that different regional consumption structures also imply different average tax rates and different average propensities to import.

MULTI2C models are commonly applied, using the standard approach, as 'closed' in relation to households that live mainly on labor income. Thus, the estimation of the income share that is directly distributed by each industry, in each region, to the households (in particular to those mainly living on labor income) was considered to be critical. This income is divided into two different income-types: the compensation of employees and the mixed-income resulting from the own-account workers' contribution. Firstly, household income associated with the compensation of employees was obtained directly from Regional Accounts. However, Regional Accounts do not directly provide the household income associated with the mixed-income. Therefore, the estimated mixed-income by industry at national level was regionally distributed according to the distribution of own-account workers by industry and by region.

These specific procedures led to two independent processes to estimate the labor income and the consumption of households within each of the regions, resulting in different propensities to consume by region.

Two important remarks should be made at this point. First, the procedure explained in this sub-section to derive product final consumption by region is, as yet, an incomplete process (this is similar to the intermediate consumption context as explained before). So, at this moment, it only represents the final consumption by regions of nationally (still not regionalized) supplied products. The determination of each specific regional origin is explained in section 3.4.. Secondly, the assumption that income is entirely earned by households living in the same region where the industry is located is very restrictive (moreover, if taking into account the commuting phenomenon). This option can be considered acceptable when dealing with regions where commuting into neighboring areas is negligible, but a more in-depth treatment should be applied when dealing with regions where commuting and/or shopping flows are intense between them (Oosterhaven and Folmer, 1985; Hewings et al., 2001; Ferreira et al., 2015a). This second issue will be deeply explored in chapter 4.

3.3.4. Regional Other Final Demand

To complete the regionalization of all of the elements of the 30 I-O tables, the last information to be estimated consisted of the remaining elements of the other final demand (considered in the exogenous part of the MULTI2C frameworks).

First, the approach to estimating the other final demand components followed a different rationale to the one applied to the intermediate or household final consumption. In this particular case, our method consisted of estimating the specific demand directed to each region's product production (independently from the region where the demand originated). The lack of information associated with the differences in demand by region did not allow for more accurate estimations. The starting point for this specific part of the model reflected only the domestic flows (expurgated from international imports) at basic prices. These specific components (General Government and Non-profit institutions serving households final consumption, Fixed Capital Formation, Changes in Inventories, Acquisition less Disposable of Values and International Exports of Goods and Services) were regionalized by product according to the regional share of the product production. The most important exception to this rule was the demand for Construction related products associated with Fixed Capital Formation. As, by definition (and according to the Regional Accounts rules), Construction is regionally recorded as being produced in the construction actual place, these specific cells assume the values that equal the supply to the demand of each product in each region.

Then, the final consumption of non-residents in Portugal (a last final demand component) by region was estimated resorting by default to the number of nights spent in touristic establishments, by region, by non-residents in Portugal. This distribution was used except for two specific (but very important) products. First, to estimate the regional consumption of the product "Services of Hotel Accommodation" the number of nights was weighted with the "Average revenues per hotel room by geographical localization" (INE, 2011c), in order to include the regional price disparity in the provision of this specific product. Second, the number of same-day visitors at the frontier with Spain (INE, 2013b) was considered and accounted for the non-residents' consumption of "Food and beverage service" product.

The application of multiple steps and the procedures described allowed for regionalizing the total demand associated with the industries' intermediate consumption, households' final demand and other final demand, and for distinguishing between the "uses" associated with the national domestic supply of products and internationally imported inputs. These uses take place in each of the regions, but the origin of the demanded products is still referred to Portugal as a whole. Thus, an additional purpose consisted of regionalizing the different products' origins. As already mentioned, in the application of regional I-O models, an important step should focus on the estimation of the interregional trade affecting the different products and their uses in each of the regions considered within a specific framework. Taking into account the different methodologies associated with the estimation of interregional trade, an in-depth discussion of this particular (and critical) procedure is addressed in the next sub-section.

3.4. MULTI2C - MRIO Matrices and Interregional Trade

Multi-Regional Input-Output frameworks extend the scope of I-O models by incorporating the interactions between industries (and households) among different regions. Miller and Blair (2009: 76) explain that this is an important advantage when compared with single-region models since one important flaw of these models is that they do not recognize the interconnections between regions. In the case of Portugal, MULTI2C models have emphasized the existence of spillovers and feedback effects. For example, Ramos et al. (2015a) evidenced that the production of "processed food products and beverages" in the Interior of Portugal, even inducing some demand by agricultural products in the same region, has important spillovers concerning other inputs (for example "pesticides and other agrochemical products"), which leak to the Coastal region.

The process of deriving the I-O tables for the Portuguese NUTS III regions presented until now did not address one important issue: interregional trade estimation (and, consequently, intra-regional domestic demand). Indeed, in the procedures presented up to now, the derived production and use matrices by regions already provided the total products' regional demand and supply, in each NUTS III. The difference between each product's supply and demand gives the total amount of net exports. Thus, if one region produces more of a certain product than its regional demand for that product, the "residual" value is the (net) export to other regions. This method is commonly referred to as the commodity-balance method, since it relies upon the balance that must hold between total supply and total demand for each commodity in each region. The total regional supply is equal to the sum of regional output and regional imports; the total demand is given by regional requirements plus regional exports. Therefore, the difference between the total supply and demand at regional level must equal regional exports less imports. Following Jensen-Butler and Madsen (2003), the first steps in the MULTI2C interregional trade estimation consist of computing the net exports of the 431 products in each region.

Then the net trade can be estimated for each product in each of the 30 NUTS III regions considered in the MULTI2C database in a straightforward way. However, separate knowledge of gross exports and imports and the interregional trade matrix involving all of the regions is needed in order to derive a MRIO framework. In the case of a bi-regional model (where both regions exhaust the Portuguese economy), this problem becomes less complex to solve, as one region's exports are the other region's imports (and vice-versa). Miller and Blair (2009) refer to the major difficulty in the application of many-region I-O modeling: the estimation of the transactions between regions. Indeed, MRIO models imply the complete characterization of the destination of the products produced in each region and the specific "use" that each product will satisfy independently of the region in which it is consumed. In bi-regional I-O models, this involves the estimation of two interregional trade matrices (products produced in region A are used in region B, or vice-versa); however the requirements can grow quickly as the number of regions increases - a three-region model has six interregional matrices, a four-region model has 12, and so on. Each of these interregional matrices is composed of cells that record the transaction of products produced in one region and their specific use by an industry located in another region.

Therefore, the commodity balance method alone does not solve the problem of estimating the interregional trade flows. The problem of obtaining gross exports and gross imports from the net trade balance is designated the crosshauling problem (Sargento, 2009) and results from the realistic observation that economic agents in a given region can import a product that they also export (and vice-versa). Polenske and Hewings (2004) consider that this problem should be addressed as it is expected that crosshauling continues to increase (worldwide) for two major reasons: first, regional trade leakages are growing in sophistication as firms look across the whole country (or even internationally) to find the most cost competitive locations in which to produce; and second, the increasing search for product differentiation, with consumers seeking greater variety in differentiated products (that can be produced locally or in other regions).

The crosshauling problem could easily be approached if some relevant data could be estimated through survey methods or if more data were to be made available by the Statistical Institutes. However, the process of deriving interregional trade flows among regions can be a serious difficulty when there is lack of data on interregional trade statistics, as is very often the case, and is also true in the Portuguese case. The implementation of a survey capable of describing the interregional trade of products is considered to be too expensive (Richardson, 1985: 624) and time consuming (Miller and Blair, 2009). Therefore, the problem of crosshauling must be solved through the application of statistical methods to estimate the interregional flows consistently. These methods are commonly referred to as non-survey methods applied to estimate the interregional trade among regions. Other "hybrid" approaches are also proposed, in which some kinds of relevant information (from small focused surveys, expert opinions, etc.) are incorporated into another "non-survey" procedure.

In these "hybrid" approaches, the crosshauling share is not settled on a complete ad-hoc basis, but rather, is based on some information on interregional trade flows available from transport statistics (Stevens et al., 1989; Ramos and Sargento, 2003). However, this is not a straightforward solution, given the known drawbacks of transport statistics. In the Portuguese case, Ramos (2001) refers to two relevant problems (among others) related to transport statistics. First, these statistics do not provide information on service flows, since these are not carried in the usual way (roads, railways, etc.), on which these statistics focus. Second, Portuguese transport statistics flows are expressed in physical units and do not accurately describe the value of the commodity (being transported). This last problem is reinforced by the fact that for road traffic data, the sampling process excludes all vehicles below a certain level of capacity, which sometimes are the ones responsible for transporting the most valuable goods.

To overcome these difficulties, the most usual solution is to apply non-survey methods. Many different methodologies have been suggested. Some of them are based on the Simple Location Quotients (SLQ) as a measure of the relative specialization of a given region in producing a certain product. In such specific works it is assumed that if the production of a certain product is more concentrated in the region than in the nation as a whole (SLQ>1), then all of the requirements of the product to meet intermediate and final consumption are provided by the region itself. Conversely, if a region is relatively less specialized in the production of a given product than the nation as a whole (SLQ<1), then it is assumed that some of the regional requirements of that specific product have to be imported (Miller and Blair, 2009). The problem with this simplified approach is that it ignores crosshauling when the region is a positive net exporter of a product. When SLQ>1 there are no imports and net exports equal gross exports. This is an extremely simplistic approach, given that net flows can, for certain products, be a very small share when compared to the gross values of exports and imports (Susiluoto, 1997). For example, if there exists a positive residue in “wine products” in a certain region, it is not a sufficient (and realistic) assumption to admit that all of the industries and households located in that particular region will only consume local wine.

A second problem with SLQ is that the concentration of production of a given product at the national level may not be a good proxy for the demand directed to one region. For example, one region may have an SLQ > 1 for one product, but it may be specialized in another product that uses the former one intensively as an input. In that case, it may have to import the product from other regions in spite of the fact that the SLQ exceeds unity. To overcome this second problem several consecutive adjustments have been proposed in the literature. A first variant was the Cross-industry quotient (CIQ). This allows for differentiating cell-by-cell adjustments within a regional matrix rather than using uniform adjustments along each row – mainly taking into account the relative importance of both the selling industry and buying industry in the region and in the nation. This development has led to other methodologies such as the one proposed by Flegg and Webber (1997), the Flegg Location Quotient, or the Adjusted Flegg Location Quotient, also proposed by Flegg and Webber a few years later (2000). However, the majority of the applications of these sophisticated methods do not solve the problem of null crosshauling, at least for products in which the region is a positive net exporter. Nevertheless, this is still an ongoing debate and research continues to be published every year regarding the determination of interregional trade. Reinforcing this, Miller and Blair (2009: 362) compared the results obtained by different statistical methods and concluded that some of these techniques result in the overestimation of the output multipliers while others contribute to underestimating. So, it is possible to conclude that the ‘perfect’ method is not yet known.

Another relevant proposal to estimate interregional trade flows is the so-called Moses Technique (MT) (Harrigan et al., 1981), in which specific proportions are assumed to describe the way each origin (the region itself, the rest of the country and the rest of the world) contributes to the total supply of a certain product in a given region (i.e., they represent the average import propensity of a product according to different products' origins). After this, the intra and interregional imports may be computed. This and other similar models are always dependent on the determination of ad-hoc parameters to compute interregional flows. Many works (Oosterhaven and Stelder, 2007; Pereira et al., 2013) have mentioned the relevance of determining distinct parameters in establishing different interregional trade flow estimations.

Three important conclusions can be highlighted from this ongoing debate. The first is the importance of the statistical information disaggregation level. After referring to several works that propose different methodologies to estimate the interregional trade flows, Miller and Blair (2009: 363) assume that the results vary widely and "as always, the results often depend on the statistic(s) used to rate the techniques". However, in a former work, Madsen and Jensen-Butler (1999: 297) also consider that "the principle of applying a high level of disaggregation, both in terms of commodity and geography, reduces the problem [of determining regional gross imports and exports] somewhat".

Second, another important conclusion is related to the influence of the nature of the product. Miller and Blair (2009) bring up this problem when comparing the expected trade flows between Coca-Cola (which has the same recipe all over the world) and other more specialized products. A more broad comprehension of this problem can arise since different products in a certain region have different preferences associated with the local or non-local consumption. For example, even within food industry products, it can be expected that people consume more locally produced bread than e.g. "processing and preserved fish, crustaceans and mollusks". Finally, assuming that the imported share of each total use flow does not vary with the type of use is also a relatively important simplification. In reality, sometimes intermediate uses tend to reflect a greater import propensity than final uses and some final uses tend to show a lower import propensity than others (Sargento, 2009).

Since the main goal in applying the MULTI2C data generally consists of performing an impact analysis for different scenarios directed to specific geographical configurations, a pragmatic methodology was followed in order to solve the specific issue of gross interregional trade estimation, making the best use of the disaggregated information and of the team specific knowledge on different products produced in Portugal and their respective uses.

In order to deal with the heterogeneity between products, distinct hypotheses are considered for each of the 431 products, according to their specific characteristics (tradable, non-tradable or others), as presented by Ramos et al. (2013), Ramos et al. (2015a) and Ramos et al. (2015b). In some (although rare) cases the product classification also depends on the use. More often it may vary with the region in analysis (taking into account that these models developed under the MULTI2C scope refer to different regions). Accordingly, each product can be included in one of two extreme categories, which have a 'simple' solution for the coefficients:

- type A products are regionally non-tradable, i.e., products that must be produced in the same region where they are consumed, and consequently are not imported from other regions.

- type B products are fully tradable, international and interregional, i.e., products that move between regions at no (or non-significant) cost, namely within a small country like Portugal; in this situation, our proposal is that the weight of local sourcing is supposed equal to the region output weight of that product in the national total.

A significant number of products fall into one of these two extreme types, A or B, and so a straightforward criteria exists for determining the corresponding entries in the construction of the regional input coefficients matrix. There are however exceptions to this binary classification. Indeed, some products fall into an intermediate category:

- type C products are regionally tradable between specific regions, sometimes with nearby regions, and in other cases with regions that for some special reason assume a special role. The first condition includes products with significant shipping costs, or other restrictions to their mobility between regions (typically these products are largely produced in the region in which they are consumed, but they may be partly imported from neighboring regions/countries). Another interesting situation leading to the classification of some products such as type C is the "headquarters effect". Indeed, some services' demand is locally revealed, but is met by nationwide companies that have a significant part of their business located in the national or regional headquarters. Although this is essentially locally satisfied demand, production occurs partially in other regions, which is equivalent to the import from these regions, a fraction of the total product output.

This procedure generates a first estimate of the gross interregional trade in both regions. As explained before, gross imports depend on the type of product classification, net interregional exports are previously known and, therefore, gross exports are obtained by adding them. Moreover, one important feature of a two-region interregional model is that one region's (domestic) exports of a particular good have to be the other region's (domestic) imports. However, contrary to what is observed in net interregional trade, where this rule arises as long as a consistent procedure was assumed, for interregional gross trade, most of the product's gross imports do not match with the gross exports of the same product in the other region. It is therefore essential to consider an additional adjustment, based on an iterative process, that a simultaneous increase in one product's interregional exports and imports in one region, is combined with a simultaneous reduction in the same product's exports and imports, in the other region, until the interregional trade gross flows are equal. The distribution of these adjustment weights is made according to the product's relative output in both regions.

At the end of this process, the interregional estimated flows are consistent in both regions (when dealing with a bi-regional model). However, a challenge addressed by this thesis is to extend the MULTI2C approach to a tri-regional I-O model. So, the next sub-section is devoted to the approach being applied to derive a tri-regional I-O framework to the Lisbon Metropolitan Area. This was a pioneer objective in the context of MULTI2C applied works.

3.5. Stepping Forward: A LMA Tri-regional I-O Model

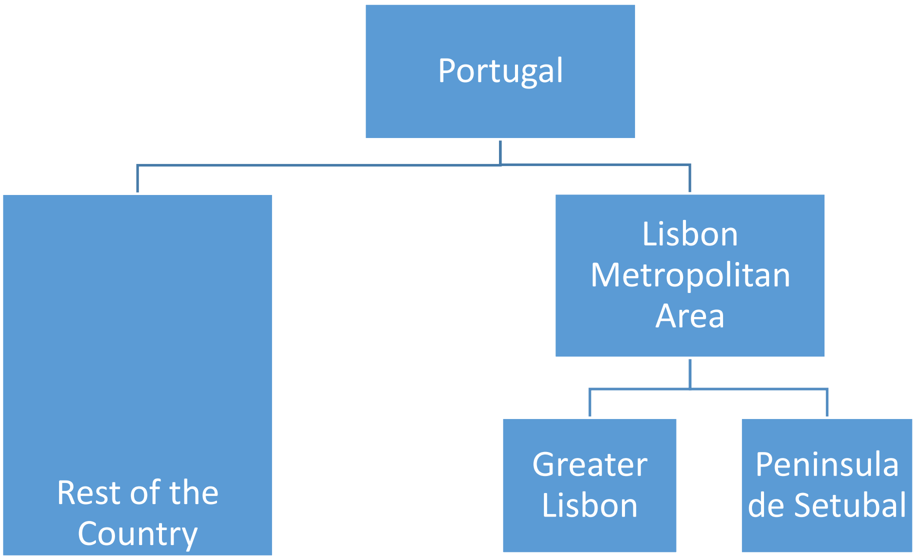
As the objective of this research is the application of this modeling framework to the LMA, the consideration of two regions is too restrictive, namely due to the important commuting flows between the Greater Lisbon and the Peninsula de Setubal regions (as presented in Chapter 2). On the other hand, these two regions are different NUTS III within the available Portuguese statistics, and therefore they have their own detailed information in the MULTI2C database. Thus, to achieve the goal of better understanding the dialectic relationship between commuting and production, a model with 3 regions - Greater Lisbon area, Peninsula de Setubal and the 'Rest of the Country' – was considered essential.

3.5.1. Deriving Regional Matrices and Trade estimations

One major difficulty arises in an MRIO model with more than two regions. This problem is associated with determining which region(s) is/are the destiny and which one(s) is/are the origin of the interregional trade flows. Therefore, the "calibration" of a more than two-regional model is not straightforward. As the purpose consists of deriving a tri-regional model, an estimation for each kind of flow, 3 intraregional matrices and 6 interregional matrices, is mandatory.

To solve the problem of the interregional trade, i.e. determining the origin and destination of domestic imports and exports between the two NUTS III regions, a "cascade-stepwise procedure" was applied, as represented in Figure 8. The idea was, in the first step, to construct bi-regional models for the LMA and the 'Rest of the Country'. Afterwards, in a second step, the LMA is split into its two NUTS III: Greater Lisbon and Peninsula de Setubal. Using this methodology the interregional trade flows between more than 2 regions is solved as each step only reflects the estimation of gross imports and exports between two regions. Therefore the procedure applied to estimate the interregional flows between the LMA and the Rest of the Country regions is "almost replicated" to estimate the interregional flows between the two NUTS III (Greater Lisbon and Peninsula de Setubal) that comprise the LMA.

Figure 8: "Cascade-stepwise" derivation of the MRIO flows and matrices



There is however a remaining problem that is not yet solved through the cascade stepwise procedure. The exports from the LMA to the 'Rest of the Country' have to be split by the two NUTS III, and the same applies to its imports. The distribution of the LMA imports, which are the exports from the 'Rest of the Country', among the two NUTS III regions, was in accordance to the share of each product's "use" (from domestic total flows) in each of the regions. From this estimation it is possible to identify the imports made by the Greater Lisbon and Peninsula de Setubal regions from the 'Rest of the

Country' (or, in other words, the production in 'Rest of the Country' aimed to satisfy the Greater Lisbon and the Peninsula de Setubal demands). Additionally, the total exports from the LMA were split between the Greater Lisbon and Peninsula de Setubal regions, according to the specific share of product production for both regions in the LMA.

These results on the interregional trade estimation among the Greater Lisbon, the Peninsula de Setubal and the 'Rest of the Country' regions were already presented in sub-section 2.3. and had a critical role in describing the interdependencies among the economic agents and regions considered.

3.6. Final Comments

The procedures described in this chapter allowed for a significant level of descriptive data, which contributed to strengthening the foundations of the model to be derived in the next chapter. As described, the process of applying an MRIO model demands for the use of substantial information describing the industries (e.g. the technology, employment, income, international imports or taxes supported by the different industries) and their relation with the products' production and consumption allocated by consumption type (i.e. disaggregated into intermediate consumption, household and other final consumption components). Moreover, the significant disaggregation level used also required, at every step, the carefully testing of the consistency of the results. All this information was then regionalized and prepared to be applied in a more sophisticated approach, which will be explained in detail in the next chapter.

Finally, the interregional linkages analysis made it clear that the production of several industries uses goods and services that come from other regions. In the metropolitan areas this is also true beyond commodities, namely for some productive services, especially labor. Indeed, commuting is the activity of 'trading' the labor-force among regions. The next chapter is devoted to explaining how MRIO models can be transformed in order to better specify this phenomenon and several other consequences that accrue from it.

"Our city can no longer afford to be a city divided between downtown and neighborhoods, with a downtown that becomes a ghost town when the workers go home for the evening."

Gavin Newson, 2006

CHAPTER 4 – COMMUTING SATELLITE ACCOUNT: CONCEPT, DEVELOPMENT AND APPLICATIONS

4.1. Introduction

Commuting is a complex phenomenon, which is inseparable from the increasingly complex urban structures (Sultana, 2002) and plays a central role in regional and urban economics. As more people travel longer distances between their place of residence and their workplace, commuting (and sprawling) implies that a significant part of households expenditure living in a certain region is dependent on the income generated by industries located in other regions (Aroca, 2001; Aroca and Atienza, 2011; Ferreira et al., 2014b). Moreover, intensive commuting flows lead to major implications for the household consumption structure, as well as redistributive effects involving real estate rent owners, while at the same time exacerbating energy consumption and CO_2 emissions. Surprisingly, although these findings may seem fundamental, their simultaneous modeling has been almost absent from the regional and urban economics literature (as shown in Chapter 1).

The characteristics and extension of the commuting phenomenon depend on the interdependencies established between different regions, particularly within and between metropolitan areas and their surroundings. Therefore, Multi-Regional Input-Output

(MRIO) models (similar to the ones developed in Chapter 3) can be an important tool in assessing multi-dimensional commuting impacts, as they also allow for extending the analysis to integrate other dimensions, namely the environmental one.

The main aim of the current chapter is to contribute to the design of what, in the 'National Accounts' language, can be designated as a "Commuting Satellite Account",[42] which will then allow for the analysis of commuting flows in urban economies and the comprehensive assessment of their corresponding effects. The proposal consists of developing a tool capable of assessing a large set of impacts in metropolitan areas' economies. Accordingly, the proposed 'Commuting Satellite Account' (CSA) modeling framework is applied here to assess the impacts of: (1) changes in households' residential location; and (2) changes in the location of economic activities (and therefore of households' workplaces). It is expected that these applications will contribute to a better understanding of two different issues: (1) the extent to which the CBD and the suburbs are dialectically interdependent; and, (2) how commuting shapes urban economies (or, in other words, what are the opportunity costs or gains supported by the society).

This chapter starts, in the next section, by resuming as a departure point the multi-regional model structure (as presented in Chapter 3, in its 'most traditional' structure). Then, the proposed elements to be incorporated into a CSA are derived (in this specific case with regard to the Lisbon Metropolitan Area - the most commuting intensive region in Portugal, as shown in Chapter 2) and its theoretical structure is presented. The method followed to regionally distribute labor income (associated with commuting) is discussed in section 4.3.. Section 4.4., focuses on how the household consumption structure of those mainly living from labor is disaggregated, in order to differentiate the consumption structures of commuter and non-commuter households. Section 4.5. is devoted to the specific treatment given to real estate rental activities and to a discussion of its relevance in an MRIO model applied to metropolitan areas. Next, section 4.6. presents the proposed design of the Commuting Satellite Account framework. Section 4.7. is dedicated to the integration of the CSA into the MRIO framework and its extension with an environmental satellite account. Section 4.8. is the core of this PhD dissertation. Its purpose consists in measuring the opportunity costs of commuting by the projection

[42] The proposal of a Commuting Satellite Account, sharing the same lines of this Chapter, was introduced and developed in a paper submitted to the Economic System Research, entitled "A Commuting Satellite Account framework: Measuring the opportunity costs of commuting in Lisbon Metropolitan Area" that is currently under review in that journal.

of two "extreme" scenarios. In the first one, all commuters come to live to proximities of their workplace, while in the other the economic activity is decentralized to the place of residence of the commuters. In both scenarios, commuting ceases such that they constitute the landmark to which the prevailing situation is compared. Next section 4.9., presents the application of the CSA extension to a more 'realistic' scenario concerning a reduction in 'wasteful commuting' and the promotion of urban recentralization. Section 4.10. describes the estimation of the commuting embodied in the product production in urban areas by using the proposed CSA. Finally, section 4.11. concludes this chapter by presenting the most relevant conclusions from the model and scenarios designed.

4.2. A 'traditional' MRIO approach

Most of the applied 'versions' of MULTI2C derived models are similar to other more 'traditional' MRIO models. Figure 9 represents a generalized structure of a bi-regional I-O model derived from the MULTI2C framework that is similar to many other MRIO models (e.g. similar to the ones presented in Oosterhaven (1984), Hewings and Jensen (1986) or Miller and Blair, 2009). For simplicity, and despite this chapter 'real-world' application comprises three regions, a 'confined' bi-regional model is presented. As mentioned before, the model is based on a 'rectangular supply and use format', where each industry produces one or more products. The data benefits from a significant level of detail concerning both the number of products (431) and industries (134) where they are produced. The derived frameworks also benefits from the partition of final household consumption into 5 different household types, according to their main income source: (1) labor; (2) real estate rental activities; (3) capital-income; (4) pensions, and (5) other social transfers.

Figure 9: Bi-regional Input-Output model derived from the MULTI2C framework

		Products				Industries				Other Final Demand		Total
		Region A		Region B		Region A		Region B		Region A	Region B	
Products	Region A	0				IC^{AA}	HC^{hAA}	IC^{AB}	HC^{hAB}	OFD^{AA}	OFD^{AB}	TPO^{A}
						HI^{hAA}	0	0	0	0	0	THI^{hA}
	Region B					IC^{BA}	HC^{hBA}	IC^{BB}	HC^{hBB}	OFD^{BA}	OFD^{BB}	TPO^{B}
						0	0	HI^{hBB}	0	0	0	THI^{hB}
Industries	Region A	P^{AA}	0	0		0				0		TIO^{A}
		0	THI^{*hA}									THI^{hA}
	Region B	0		P^{BB}	0							TIO^{B}
				0	THI^{*hB}							THI^{hB}
Taxes less subsidies on products falling upon interm. consumption or final demand		0				$T(IC)^{A}$	$T(HC)^{A}$	$T(IC)^{B}$	$T(HC)^{B}$	$T(OFD)^{A}$	$T(OFD)^{B}$0	TT
International Imports used as intermediate consumption or final demand						$M(IC)^{A}$	$M(HC)^{A}$	$M(IC)^{B}$	$M(HC)^{B}$	$M(OFD)^{A}$	$M(OFD)^{B}$	TM
Total Intermediate Consumption/Final Demand, at purchasers' prices						TIC^{A}	THC^{A}	TIC^{B}	THC^{B}	OFD^{A}	OFD^{B}	TIC + TFD
Gross Value Added which is not distributed directly to households						$NHVA^{A}$	0	$NHVA^{B}$	0	0	0	TNHVA
Households Savings and net transfers to other institutional sectors						0	S^{hA}	0	S^{hB}	0	0	TS
Total		TPO^{A}	THI^{hA}	TPO^{B}	THI^{hB}	TIO^{A}	THI^{hA}	TIO^{B}	THI^{hB}	OFD^{A}	OFD^{B}	

Variable	Description	Matrices Dimension*
IC^{ij}	*i = A, B; j = A, B* - Intermediate consumption of region *i* products, used by industries located in region *j*.	P x I
HC^{hij}	*i = A, B; j = A, B* - Final consumption by endogenous households of type *h,* of region *i* products, living in region *j*.	P x H
OFD^{ij}	*i = A,B; j = A,B* - Other final demand for region *i* products, used in region *j*.	P x 1 or 1 x P
HI^{hij}	*i = A, B; j = A,B* – Income received by households of type *h*, living in region *i* paid by industries located in region *j*.	H x I
THI^{hi}	*i = A,B* – Total income received by households of type *h*, living in region *i*.	H x 1 or 1 x H
THI^{*hi}	The same of **THI^{hi}** but in the form of a diagonal matrix.	H x H
TPO^{i}	*i= A, B* - Total product output produced in region *i*, at basic prices.	P x 1
P^{ii}	*i = A, B* - region *i* products, according to the producing industry	I x P
TIO^{i}	*i= A, B* – region *i* total industry output, at basic prices	I x 1 or 1 x I
$T(g)^{i}$	*g= IC, HC, OFD; i= A,B;* - Taxes (less subsidies) on products falling upon *g*, in region *i*.	g = IC → 1 x I g = HC → 1 x H g = OFD → scalar
TT	Total taxes less subsidies on products	scalar
$M(g)^{i}$	*g= IC, HC, OFD*; *i= A,B ;* - International Imports destined to use in *g*, in region *i*	g = IC → 1 x I g = HC → 1 x H g = OFD → scalar
TM	Total International Imports	scalar
TIC^{i}	*i= A, B* - Total intermediate consumption by industries, in region *i*, at purchasers' prices	1 x I
THC^{hi}	*i= A, B* - Total region *i* consumption by households of type *h*, at purchasers' prices (only "endogenous" household types).	1 x H
OFD^{i}	*i= A, B* - Other final demand in region *i*, at purchasers' prices	scalar
TIC + TFD	Total intermediate plus final demand, at purchasers' prices	scalar
$NHVA^{i}$	*i= A, B* - Gross Value Added that is not directly distributed to households, in region *i*	1 x I
TNHVA	Total Gross Value Added that is not directly distributed to households	scalar
S^{hi}	*i= A, B* - Households' savings and net transfers to other institutional sectors, by households of type *h*, in region *i*	1 x H
TS	Total savings and net transfers to other institutional sectors	scalar

* P, I and H are equal to, respectively, the number of products, industries and household types considered in the endogenous part of the matrix; the superscripts *i* and *j* refer to regions and *h* only covers endogenous household types.

Inside the bold border, representing the 'core' of this MRIO framework and comprising the supply and use matrices, are the elements that are further transformed to compute the Leontief Inverse. The supply (or production) matrices **P** describe each industry product production structure, i.e. the products produced by each industry, in each region. As explained in Chapter 3, industries produce one (or more) primary products but they may also produce other products as a result of secondary production. In the Use matrix, the consumption of inputs by each industry (**IC**) or the final consumption of different endogenous household types[43] (**HC),** in each region, is registered according to its regional origin: they may be produced in the region where they are used, or interregionally imported. The regional matrices are at "domestic flows", i.e. they concern the products produced within regional economies and national borders (the international imports– **M** and **TM -** are treated separately). All transactions are expressed at "basic prices", i.e. excluding the value-added tax and the other taxes less subsidies on products (**T**). Finally, trade and transportation margins are treated as inputs provided by the Retail and Wholesale Trade Services or the Transport Services (integrated in **IC** and **HC**).

The Other Final Demand (**OFD**) includes the consumption of other household types (not considered in the 'core' of the matrix, i.e. exogenous household types, whose expenditure is not supposed to be (directly) dependent on industries' income distribution). The **OFD** also includes the general government and non-profit institutions serving households' final consumption, investment, final consumption of non-residents in Portugal and international exports of goods and services.

This 'traditionalistic' approach presents a set of limitations when considering the motivation and ambition of this research project, as well as its application to metropolitan areas. The first is the absence of a direct regional distribution of income. Observing Figure 9, it can be seen that only $\mathbf{HI}^{\mathbf{hAA}}$ and $\mathbf{HI}^{\mathbf{hBB}}$ are considered, meaning that all households income is directly distributed by industries to the households living in the same region. This can be an acceptable assumption when dealing with very large regions, where only a small share of workers commute. However, as shown before, this hypothesis is very restrictive to a model addressed to metropolitan areas, since commuting exacerbates interregional income flows and, consequently, interdependencies.

The second is the undifferentiated treatment of household consumption patterns, according to their status as commuters or non-commuters. In metropolitan regions, the

[43] As mentioned in Chapter 3, in most of the MULTI2C applications, the model is 'closed' exclusively to households mainly living on labor income, which is considered the only endogenous type.

existence of commuting implies that consumption patterns may differ substantially (Ferreira et al., 2014a), as commuters spend more on fuel, tolls, car maintenance and other commuting related products, while non-commuters are expected to consume relatively more of other types of products. Simultaneously, commuters are also expected to buy a share of their consumed products in the region where their workplace is located, while non-commuters' consumption is more confined to the region where they work and live.

A third limitation refers to the (non) treatment of rental activities. Commuting is also dialectically linked with the housing market and other real estate rents. As shown in Chapter 1, commonly a more densely occupied CBD (either in terms of firms or inhabitants) is usually associated with higher household expenditure on real estate rents and increased housing prices. An effect on offices and other industrial buildings is also expected. Thus, a change in commuting patterns potentially affects the distribution of income through the real estate rental market. Accordingly, specific modifications need to be implemented in order to more assertively incorporate real estate rental activities into the modeling approach.

So, a proposal to overcome these limitations, through the introduction of additional features, is hereafter addressed. More precisely, such additional features are introduced with a focus on achieving the outcome of assessing the multi-dimensional impacts of commuting changes. Accordingly, a set of 'transformations' is proposed that allow for the comprehensive integration of five critical dimensions:

(1) Commuting occurs in (and is influenced by) a specific geographic and economical context (Verhetsel and Vanelslander, 2010; Zhao et al, 2011; Haddad et al., 2015);

(2) Household commuters' expenditure in a specific region is dependent on the income generated by industries located in other regions (Hewings et al., 2001; Aroca and Atienza, 2011; Ferreira et al., 2014b);

(3) Different commuting status implies different household consumption structures (Ferreira et al., 2014a);

(4) As travel-to-work journeys link the workplace and the place of residence, commuting is also correlated with rental prices, of both housing and business offices (Malpezzi, 1996; Cameron and Muellbauer, 1998; Kim and Lahr, 2013); and

(5) Commuting is a major cause of energy consumption and CO_2 emissions (Golob and Hensher, 1998; Muñiz and Galindo, 2005).

So, the next four sub-sections are devoted to explaining how these different components are estimated and, therefore, how it is proposed that they will be incorporated into the MRIO model. In the scope of this scientific research, this modeling framework is applied to the Lisbon Metropolitan Area.

4.3. Regional Income Distribution

Commuting is more intensive in metropolitan areas (Gardner and Marlay, 2013), namely because Central Business Districts (CBDs) are highly dependent on labor availability from the suburban regions (and those are dependent on income generated in the CBD). So, the share of income distributed by each industry, in each region, from the CBD to the suburbs is a central element for deriving a CSA. The consideration of regional income distribution in IO frameworks was proposed by Madden and Batey (1983) and deeply explored by Oosterhaven and Folmer (1985). The adaptation to MRIO frameworks was suggested in the works of Jun (1999; 2004) and Hewings et al. (2001). Madsen and Jensen-Butler (2005) also observed commuting as an activity involving a regional distribution of generated GVA outside the region and brought into the region as income.

So, several transformations have been performed with the goal of estimating and incorporating regional income distribution into the LMA tri-regional model. Firstly, it is assumed that labor-income is not exclusively distributed to households mainly living on labor income. Thus, other household types can also benefit directly from this kind of income generated from industries (despite it not being their main income source). Table 23 presents the Portuguese national distribution of labor income according to each household type.

Table 23: Share of household types in the national distribution of labor income (2010)

Household Type	Share of labor-income
Workers and own-account workers	95.2%
Landlords	0.2%
Capital-Income	0.1%
Pensions	3.8%
Other Social Transfers	0.7%

Source: 2010-2011 Household Budget Survey (INE, 2012d)

Taking into account the information presented in Table 23, the household income distributed by the different industries located in each region[44] (**HI**) was weighted by the

[44] At this stage, this refers exclusively to the compensation of employees and mixed-income distributed to households.

share corresponding to each household type. This national share was equally applied in all of the industries located in the three regions, as detailed information regarding the labor income regional distribution by industry and household type is not available. Accordingly, household income by industry does not entirely influence the household consumption of those mainly living on labor income but marginally increases the income of other household types that may be considered in the exogenous part of the model.[45]

Furthermore, the most relevant transformation associated with income distribution consists of explicitly splitting households' income earnings (**HI**) between commuter and non-commuter household types and including this break in the endogenous part of the framework. It is important to stress that there are some households that have both commuters and non-commuters among their members. In the particular case of this model, these mixed households are notionally split taking into account their members' commuting status, such that the commuter members consume as commuter households while the non-commuters adopt the corresponding household type profile.

This extension to the MRIO model allows a more realistic assessment of the effects generated by a shock, e.g. in a specific demanded product. Indeed, if one region's industry changes its production, as the income is distributed between non-commuter and commuter households (or one of the other household types), the direct effects may be felt in each household type's consumption and more accurately spread throughout the regions. For this, a share of labor-income is also distributed to households that commute between different municipalities *within* the same region and to households that commute *among* regions. As mentioned before, for the purposes of this work, commuters are those living in a different municipality (or even region) from their workplace while non-commuter households are those living in the municipality where they work. So, the interregional distribution of labor-income concerns specifically the commuter household types. Otherwise, non-commuter households receive their labor-income exclusively from industries located in the same region.

The regional labor income distribution by household and regions is estimated according to the workers' travel-to-work journey information, by industry and by region.[46] The wages and mixed-income earned by employees and self-employed workers are distributed among the three regions considered in the CSA modeling framework, taking into account the industries' asymmetries concerning their commuting intensity and

[45] In the CSA modeling framework, this was included in the $\mathbf{NHVA^i}$.

[46] In Chapter 2, it was emphasized that workers in different industries have distinct commuting patterns.

assuming the same partition of the labor average earnings by commuter and non-commuter groups within each industry in each region.[47] These figures aggregated to all of the industries are presented in Table 24.

Table 24: Income distribution by region (10^6 €)

		Income distributed to non-commuters	Income distributed to commuters according to their area of residence		
			GL	PS	RC
Place of work	GL	14,370	12,104	3,391	1,234
	PS	3,334	361	1,403	101
	RC	---- [i]	337	106	---- [i]

[i] Commuting (and, consequently, non-commuting) within the 'Rest of the Country' region is not displayed as this research only concerns the assessment of commuting flows in the LMA.
Source: Own calculations

According to the data in Table 24, it is possible to quantify how industries in the Greater Lisbon area contribute to the spread of income to commuters living in other regions; e.g., the income distributed to households living in the Peninsula de Setubal but working in Greater Lisbon (3.4 x 10^9 €) exceeds the income distributed by the industries located in the Peninsula de Setubal either to non-commuters (3.3 x 10^9 €) or to commuters (1.4 x 10^9 €) within this region.

These estimations allow for the introduction of a 'new input' into the tri-regional model. In fact, the income distribution resulting from production activities directly benefits some regions while diminishing the income (directly) retained in other regions. Table 25 gives a picture of income in and outflows associated with the commuting process.

Table 25: Income in and outflows by region (10^6 €)

	Inflow	Outflow	Net flow
GL	698	4,625	(-) 3,927
PS	3,497	462	(+) 3,035
RC	1,335	443	(+) 892

Source: Own calculations

Table 25 makes clear the relevance of the industries located in the Greater Lisbon region to the income flow into the Peninsula de Setubal and on a smaller scale to the 'Rest of the Country'. Thus, this modeling approach now benefits from the introduction of these

[47] It is important to highlight that this estimation was performed taking into account very detailed (134 industries) travel-to-work journey data by region. This may help to reduce the consequences of the rough assumption of equal labor earnings of commuters and non-commuters by industry since different industries simultaneously have different average compensations and different "commuting propensities".

variables, allowing for accounting for the fact that household income (**HI**) can also influence the final consumption of household commuters that live in a region different from the one where the industry is located.

To sum up, commuting generally implies that households living in the suburbs are dependent on the income generated (and earned) in the CBD. The estimation of these flows gave us the opportunity to include in the model commuting related interregional links that have been neglected in former applications of the MULTI2C framework, and in many other MRIO models.

4.4. Household consumption structures: commuters vs non-commuters

The interregional distribution of income is one important element that stems from considering commuting flows in the modelling framework. Another important feature is that commuting also influences households' regional consumption in two additional significant ways. On the one hand, it influences households' consumption structure (Ferreira et al., 2014a) and, on the other, it affects the place of acquisition of several products. Households that live near the most relevant employment centers spend more on housing rents and local services and less on fuel and other commuting related products (e.g. cars, maintenance, tolls, insurance). On the other hand, commuters not living in the region where they work are expected to directly purchase several products – mainly non-tradable products (e.g., housing, electricity, water services) - in the region where they live and share other purchases with the region in which they work. These distinct consumption patterns have implications for the location where the consumption actually takes place as well as affecting consumption structures by product.

Other works derived from the MULTI2C framework take advantage of the disaggregation into five household types according to their main income source. In this specific case, a new disaggregation is proposed, with the main goal of incorporating the differences in commuter and non-commuter household consumption structures. At this stage, the regional distribution of income associated with each of the household types (commuters vs. non-commuters) was already known. Due to the lack of appropriate statistical information, a stable propensity to consume was assumed for both groups living in each of the regions considered. So, departing from the income distributed to each of these groups, the total consumption of each of these specific household groups (at purchasing prices and total flows) was estimated.

Splitting the regional income distribution into commuters and non-commuters while simultaneously specifying two different consumption structures for these different household groups is, to the best of our knowledge, one of the novelties of this work, and is an important additional step forward towards improving the model's realism. Additionally, it allows for assessing, in the case of changes in the commuting flows, the simultaneous modification in regional income distribution and in the overall consumption structure felt in each region and how this shapes the different economies.

Since the overall consumption of each group had already been fixed, the next goal consisted of typifying consumption patterns for commuter and non-commuter households at the multi-regional level. Some enhancements are proposed in this work to the methodology followed for the national economy by Ferreira et al. (2014a). At first, this process involves determining which products are consumed to different extents by commuters and non-commuters living and working in the LMA.[48] This analysis departs from the Household Budget Survey (HBS) (INE, 2012d), more specifically after determining a sub-sample of 854 households mainly living on labor income in the LMA. The HBS survey provided important information describing household consumption with a high disaggregation level (199 products), while also characterizing households regarding other socio-economic variables. However, one important limitation of the HBS survey is the lack of information regarding each household's commuting pattern or residence/workplace location. To overcome this difficulty a pragmatic method was applied. As commuters can travel basically either by private car or by public transportation,[49] the households that are more dependent on the commuting activity were identified and defined as the ones that spend more on: (1) public transportation or (2) fuel (petrol, diesel and LGP) consumption for vehicle use.

Regarding public transportation, according to the information available from the Portuguese Census (INE, 2012c), different thresholds[50] were considered regarding

[48] Despite their commuting status, the households living and working in the 'Rest of the Country' are aggregated together (in terms of income and consumption), since this particular study focuses on the LMA. Thus, only those that live in the 'Rest of the Country' but work in the LMA are defined as the commuters that live in the 'Rest of the Country' region.

[49] Commuters (among municipalities) can also travel using non-motorized means of transport, but according to the 2011 Portuguese Census, this number is residual (less than 0.5%).

[50] The thresholds were calibrated according the information in the Portuguese Census (INE, 2012c) and available in Table 18 in Chapter 2. The thresholds considered were 1.1% in the case of boat transportation, 7.3% regarding bus transportation, 9.5% concerning train/subway and 8.5% in the case of combined passes.

household expenditures on these services. In other words, if a certain household is among one of the highest "spenders" on one (or more) of the different types of public transport (boat, bus, train or combined passes) it is considered as a "commuter" household. The values obtained at every step of this process were systematically observed with a critical view and compared with the Portuguese Census Data (INE, 2012) to ensure adequate consistency. Additionally, to determine the households that drive their private car most intensively, another threshold was defined considering their fuel consumption expenditure.[51] After determining these two groups of households, a binary variable was defined in order to divide the sample into commuters and non-commuters.

Next, a new approach needed to be applied in order to detect whether these different household groups had distinct consumption levels regarding each of the products. Again, a pragmatic approach was followed in order to identify them. 199 simple-OLS regressions were performed (corresponding to the 199 products represented in the HBS database), in order to identify those products where the binary variable was statistically significant after controlling for the households' average consumption.

However, one product deserved a particularly detailed approach: the fuel consumption associated with private car use. The main goal consisted of estimating the additional costs supported by commuters according to their different travel patterns. The idea is that distinct travel patterns, particularly when performed by car, are dependent on the distance travelled. So, the journey-to-work matrices were multiplied by a distance matrix (describing the distances between the Portuguese municipalities) (Ferreira et al., 2012). Assuming that commuters travel twice per day, it is possible to estimate the daily kilometers travelled by commuters living and working in each of the Portuguese municipalities. These results were presented in Chapter 2 (Table 15). The total number of kilometers travelled by commuters, by municipality, was weighted by the share of commuters that stated that they mostly use the car as their means of transport (INE, 2012). Then, the total number of kilometers travelled by car was split by the different types of fuel used by cars in Portugal, according to the data from the Portuguese Transport Statistics (INE, 2011). In 2010, among the passenger cars registered approximately 53% used gasoline as fuel, 46% used diesel and 1% used liquefied petroleum gas (LPG). Finally, these values were weighted by the average consumption of different fuel type

[51] Accordingly, approximately 28% of the households that spent relatively more in car fuel were also identified/considered to be commuters.

cars and then multiplied by the average annual cost of the three fuel types.[52] This allowed us to estimate the cost associated with inter-municipality commuting, by different fuel types, in the different regions considered. In order to estimate the annual fuel consumption, it was assumed that, in 2010, an average worker travelled 220 days to work. The results for the three fuel types are presented in tables 26a, 26b and 26c.

Table 26a: Petrol consumption (commuting-responsibility) of commuters living or working in the LMA (10^3 €)

		Place of Residence		
		GL	PS	RC
Place of Work	GL	139,285	42,253	48,029
	PS	8,382	18,276	6,459
	RC	14,290	5,736	----

Table 26b: Diesel consumption (commuting-responsibility) of commuters living or working in the LMA (10^3 €)

		Place of Residence		
		GL	PS	RC
Place of Work	GL	101,921	30,918	35,145
	PS	6,133	13,374	4,726
	RC	10,457	4,197	----

Table 26c: LPG consumption (commuting-responsibility) of commuters living or working in the LMA (10^3 €)

		Place of Residence		
		GL	PS	RC
Place of Work	GL	1,284	390	443
	PS	77	168	60
	RC	132	53	----

Source: Own calculations

The information presented in Tables 26a, 26b and 26c served as the basis to estimate the fuel consumption associated with commuting and the corresponding “amount” that should differentiate the consumption of commuters and non-commuters, in each of the regions.

The specific information on the consumption of the different fuels, as well as the estimation associated with the remaining products provided by the HBS, were adapted to the MRIO model with 431 products and served as an initial input to an RAS process. This

[52] According to the DGEG (2014), in 2010 the average annual cost of gasoline, diesel and LPG was 1.58 €, 1.43 € and 0.77 € per liter, respectively.

RAS process was applied to split the final consumption of households living mainly on labor, by products, while the total consumption of commuters and non-commuters should be equal to the values estimated in the sub-section 3.3.3. (for those living mainly of their labor income).

As stated before, it is important to note that the total expenditure by household type (commuters and non-commuters) in each region has already been estimated. Similarly to the procedures applied in sub-section 3.3.3., this estimation was done first at purchasers' prices and total flows and then, in order to incorporate it into the LMA tri-regional model, it was transformed into "basic prices" and "national domestic flows"[53]. Table 27 shows the commuters' and non-commuters' consumption structures for Greater Lisbon, the Peninsula de Setubal and the Rest of the Country.

Table 27: Commuters' and non-commuters' consumption structures (total flows, at purchasers' prices)

	Greater Lisbon (GL)		**Peninsula de Setubal (PS)**		**Rest of the Country (RC)**	
	Commuters	Non-commuters	Commuters	Non-commuters	Commuters	Non-commuters
Agriculture, forestry and fishing	3.1%	3.2%	3.0%	3.3%	3.2%	3.6%
Manufacturing	44.4%	43.1%	44,2%	41,6%	48,2%	46,5%
from which: fuel consumption for vehicles	*(5.3%)*	*(2.9%)*	*(5.4%)*	*(1.7%)*	*(7.8%)*	*(5.0%)*
Energy, water supply and sewerage	3.3%	3.6%	3.3%	3.6%	3.3%	3.7%
Construction	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Accommodation, food services; Wholesale and retail trade, motor v. and motorcycles	13.9%	12.5%	13.4%	12.3%	12.0%	11.3%
Transportation, storage; information, communication	7.8%	6.9%	7.5%	6.9%	8.2%	5.9%
from which: Public transportation	*(3.0%)*	*(1.1%)*	*(2.6%)*	*(1.1%)*	*(3.2%)*	*(1.1%)*
Financial, insurance and real estate	14.1%	15.3%	15.3%	16.8%	15.3%	17.1%
Other services	13.3%	15.4%	13.3%	15.6%	9.8%	11.8%
Total expenditures at purchasers price (10^6 €)	8,707	10,040	2,949	2,015	901	40,274

Source: Own calculations

[53] It is important to note that although the "average propensity to consume" was assumed to be the same for commuters and non-commuters at 'total flows' and 'purchasers' prices', this is not true at 'domestic flows' and 'basic prices'. The different consumption patterns of commuters and non-commuters result in a distinct consumption of products that support different tax rates or have different imported average contents in their supply.

Table 27 presents the different consumption structures for the different groups (for simplicity, this is summarized in 8 major sets of products). These consumption structures are central in the development of this modeling framework.

To sum up, if, for example, a household living in one region with the status of commuter or non-commuter has a specific consumption structure, that structure is going to change if the household moves to another region or simply changes its commuting status (and continues in the same region). This has important consequences at the regional and national levels (e.g., in terms of national industries' output, international imports and taxes on products).

4.5. Real Estate Rental Activities

Commuting patterns influence the extension and density of specific metropolitan areas. While influencing the regional distribution of income and household expenditure, commuting is also linked with the housing market and other real estate rents. Areas with more density (in terms of firms and/or inhabitants) are associated with higher expenditure on real estate rents.[54] So, potential commuting patterns changes, affecting housing or firms' locations, also affect this particular expenditure type. Indeed, different commuting patterns imply important changes in the (economic and demographic) density of a given region and thus these changes can lead to income redistribution that may benefit (or prejudice) those having real estate income revenues in different regions.

According to the Portuguese National Accounts, firms demand offices or other specific buildings, while households demand housing, but both office and housing rents can be paid either to firms or to households. It is important to clarify that in this section, the more suggestive term "offices" is used, but this reference also includes other buildings (but only buildings, not other kinds of physical capital) rented by firms. Table 28 shows the relation between rents paid (for offices and for housing) and rental income benefitting the different economic agents (firms and households) at the national level. Table 28 benefits from the disaggregation provided by the Portuguese National Accounts to which the rents for residential buildings (houses) were represented as a different product than the rents for non-residential buildings (offices and other industrial).

[54] This sub-section only refers to "Renting of leased real estate" (actual rents). The specific treatment to deal with the "Renting of own real estate" (or, as is commonly stated the "imputed rents of own-occupied dwellings") was explained in Chapter 3.

Table 28: Renting-flows: Origin-Destination (2010)

		Rent-income distribution (10^6€) by:	
	Total amount (10^6€)	**Firms**	**Households**
Housing	2,265	516	1,749
Offices / Industrial Buildings	2,812	793	2,019
TOTAL	**5,077**	**1,309**	**3,768**

Source: 2010 Portuguese National Accounts (INE, 2011a)

Table 28 highlights that in terms of rental activities (both for housing and offices) the most important share is paid to households, while the total amount of rents paid is higher for offices or industrial buildings. According to the Portuguese National Accounts, real estate rental services, when supplied by other firms, are sparsely produced by almost all of the sectors as a secondary product (though only three industries produce them, in a significant amount, as a secondary product: "Buying and selling of real estate", "Trusts, funds and similar financial entities" and "Insurance and Reinsurance" - sub-sectors of the financial industry). So, the business of "real estate renting" (registered in the production of that specific industry), as a main/unique activity, is then basically confined to households[55] and, according to the Regional Accounts rule, is reported in the region where the buildings (residential or non-residential) are located.[56] However, if one considers the existence of an interregional distribution of income among regions, then buildings and their owners can in fact be located in the same or another region. For example, it is possible that a building rented in the Lisbon municipality is owned by a landlord that lives in Coimbra or Oporto. This assumption applies both to residential and non-residential buildings and to either households' or firms' revenues (resulting from real estate rental activities).

The MULTI2C 'standard' models did not include this regional distribution of income and considered (implicitly) that the revenues generated by rental activities were integrally distributed in the region where the building was located. So, this is a particularly important feature of this research work, which derives from the particular focus on the relationship between commuting flows, urban density and the real estate market.

It should be noted that when Table 28 is applied at the regional level, regionalization can be observed in two different ways, originating two distinct tables: one that depicts the

[55] This feature is consistent with the residual level of employment and establishments associated with this industry.

[56] According to ESA (EUROSTAT, 2010: 27), all units, in their capacity as owners of land and/or buildings forming part of the economic territory, are resident units or notional resident units of the country (or region) in which that land or those buildings in question are located.

relation between the rents paid (for offices and for housing) according to the place where the building is located; and, another that represents the real estate rental income benefitting the different economic agents (firms and households) according to the region where they are located/living.

Table 29a: Renting-flows – Origin-Destination according to building location at regional level (2010)

		TOTAL	Firms	Households
Housing	Greater Lisbon	872	196	676
	Peninsula de Setubal	232	53	179
	Rest of the Country	1,161	267	894
	TOTAL	**2,265**	**516**	**1,749**
Offices	Greater Lisbon	1,233	346	887
	Peninsula de Setubal	135	38	97
	Rest of the Country	1,445	410	1,035
	TOTAL	**2,812**	**793**	**2,019**
TOTAL		**5,077**	**1,309**	**3,768**

Table 29b: Renting-flows – Origin-Destination according to the place of residence of the building-owner at the regional level (2010)

	TOTAL				Firms			Households		
	Σ	Greater Lisbon	Penin-sula de Setubal	Rest of the Coun-try	Greater Lisbon	Penin-sula de Setubal	Rest of the Coun-try	Greater Lisbon	Penin-sula de Setubal	Rest of the Coun-try
Hou-sing	***2,265***	1,067	181	1,017	387	7	122	680	174	895
Offices	***2,812***	1,262	172	1,378	421	26	346	841	146	1,032
TO-TAL	***5,077***	***2,329***	***353***	***2,395***	***808***	***33***	***468***	***1,521***	***320***	***1,927***

Source: MULTI2C and own estimations

As already referred to there is a difference between the "Total" column in Table 29a and the "Total" row in Table 29b for firms or households located in each of the regions. So, rents paid by firms/households in one region are not necessarily equal to the income benefitting the economic agents located in that same region. For example, firms and households in Greater Lisbon region pay 2,105 million Euros in real estate rents and benefit from 2,329 million Euros from real estate rental activities.

The values presented in Table 29a and Table 29b were obtained from different sources of information and by applying different procedures. Four different sets of estimations were implemented at the regional level: rents paid by offices (or other industrial buildings); rents paid by households; rents received by firms; and, rents received by households.

First, regarding the information presented in Table 29a, the office/industrial buildings rents paid by firms according to the region where the building is located were derived from each industry technology production information that is already available in the MULTI2C database. In other word, in each regional Use matrix there is an estimation of the rents paid by firms for their establishments, according with the location of the building, as part of their Intermediate Consumption. Then, the housing rents paid by region were obtained from the 2011 Census, after weighting the "average price of rented dwellings" by the total number of "rented dwellings" in each region.[57] This methodological procedure only explains the distribution regarding the "Total" column. The distribution concerning the part of the rents paid by housing and offices that was benefitting households or firms followed the national numbers represented in Table 28.

The next step consisted of estimating the rents received by firms and by households, in each region, represented in Table 29b. The rents received by each firm in each region resulted from the secondary production of other industries of these kinds of products. This follows the procedure to regionalize the Production matrices (**P**) that was explained in Chapter 3. These matrices allow for the disaggregation of rents of house and offices. So, as the secondary production of the different industries was distributed considering the regional distribution of the different receiving industries, the estimated results pointed out to an important share of the real estate rents benefitting firms located in the Greater Lisbon region (61.7%). This is the outcome of the important concentration of "Trusts, funds and similar financial entities" and "Insurance and Reinsurance" industries in the Greater Lisbon region. Finally, in the specific case of the rents received by households in each region, the disaggregation of the national value into regions was performed taking into account the information provided in the Households Regional Accounts (INE, 2015).[58]

At this stage of the estimation process, only the total amount of rents paid by region and the rents received by households and firms in each region were known. However, as the rents paid by households/firms in one region may benefit households or firms located in the same or in another region, an additional estimation procedure needed to be performed. Tables 30a and 30b present the results for these regional origin-destination

[57] The partition between the rents paid by the different households types (not shown in the table) followed the methodology of MULTI2C, which was explained in sub-section 3.3.3. and took into account the distribution of the different household types by region.

[58] This information is only available at NUT II level and so, the value was disaggregated (between the Greater Lisbon and the Peninsula de Setubal) according to the data performed by the regional accounts for the production of the "Rent of Leased Real Estate" industry.

matrices, specifically representing rents received by firms and by households, respectively.

Table 30a: Origin-destination rent flows received by firms (10^6 €)

Destination: Location of the firm earning the rental income		Origin: Location of the rented office GL	PS	RC	TOTAL
	GL	279	13	129	421
	PS	4	17	6	26
	RC	63	8	275	346
	TOTAL	346	38	410	793

Destination: Location of the firm earning the rental income		Origin: Location of the rented house GL	PS	RC	TOTAL
	GL	186	42	160	387
	PS	0	6	0	7
	RC	10	5	107	122
	TOTAL	196	53	267	526

Table 30b: Origin-destination rent flows received by households (10^6 €)

Destination: Location of the household earning the rental income		Origin: Location of the rented office GL	PS	RC	TOTAL
	GL	615	19	208	841
	PS	50	53	42	146
	RC	222	25	785	1,032
	TOTAL	887	97	1,035	2,019

Destination: Location of the household earning the rental income		Origin: Location of the rented house GL	PS	RC	TOTAL
	GL	464	36	180	680
	PS	44	98	32	174
	RC	168	45	682	895
	TOTAL	676	179	894	1,749

Source: Own calculations

Table 30a and Table 30b represent the flows according to the economic agent benefitting from the flow – firms or households. As it is possible to observe the "Total" rows and columns presented in Table 30a and Table 30b are equal to the values displayed in Table 29a and Table 29b. The cells located in the 'core' of the tables presented above correspond to the regional renting flow and were estimated through an RAS procedure. The application of the RAS method departed from an assumption that 50% of the rents are paid in the same region where the office/house is located and the remaining 50% was distributed according to the shares in Table 29b.[59]

To ensure the realism of the model, it was assumed that all types of households can earn a share of their income from rental activities, despite the possibility that they had another main source of income. So, the share of rents distributed to each type of household was estimated at the national level departing from the information available in the HBS. Table 31 offers the results of the distribution by household type of the rents paid to households.

Table 31: Distribution of the rents paid to households, by households' main income source (2010)

Households types	Share of rental income
Labor (Commuters + Non-Commuters)	25.2%
Real estate renting	48.5%
Capital	0.4%
Pensions	25.4%
Other social transfers	0.5%

Source: 2010-2011 Household Budget Survey (INE, 2011c)

The highest share of rents is paid to households mainly living on income from rental activities (Landlords). However, the households living mainly on retirement or labor income also earn an important share of the total amount of rents paid in the Portuguese economy. Nevertheless, as the number of households in each group type is quite different, the rental income has a very different relative importance in the total income earned by each of these groups. The data information presented in Table 31 is only accurately available at the national level.[60] Thus, this same distribution was also applied to the different regions.

The monetary flows between office (or other industrial buildings) and housing rents paid and the corresponding firms' and households' earnings, per region (e.g., a firm in region A can pay the rent for an office to a household that lives in region B), are now ready to be incorporated into the model.

[59] The consideration of this hypothesis resulted from a sensitivity analysis, where different departure hypotheses for the RAS process were tested. The deviance from assuming the hypothesis of 50% (local vs. abroad location of the beneficiary agent) to assuming 30% or, alternatively 70% was always less than 10% (when compared with the 50% hypothesis) of the rental income flow distributed to each group of economic agents in each of the regions. The major sensitivity analysis was felt in the cells referring to the rents received by the economic agents owning/living in the smallest region: the Peninsula de Setubal.

[60] In the specific case of Table 31 (based on the HBS), theoretically it could have been used data regarding NUTS II. However, the option to disregard these data results of a lack of statistical significance (and even reasonableness) regarding some household types' information in some of the regions that were considered.

To sum up, due to its importance real estate rental activity is now considered in the endogenous part of the model since changes in commuting patterns tend to affect the concentration (or dispersion) of a given urban area and that has important effects on the real estate rental activity. Additionally, as this variation in income particularly affects landlords (those mainly living on labor from rental activities), this group of households is also included in the endogenous part of the model. The complete set of transformations incorporated in the 'traditional' MRIO model are now presented in the following section.

4.6. The Final Framework of the Commuting Satellite Account

Typically, when applied to national economies (or big regional economies), 'closed' I-O models consider that household income is entirely distributed to households within the region where the industry is located, and therefore the household consumption inside this country/region is directly affected by changes in income (Miller and Blair, 2009). Indeed, this simplification was considered to be an important limitation when dealing with commuting in metropolitan areas, and the interregional distribution of income was considered critical. Thus, an innovative Commuting Satellite Account is proposed. This is the main reason why it was considered that several elements should be added to Figure 9 presented in section 4.1.. These new elements considered in the model are now highlighted in Figure 10 in blue circles.

Figure 10: The structure of the Commuting Satellite Account

		Products				Industries				Other Final Demand		Total
		Region A		Region B		Region A		Region B		Region A	Region B	
Products	Region A	0				IC^{AA}	HC^{hAA}	IC^{AB}	HC^{hAB}	OFD^{AA}	OFD^{AB}	TPO^{A}
						HI^{hAA}	R^{hkAA}	HI^{hAB}	R^{hkAB}	OR^{hAA}	OR^{hAB}	THI^{hA}
	Region B					IC^{BA}	HC^{hBA}	IC^{BB}	HC^{hBB}	OFD^{BA}	OFD^{BB}	TPO^{B}
						HI^{hBA}	R^{hkBA}	HI^{hBB}	R^{hkBB}	OR^{hBA}	OR^{hBB}	THI^{hB}
Industries	Region A	P^{AA}	0	0		0				0		TIO^{A}
		0	$THI*^{hA}$									THI^{hA}
	Region B	0		P^{BB}	0							TIO^{B}
				0	$THI*^{hB}$							THI^{hB}
Taxes less subsidies on products on interm. consump. or final demand		0				$T(IC)^{A}$	$T(HC)^{A}$	$T(IC)^{B}$	$T(HC)^{B}$	$T(OFD)^{A}$	$T(OFD)^{B}0$	TT
International Imports used as intermediate consumption or final demand						$M(IC)^{A}$	$M(HC)^{A}$	$M(IC)^{B}$	$M(HC)^{B}$	$M(OFD)^{A}$	$M(OFD)^{B}$	TM
Total Intermediate Consumption/Final Demand, at purchasers' prices						TIC^{A}	THC^{A}	TIC^{B}	THC^{B}	OFD^{A}	OFD^{B}	TIC + TFD
Gross Value Added which is not distributed directly to households						$NHVA^{A}$	0	$NHVA^{B}$	0	0	0	TNHVA
Households Savings and net transfers to other institutional sectors						0	S^{hA}	0	S^{hB}	0	0	TS
Total		TPO^{A}	THI^{hA}	TPO^{B}	THI^{hB}	TIO^{A}	THI^{hA}	TIO^{B}	THI^{hB}	OFD^{A}	OFD^{B}	

Variable	Description	Matrices Dimension*
R^{hkij}	*i = A, B; j = A, B* – Housing rents paid by household type *k*, living in region *j*, to households of type *h*, living in region *i*.	H x H
OR^{hij}	*i = A, B; j = A, B* – Housing rents paid by the exogenous group of households in region *j*, to households type *h* living in region *i*.	H x 1
HI^{hij}	*i = A, B; j = A,B* – Income received by households of type *h*, living in region *i* (compensation of employees, mixed income and business rents) paid by industries located in region *j*.	H x I

* NOTE: As in Figure 9, H is the total number of endogenous household types and I is the total number of industries. *i* and *j* refer to regions, *h* and now as well *k* refers to households, only the ones deemed to be endogenous in the model.

An important feature of the proposed CSA covers the inclusion of three household types whose income and consumption are endogenous, i.e., (i) non-commuters, (ii) commuters, and (iii) real estate rent beneficiaries (landlords). As such, the reference to households *h* and *k* in **HC**, **HI** and **R** considers the final consumption, the labor income and the rents received or paid by these three household types. With the incorporation of the regional distribution of labor income, the income of households living in region B may have as origin the industries located in region A. So, the superscripts in the Household Income ($\mathbf{HI^{hij}}$) are not constrained to having *i* equal to *j*. One important point is that this interregional distribution of income was also applied to the real estate rental activities. So, a household located in region A can benefit from the rental income from a building located in region B. Indeed, if the rents are paid by firms they are also included in $\mathbf{HI^{hij}}$. If instead, the rents are paid by endogenous households to the same or other endogenous households group, this renting flow is described in $\mathbf{R^{hkij}}$. Once again, *i* and *j* can be different, which means that the interregional flow of income associated with household rental activities is considered. The rents paid by the exogenous household type to the endogenous households types are represented in $\mathbf{OR^{hij}}$ [61]. Finally, as in Figure 9, the rents paid to firms continue to be specific rows in $\mathbf{IC^{ij}}$, $\mathbf{HC^{ij}}$ and $\mathbf{OFD^{ij}}$ according to the type of unit associated with the rental activity.

The 'core' of this extended MRIO is delimited in Figure 10 by the bold border, comprising the supply and use matrices, which is the part used in the computation of the Leontief Inverse. Similarly to Figure 9, the supply (or production) matrices **P** describe

[61] The rents received by the households considered in the exogenous part of the model are not relevant for this purposes, as their income is not incorporated in the proposed model.

each industry's product production structure, i.e. the products produced by each industry in each region. In the Use matrix, the consumption of nationally produced inputs by each industry (**IC**) or endogenous household type (**HC**), in each region, is described according to its regional origin: they may be produced in the region where they are used, or they may be interregionally imported.

Algebraically, the incorporation of the different components referred to above resulted in an extended 'core' of the MRIO modeling framework. So, the information for each region, displayed in the Use matrix (and transposed in the Production Matrix), is now composed of 431 products, 134 industries, 3 additional columns (concerning the household consumption of the three household types) and 3 extra rows (associated with the income benefiting these household types). The 'core' of the matrix is then composed of 1713 rows and 1713 columns.

As in Figure 9, in Figure 10 regional matrices are represented at "domestic flows" (i.e. international imports – **M** and **TM** – are treated separately) and "basic prices" (i.e. without the value-added tax and the other taxes less subsidies on products - **T**). The Other Final Demand (**OFD**) includes the consumption of other household types (households living mainly on capital-income except rents, from pensions and other social transfers) and exogenous other "uses". Additionally, $\mathbf{NHVA^i}$ also includes the Gross Value Added that is not directly distributed to endogenous households (which in the case of this CSA application may also include a part of the office rents that are distributed to exogenous households).

4.7. A Rectangular I-O Model based on the CSA Framework

4.7.1. The General Procedure

In this sub-section, the CSA framework presented in this Chapter is now transformed into an MRIO framework that is suitable to assess the impacts of different shocks, namely those directed to the final demand.

In the specific case of this work, the CSA is a 'closed-type' I-O model. As these specific models consider the endogenous variation of some groups of households' income and consumption, the total estimated effects can be disaggregated into direct, indirect effects and induced effects. 'Open' I-O models only estimate the direct and indirect effects. This type of model produces smaller effects as it does not consider household income and consumption as endogenous, which means that they are kept stable even when changes in the industries' output occur (Miller and Blair, 2009). To clarify, according to the Input-Output terminology, if a change in final demand of a certain product is assumed, there will also be a change affecting the inputs required for that specific production. This first-order impact is the direct effect. Thus, as the industries that produce these inputs also change their production, other inputs producers will be further affected; the sum of these second, third, fourth (…) order effects are defined as the indirect effects. If ultimately, these changes also affect households' income and, therefore, consumption, this will add other effects to the total effects. This last set of effects are defined as induced effects.

So, departing from Figure 10, a set of input coefficients were derived, referring to the 'core' matrix. These coefficients were computed by dividing each of the core cells by the corresponding total domestic product supply (**TPO**), industries' total production (**TIO**) and total endogenous household income ($\mathbf{THI^h}$), i.e., by the corresponding values in the bottom row of Figure 10. This procedure leads to two sets of input coefficients – the sub-matrices **B** and **Q** - representing the nationally produced inputs used in the industries' production processes (and the household budget coefficients as a proportion of their total income, by household type) and each industry share in a specific product's production, respectively. The **B** dimension is given by [R x (P + H)] x [R x (I + H)] where R is the number of regions,[62] P is the number of products, H is the number of endogenous household types considered and I is the number of industries. Additionally, the **Q** dimension is [R x (I+ H)] x [R x (P + H)]. Therefore, the total input coefficients square matrix **C** takes the shape:

$$\mathbf{C} = \left[\begin{array}{c|c} 0 & \mathbf{B} \\ \hline \mathbf{Q} & 0 \end{array}\right] \qquad (1)$$

So, matrix **C** is a square matrix with 1713x1713 dimension (431 products, plus 134 industries, plus 3 types of endogenous households, considered twice in the use and in the supply matrices, multiplied by 3 regions). This specific procedure, which is typical of several rectangular MRIO models, implies that a number of assumptions are being followed and that fixed proportions are applied in: i) the technical and trade structure of each industry production process, represented in matrix **B**; ii) the final consumption

[62] Equal to three in this particular application.

composition of each household group taken as endogenous in the model (including the interregional domestic shares of the origin of these consumptions, also represented in matrix **B**); iii) the industries contributions to each product's supply, represented in matrix **Q**. These hypotheses result from the "industry-based technology (IBT)" assumption (as designated in the I-O terminology) that this model follows. Accordingly, industry input structures (in the columns of **B**) are the basic data, and commodity input structures are found as weighted averages of these columns. So, the IBT means that the production technology is the same for all of the products produced by each industry, even for the secondary products that are typically produced by other industries. Part of the literature on rectangular I-O models (Oosterhaven, 1984; De Mesnard, 2004) admits that this assumption may be less realistic in some circumstances than the "commodity-based technology" assumption (that however is a more intricate approach), where each product is produced by its own technology regardless of the industry that produces it. Miller and Blair (2009: 194) also consider that a "commodity-based technology (…) is more appropriate for subsidiary products that are produced by an industry in a separate facility, employing a similar technology to the one used by the industry to which the commodity is primary". However, in this work, the irrelevance of secondary production in Portugal for the majority of the industries, as is recorded in the official National Accounts, led us to adopt the easier-to-implement IBT.

Despite the adoption of the IBT assumption, the option followed consisted in applying the rectangular Supply and Use Tables in order to incorporate the large diversity of primary products and the richness of the product specific information regarding trade, margin and tax coefficients.[63]

Returning to matrix **C**, the standard I-O procedure for calculating the total production needs, for a given final demand vector, is represented in the next equation:

$$\mathbf{x} = (\mathbf{I} - \mathbf{C})^{-1}\,\mathbf{y} \tag{2}$$

where **y** is the exogenous final demand vector, comprising the final consumption of the exogenous households and the other final demand (directed towards each of the three regions), and **x** is the 'commonly' referred total output vector. It is important to note that in spite of the designation, **x** includes the total output of products and industries in the

[63] If instead of applying a Supply and Use Table, the option consisted of transforming this model into a symmetric I-O model (instead of a rectangular one), that would mean to give up of the 431 products, and only confine to 134 more aggregated products. The same reduction (to 134 products) would also be an implication of the adoption of a commodity-based technology.

three regions, and also includes cells that represent the total income of the endogenous households living in each of the regions (its dimension being 1713 x 1). **y** is also 1713 x 1, but only product demands and rent payments from exogenous households have non-null values, while the remaining vector, corresponding to industries and households, is filled with 0. Moreover, it is possible to write:

$$\mathbf{D} = (\mathbf{I} - \mathbf{C})^{-1} \qquad (3)$$

Then **D** is a multiplier matrix that is commonly referred to as the Leontief Inverse matrix (or the total requirements matrix). It has a dimension of 1713 x 1713, and allows for estimating the resulting impacts (in a 'rectangular' model, both in industries' output and/or in product production) of exogenous changes in final demand. For this,

$$\mathbf{\Delta x} = \mathbf{D} \,.\, \mathbf{\Delta y} \qquad (4)$$

In rectangular models it is common to divide the multiplier matrix **D** into four quadrants:

$$\mathbf{D} = \left[\begin{array}{c|c} \mathbf{D_1} & \mathbf{D_2} \\ \hline \mathbf{D_3} & \mathbf{D_4} \end{array}\right] \qquad (5)$$

$\mathbf{D_1}$ and $\mathbf{D_3}$ are respectively the sub-matrices of the impacts on products' and industries' outputs, resulting from variations in the **OFD** (the subvector of **y** actually filled with non-null values). The last three rows of each of the sub-matrices $\mathbf{D_1}$ and $\mathbf{D_3}$ – that depict equal multipliers in both sub-matrices - concern the impacts on the income of the three (endogenous) household types of those variations in the **OFD**. As the objective of this modeling consists to a large extent of assessing the impacts on **TIO** and **THI** of changes in the **OFD**, the estimations can be confined to:

$$\mathbf{\Delta z} = \mathbf{D_3} \,.\, \mathbf{\Delta OFD} \qquad (6)$$

where **z** represents the **TIO** and **THI** for the three regions considered in the model (its dimension being 411 x 1) [64].

[64] 137 (134 industries and 3 endogenous household types) multiplied by the 3 regions considered in the model.

$\mathbf{D_2}$ and $\mathbf{D_4}$ reckon the same kind of impacts on products, industries and household incomes, when the **OFD** variations are not disaggregated by product, as usual, but rather, they are directly reallocated to the industries. The $\mathbf{D_4}$ matrix (that is going to be applied next) gives the effects on industries' outputs (and on endogenous households' income) of changes in the exogenous final demand distributed by industries.

4.7.2. Integrating the Energy / Environmental Satellite Account

After transforming the MRIO model in order to incorporate different commuting attributes and implications, another commuting outcome needs to be addressed. Changing production and consumption patterns may also have a relevant effect on energy consumption and CO_2 emissions (Wier et al., 2001). Simultaneously, commuting is one of the major causes of environmental externalities within metropolitan regions (Muñiz and Galindo, 2005), influencing the amount of energy consumption and CO_2 emissions associated with the use of private (and public) transportation, depending on the number of kilometers travelled by commuters. So, the model was (further) extended to deal with both environmental and energy issues, using a "common" satellite account approach regarding primary energy consumption by industry and by household type.

Adapting the approach used (for a national economy) by Cruz (2009) and Cruz and Barata (2012) to an MRIO framework, this research methodology takes a step forward and is applied to estimate regional sectoral primary energy intensities per unit of total output (in toe/million EUR). In this work, three types of primary energy were considered: coal, natural gas and oil or oil refined products. Finally, the (primary) energy requirements, as well as the corresponding CO_2 emissions, embodied in a given structure of regional production and consumption, were estimated.[65]

In algebraic terms, the total (primary) energy requirements to satisfy the production (total output) of a given economy (given by the 3x1 vector **f** corresponding to the three types of primary energy) can be obtained from:

$$\mathbf{f} = \mathbf{L} \times \mathbf{z} \qquad (7)$$

[65] According to Choi (2015), the regional environmental responsibilities associated with energy requirements and corresponding CO_2 emissions attributable to regional production activities can be differentiated between those meeting regional (type 1) and out-of-region (type 2) demand. For the purposes of this analysis, as commuting in the LMA is deemed to occur within national borders, the type 2 variations on energy use and CO_2 emissions should consider only changes in interregional demand (i.e. these estimations do not involve changes in international demand satisfied by the region production activities).

where **L** is a (3x411) matrix, whose generic element (l_{fsi}) (for the 134 columns associated with each industry in each region) represents the (physical) quantity of primary energy *f* used by industry *s* located in region *i* per unit of total output (i.e. the 'energy intensities'). Additionally, three elements (l_{fhi}), associated with the household columns in each region, represent the (physical) quantity of primary energy *f* used per unit of total income received by each (endogenous) household type *h* living in region *i*.

Moreover, anthropogenic CO_2 emissions are produced when carbon-based fuels are burned. Therefore, after adjusting the primary energy figures, it is possible to estimate the CO_2 emissions from fuel combustion, by considering the carbon content of each primary energy type. Accordingly, conversion factors from primary energy to CO_2 were applied (following the Intergovernmental Panel on Climate Change's default methodology to create countries' GHG emissions inventories (IPCC, 2006)), and arranged in a vector of CO_2 emissions per unit (tons of oil equivalent - toe) of fuel burnt (vector **e**).

Considering **e'** as the 1x3 transpose vector of **e**, whose generic element (e_f) represents the amount of CO_2 emissions per unit of primary energy *f*, the total CO_2 emissions embodied in the satisfaction of the production (total output) of a given economy (given by the scalar *c*) can be obtained from:

$$c = \mathbf{e'} \times \mathbf{L} \times \mathbf{z} \quad (8)$$

Therefore, the elements of the row-vector (**e'.L**) represent the quantity of CO_2 generated by each industry in each region per unit of total output and by each endogenous household type living in each region per unit of total income (in tons of CO_2/million EUR), generally designated as 'CO_2 intensities'. So, the information for the CO_2 emissions for the total industry output and endogenous household types can now be estimated. These estimations can be done by region, as **z** (and **L)** can be split taking into account the three regions considered in the LMA tri-regional model.

To sum up, in this section the methodology followed to embody the CSA framework into an MRIO framework was presented. This will enable the proposed model to consider the endogenous variation in 3 types of household income and consumption, according to the commuting intensities of the workers in each specific industry. Induced changes in commuting flows will affect households' consumption in two different ways: through a change in the region where the consumption (of certain products) occurs, simultaneously with a shift in those households' consumption structure. Additionally, the environmental impacts of potential commuting pattern changes are also assessed through this methodological framework. These issues are addressed in the next sections.

4.8. Assessing Commuting (Opportunity) Costs in the LMA

4.8.1. Deriving Two "Extreme" Scenarios

This section explains the two major scenarios addressed in this chapter regarding hypothetical changes in households' residential location and economic activities location. These two scenarios are considered in order to assess the economic, social and environmental commuting opportunity costs. As the purpose of this work consists of measuring the opportunity costs of commuting, these scenarios were conceived as extreme ones, where commuting flows vanish. Scenario A consists of hypothetically 'reallocating' the commuters' housing location to the municipality in which they work. Scenario B involves a hypothetical redistribution of the industries' economic activity to different municipalities, according to the commuters' place of residence.

Both scenarios involve ceasing commuting flows and represent the counterfactual to the current status where commuting prevails. But scenarios A and B differ substantially. For example, in scenario A the households living in a municipality located in the Peninsula de Setubal and working in Greater Lisbon change their status to non-commuters and are supposed to become inhabitants of Greater Lisbon. The same happens to the commuters that live in the other regions. In scenario B, the households also become non-commuters, but now because it is assumed that production is displaced towards the region where they live. Thus, scenario A involves the strengthening of agglomeration economies as the population density near the most important employment centers increases (despite fewer households also changing their place of residence to the suburbs). In scenario B, the dispersion of industries and economic activity increases, leading to a loss in the agglomeration economies. In this particular case, the production activity is displaced to the suburbs, namely to the place where people live. It is relevant to highlight that this scenario admits a global loss of productivity, since many economic activities are reallocated from a higher (Greater Lisbon) mainly to a lower labor productivity NUTS III region (the Peninsula de Setubal).

As a first step, both scenarios require a transformation in matrix **C** (specifically in sub-matrix **B**). As commuting ceases in both cases, this means that the income distributed by each industry (and also by the rental activities) will no longer be distributed to commuter households. The corresponding rows then become 0 (null) in all of their entries. The labor income (of employees and the self-employed) is now entirely distributed to households that do not commute, within the region where the industries are located. The same applies to the place of payment of rents of the former commuter households. This new territorial distribution of income leads to a new reallocation of the households' consumption between the regions. Moreover, the overall consumption structure is also affected, since commuter consumption vanishes and all households living on labor income are now assumed to follow the non-commuters' consumption structure patterns.

In scenario A, the **OFD** does not change because there is assumed to be no commuting by the exogenous household types whose consumption is included in the **OFD**. Then the new **TIO** and **THI**, for the three regions, are obtained by:

$$\mathbf{z} = \mathbf{D}_3^* \times \mathbf{OFD} \tag{9}$$

$\mathbf{D}^*_3$ being the new $\mathbf{D}_3$, after the transformation of **C.** **z** is the new outputs vector comprising the new total outputs of the industries in the three regions and the new total incomes of the three types of endogenous households living in the three regions.[66]

Scenario B is also based on the hypothesis of ceasing commuting and additionally considers a change in the location of each region's industries. In this hypothetical scenario, industries reallocate a share of their production to the commuter's place of residence and reduce their production in the most important employment centers. Industries are supposed to adopt the production technologies of the regions to which it is assumed they are reallocated (and thus, their productivity). The productivity prd^{si} of industry *s* in region *i* is defined by:

$$prd^{si} = \frac{tio^{si}}{emp^{si}} \tag{10}$$

where *emp* means total (FTE) employment in industry *s* at region *i*. The amount of initial variation assumed in industries' production is obtained by multiplying the net number (outgoing less incomers) of ex-commuters by the productivity in the new region where the industry is located, in the case of regions hypothetically attracting the economic

[66] The household income of the commuters' households is now null in the three regions.

activity. Considering com^{si} as the number of ex-commuters in each industry and region ($\forall s \; \sum_i com^{si} = 0$), the changes in **TIO** are computed by:

$$\Delta tio^{*si} = prd^{si} \times com^{si} \quad (11)$$

The assumed variations in the outputs of industries *s*, labeled by *, are only initial "shocks", corresponding to the direct delocalization of production. Furthermore, the output delocalization also leads to a shift in final demand. The idea embraced in scenario B is that initially the variation in output results in a regional shift in the final demand. After this calculation of the industrial output changes, the final demand changes are also assigned to the same industries ($\Delta tio^{*si} = \Delta ofd^{si}$). This initial shock in territorial demand is going to produce plenty of indirect and induced effects over all of the three case study regions. Households' income and employment also adjust to the second order effects. The final effects of production reallocation on **TIO** are part of **Δz**, which is thus computed by:

$$\Delta \mathbf{z} = \mathbf{D}^*_4 \times \Delta \mathbf{OFD} \quad (12)$$

where $\mathbf{D}^*_4$ is the new $\mathbf{D}_4$ after the transformation of **C**, and **ΔOFD'** is a vector comprising all of the Δofd^{*si} to all *s* and *i*. This delocalization effect is cumulative to the one that derives from commuting fading out, compiled earlier in this sub-section. The next sub-section is dedicated to presenting the results for Scenario A and Scenario B.

4.8.2. Scenario Results: The Economic, Social and Environmental Impacts of Commuting

The comparison of the two scenarios contributes to a deeper understanding of the economic, social and environmental implications of current commuting patterns. Furthermore, it is important to stress that these are extreme scenarios - that have the purpose of revealing the opportunity costs of commuting - as the full cessation of commuting is not a realistic possibility. The comparison between the two scenarios may give an insight into the opportunity costs of commuting as well as the benefits associated with the agglomeration economies. Indeed, in comparison with scenario A, scenario B also considers that as industries change (mainly) from Greater Lisbon to the Peninsula de Setubal (from a more productive place to a less productive one), in the proportion of each industry (former) commuters in the total of its workers, the shock conveys a decrease in the overall output in the LMA (and in the Portuguese economy as a whole). Moreover, the two scenarios are complemented by sub-scenarios assessing possible exogenous changes in the rental income distribution associated with the demand for houses or offices.

So, all of the scenarios are assessed in a tri-regional I-O model with a CSA and energy and environmental extensions, as explained in the previous sections. In this sub-section, the results regarding the application of scenarios A and B in the context of the CSA framework, applied to the LMA, are presented. Table 32 starts by presenting the initial values for: Output, GVA - both at basic prices - Income, Employment, Energy consumption and CO_2 emissions, in each of the regions and in the Portuguese economy (as a whole). Then, the expected changes (Δ) induced by each of the two hypothetical scenarios are presented.

Table 32: Multi-dimensional impacts of Scenarios A and B

	Greater Lisbon	Peninsula de Setubal	Rest of the Country	TOTAL
Baseline				
Output (10^6 €)	99,588	18,566	192,393	310,357
GVA (10^6 €)	45,871	7,413	86,819	140,102
Residents Household Income(i) (10^6 €)	28,355	8,482	62,440	99,277
Employment (10^3 FTE)	1,204	252	3,337	4,793
Coal (10^3 toe)	9	8	1,640	1,657
Natural Gas (10^3 toe)	573	185	3,749	4,507
Oil and its derivatives (10^3 toe)	2,411	544	6,609	9,564
CO_2 Emissions (10^3 Tons)	8,636	2,130	35,040	45,806
Scenario A (Δ)				
Output (10^6 €)	1,757	-381	-65	1,312
GVA (10^6 €)	921	-216	-43	662
Residents Household Income(i) (10^6 €)	4,548	-3,207	-850	491
Employment (10^3 FTE)	29	-8	0	21
Coal (10^3 toe)	0	-1	17	17
Natural Gas (10^3 toe)	14	-4	23	33
Oil and its derivatives (10^3 toe)	-34	-77	-42	-153
CO_2 Emissions (10^3 Tons)	-73	-238	-4	-316
Scenario B (Δ)				
Output (10^6 €)	-16,173	8,500	1,245	-6,428
GVA (10^6 €)	-7,347	4,159	883	-2,305
Residents Household Income(i) (10^6 €)	-1,066	-199	-266	-1,531
Employment (10^3 FTE)	-178	126	25	-27
Coal (10^3 toe)	0	0	-17	-17
Natural Gas (10^3 toe)	-58	31	-34	-61
Oil and its derivatives (10^3 toe)	-375	80	-53	-348
CO_2 Emissions (10^3 Tons)	-1,264	318	-305	-1,251

(i) Exclusively from the endogenous household types
Source: Own estimations

Regarding Scenario A, the expected impacts on global economic activity and (on employment) are positive in the Greater Lisbon region, more than compensating for the (anticipated) losses in the Peninsula de Setubal and the Rest of the Country regions (that loose part of their population). The outcomes, at the national level, mirror the change in the structure of households' consumption, considering that the total **OFD** remains stable in both regions. So, there is a reduction in the consumption of several products that: (i) have a large share of international inputs embodied in their production (e.g., fuel), (ii) are almost exclusively imported (e.g., cars), or (iii) support a significant burden of indirect taxes incorporated into their purchaser prices. The contribution of the conversion of a commuter-type of consumption into a "non-commuter consumption" is responsible for the most important share of the total national effect. Beyond this effect, other reason for the positive national impact is that after the change in their place of residence, the ex-commuters are deemed to adopt the Greater Lisbon consumption pattern, comprising more services, and having a higher propensity to consume. Of course the economy of Greater Lisbon, whose population grew, catches the potential benefits of this scenario. The negative effects on the Peninsula de Setubal and the 'Rest of the Country' regions result from the contraction of their economies due to lower (endogenous) final demand. In sectoral terms, the industries that lose more of their national GVA are presented in Table 33.

Table 33: Industries that decline more in relative terms of national GVA (in Scenario A)

	Total GVA decline	% of decline
Boat transportation	(-) 15	11.1%
Land transport and transport via pipelines	(-) 66	2.3%
Manufacture of coke, refined petroleum products and fuels briquettes	(-) 14	1.9%
Warehousing and support activities for transportation	(-) 36	1.5%
Wholesale and retail trade and repair of motor vehicles and motorcycles	(-) 15	0.8%

Source: Own estimations

The estimated contractions of some outputs are offset by the demand expansion of other kinds of consumption, namely goods and services incorporating a higher degree of national value added. Thus, an expansionist effect is anticipated for most of the industries, with the exception of those that are more commuting related (as those included in the Table 33 above).

At the regional level, Greater Lisbon is expected to be the only region benefiting from the simulated change in households' place of residence. Indeed, it benefits both from the described change in the consumption structure and from the increase in demand, considering that the number of households living in this region increases. This mostly affects the output of industries, which provide non-tradable products or services locally, namely: water caption and treatment, retail trade, households as employers of domestic personnel, food and beverage service activities and so on. Table 34 depicts the industries in the Greater Lisbon region that are more positively affected by the modifications implemented in Scenario A.

Table 34: Industries located in Greater Lisbon that have a relatively higher increase in their GVA (in Scenario A)

	GVA increase	% of increase
Activities of households as employers of domestic personnel	45	10.1%
Water collection, treatment and distribution	13	6.8%
Arts, entertainment, sports and recreation activities	46	6.0%
Retail trade, except of motor vehicles and motorcycles	124	5.9%
Food and beverage service activities	69	4.6%

Source: Own estimations

It is important to notice that the industries presented in Table 34 are simultaneously the industries that present the major declines in the Peninsula de Setubal, as the number of resident decreases. But, this decline is expected to be softened by the expansion felt in the national economy, since it contributes to increasing the output of industries that depend mostly on national demand (e.g., electricity production, manufacture of food products, manufacture of paper and paper products, manufacture of rubber and plastic products). This partial economic expansion is also anticipated for the 'Rest of the Country' region. So, the potential impacts resulting from this hypothetical scenario prove that reducing commuting should lead to positive effects on the national economy.

Finally, in addition to the increase in economic activity and employment, this scenario also contributes to a moderate (but still positive) impact in terms of energy consumption savings and CO_2 emissions, with a 0,7% reduction in the national greenhouse gas emissions, mainly pushed by the decrease in the consumption of oil and its derivatives.

Contrarily, in scenario B, the commuters' sprawl is followed, in terms of production, by economic activity dispersion. Accordingly, the impact of firms' hypothetical decision to reallocate their production to places where ex-commuters live is analyzed. Indeed, this reallocation is conveyed to initial losses in terms of output, since average workers' productivity decreases. This specific scenario favors the economic expansion of the Peninsula de Setubal and the Rest of the Country, as these regions are the place of residence of several commuters that are now supposed to have their workplace in the municipalities in which they live. This is made at the expense of the loss in Greater Lisbon's economic activity. Indeed, in this scenario, at the national level, the estimated benefits of reducing commuting (in Scenario A) are overcome due to the overall (national) loss in productivity.

Finally, scenario B anticipates more significant positive results in terms of energy consumption and CO_2 emissions, namely with a 2.7% decrease in national greenhouse gas emissions. However, this more positive effect on the environment comes together with a relevant contractionary shock in the economy and in employment. Indeed, this result clearly highlights the existence of trade-offs between the economic and environmental dimensions associated with simultaneously ceasing commuting and decentralizing economic activity.

To sum up, the integrated analysis of both scenarios underlines the existence of a positive effect of ceasing commuting both in economic and in environmental terms. However, as it is possible to understand from scenario B, the ceasing of commuting should not be done preferentially as a counterpart to decentralizing economic activity as that can induce relevant productivity losses (although from an environmental point of view scenario B is the best).

4.8.3. Changes in real estate rents

Commuting pattern changes imply a modification in the real estate rents paid and received by different economic agents (either regarding housing or offices). Accordingly, in this sub-section the model framework is adjusted to consider the possibility of variations in rental activities. Indeed, rent price changes are expected when agglomeration (or dispersion) of people or businesses happens. In scenario A, where people move, the impact is felt on housing rents. In scenario B, where firms are reallocated, the expected effect is on office rents.

The CSA framework was then applied to simulate 4 sub-scenarios (two for scenario A and two for scenario B), where the renting burden held by economic agents' increases (20% and 50%) in the regions where the population and/or economic activity grows. In scenario A, this burden bears on housing rents (and households' consumption) as people move to live closer to their place of work. The counterpart of these rent increases is a reduction in other consumption, such that total household expenditure propensities (total flows; at purchasers' prices) are deemed to remain stable. In scenario B, it is assumed that only firms carry an additional burden in office rents. In this specific case, the increase is entirely compensated by a reduction in the "Gross Value Added which is not distributed directly to households" (excluded from the core part of the model displayed in Figure 10).

The results of those 4 sub-scenarios, for Portugal as a whole, are presented in Table 35, where the figures corresponding to "no rent change" are those estimated and displayed in Table 32.

Table 35: Sensitivity Analysis of Real Estate Rent Changes (national values)

	Output	GVA	Employment
Scenario A (Δ)			
No Rents Change	1,312	662	21
20% increase	1,184	615	19
50% increase	993	545	15
Scenario B (Δ)			
No Rents Change	-6,428	-2,305	-27
20% increase	-6,397	-2,285	-26
50% increase	-6,324	-2,249	-26

Source: Own estimations

Table 35 shows that, despite the substantial changes in the real estate rental effort, the results broadly confirm the findings in Table 32. The main reason for this is that despite rents being treated as a cost supported by households or firms, in macroeconomic terms this specific cost is not a significant burden on the economy as a whole, since it consists of a redistributive effect among economic agents. So, in the case of scenario A, an increase in the housing rents paid by households is dealt with as an income net transfer between different household groups and benefits those whose main income source is real estate rents. This fact produces a relatively small macroeconomic loss because landlords have a higher propensity to save than households that live mainly on labor (which is the main rent net payer group). Finally, in the case of scenario B, the transfer is mainly from industries' "Gross Value Added which is not distributed directly to households" to the households that benefit from rents (and in some cases to other industries where rents are produced as a secondary service) triggering private consumption, which partially offsets the contractionary national effect that this scenario admits.

However, if the macroeconomic changes in the economy do not appear to be of major importance, the increase in real estate renting may benefit some economic agents while harming others. Table 36 compares the difference in the four sub-scenarios of the income distributed to the different household types with the results obtained without any exogenous change in rents.

Table 36: Household Income changes (%) resulting from the sensitivity analysis of real estate rent changes (national values)

	Workers and own-account workers	Landlords
Scenario A (Δ)		
No Rents Change	+ 0.5%	+ 1.2%
20% increase	+ 0.4%	+ 3.6%
50% increase	+ 0.3%	+ 7.2%
Scenario B (Δ)		
No Rents Change	- 1.5%	- 2.1%
20% increase	- 1.5%	- 1.7%
50% increase	- 1.5%	- 1.2%

Source: Own estimations

Table 36 highlights that every process of rent increase will largely benefit the landlord households since it may lead to an important increase in their income. Indeed, the application of scenario A combined with a 50% increase in housing rents in the Greater Lisbon region would lead to a 7.2% increase in the national income of landlords. This number would be even higher when considering only the landlords living in the Greater Lisbon region (14.2% income increase). In scenario B, the conclusion is similar. Indeed, a change in office rents in the Peninsula de Setubal does not seem to have any effect on the households living mainly on labor income. Alternatively, a 50% increase in the offices located in the Peninsula de Setubal would reduce, almost by half, the burden on landlords that results from the application of scenario B.

So, after this sensitivity analysis, it is possible to conclude that the change in the housing renting market does not imply a significant gain/loss in macroeconomic terms. However, it can imply an important redistribution of income among the different economic agents.

To sum up, two scenarios where commuting vanishes were compared and two distinct results were found. First, in scenario A, it was assumed that commuting ceases because households return to the city center and contribute to urban recentralization. The results obtained allow us to draw two important conclusions: first, that society supports an economic cost if extensive commuting flows prevail; and second, that commuting also imposes important environmental costs, as it exacerbates energy consumption and CO_2 emissions. However, observing the results from Scenario B sheds some light on the complexity of the commuting phenomenon. Indeed, commuting as an outcome of the agglomeration process is also linked to the higher productivity and economic expansion that result from agglomeration economies. So, if vanishing commuting results from a more sprawl economic activity, this can result in important economic losses. However, as the economy shrinks, an additional consequence of this new reality concerns significant benefits in environmental terms. Finally, the potential impacts of commuting pattern changes on real estate rental activities only marginally affect the previous conclusions, despite the important effects on income distribution among the different household groups.

4.9. A 'wasteful commuting' reduction scenario

In this section, another application of the tri-regional Input-Output framework was presented, extended with a 'commuting satellite account', considering one scenario of reducing 'wasteful commuting'.[67] This definition was first proposed by Hamilton and Roëll (1982). These authors stressed that households are not able to maximize their utility function associated with the evaluation of opportunity (time and money) accessibility costs and housing prices due to existing market failures already explored in Chapter 1. Most importantly, with the specific scenario that is presented in this section, the CSA modeling framework is to be applied to a more realistic problem. Ultimately, this application is based on scenario A, considered in the last section, where commuting vanishes. However, in this case, only a small part of the commuting will cease. The reduction in commuting is presented here as being associated with the occupation of 'unoccupied' houses in the Lisbon municipality.

According to the 2011 Portuguese Census, there are 50,209 unoccupied houses in the Lisbon municipality corresponding to more than ¼ of the vacant houses in the Lisbon Metropolitan Area region (and higher than the number of unoccupied houses in the Peninsula de Setubal region).[68] In this frame, a scenario is proposed in which a portion of the households that currently commute on a daily basis to this municipality occupy 50% of these vacant houses. These numbers could actually result, in the medium-long term,

[67] This scenario and the results presented in this section form the important part of an article already submitted to the Journal of Geographical Systems entitled "Modeling commuting patterns in an MRIO framework: impacts of an 'urban recentralization' scenario". At the time this dissertation was written, this article was in the review process.

[68] 39.7% of the 'unoccupied' houses were on the market, for sale or rent, while some of the others (currently off-market) are also in a condition to be considered habitable homes. Additionally, according to the 2011 Portuguese Census, only 2% of the houses in the Lisbon municipality are considered to be uninhabitable or ready to be demolished.

from the application of concrete policies directed towards promoting urban recentralization or the return of commuters to the city center.

The purpose of this essay is to assess the potential impacts of this more realistic change while not considering further costs or other associated facts. In other words, as considered in the last sub-section, the initial shock does not include any other disturbances besides the hypothetical shift in household consumption patterns (e.g., the cost of refurbishing some deteriorated buildings is not taken into account). Note that it is considered a shift in the consumption structure of households that change from commuter to non-commuter status, as well as a change in the place where they directly buy (a substantial part of) their consumption products.

Nowadays almost two thirds of the Lisbon municipality workers live in other municipalities (43.5% in the Greater Lisbon region, 15.9% in the Peninsula de Setubal and 4.0% in the 'Rest of the Country'). This distribution was taken into account to determine the origin of the workers that are assumed to move their place of residence to reside in one of the Lisbon municipality's unoccupied houses, amounting to about 25,000 household commuters. Table 37 summarizes the redistribution between the household types considered (i.e., how a decrease in the number of Greater Lisbon, Peninsula de Setubal and 'Rest of the Country' commuter workers is offset by an increase in Greater Lisbon non-commuter jobholders).

Table 37: Greater Lisbon household types redistribution

	Greater Lisbon		Commuters from	
	Non-commuters	Commuters	Peninsula de Setubal	Rest of the Country
Households redistribution (workers in Greater Lisbon)	+ 25,105	- 17,222	- 6,286	- 1,597

Source: Own calculations

As stated earlier, the proposed scenario was implemented through changes in the coefficients matrix **C** itself, in the rows concerning the income distribution to "endogenous" households, similar to the procedure adopted in Scenario A, presented in the last section, but with a less "drastic" transformation. So, in this particular case, only some commuters became non-commuters and some households moved their residence to Greater Lisbon (in particular to the Lisbon municipality), so that more income was retained in this region (i.e. less was distributed to the others). These changes in income distribution automatically produce the adjustments referred to in consumption patterns. Any shock on exogenous final demand is considered. So, the new output was estimated by multiplying the new inverse matrix by the original vector of exogenous final demand. Table 38 gives a summary of these effects.

Table 38: Impacts of occupying 50% of the 'unoccupied' houses in Lisbon municipality

	Greater Lisbon	Peninsula de Setubal	Rest of the Country	Total impacts
Output (10^6 €)	104.1	- 27.7	- 4.2	72.2
GVA (10^6 €)	54.2	- 15.8	- 3.4	35.0
Employment	1716	- 617	- 37	1061
Endogenous Household Income				
- Non-commuters (10^6 €)	856.8	- 7.4	- 1.9	847.5
- Commuters (10^6 €)	- 553.5	- 215.5	- 53.7	- 822.7
- Landlords (10^6 €)	1.9	- 0.7	0.2	1.4
Coal (10^3 toe)	0.0	0.0	0.8	0.8
Natural Gas (10^3 toe)	- 3.4	- 1.2	- 6.8	- 11.4
Oil and its derivatives (10^3 toe)	- 40.5	- 10.4	- 51.0	- 101.9
CO_2 Emissions (10^3 Tons)	- 123.1	- 33.9	-168.5	- 325.5

Source: Own calculations

The impacts resulting from the change in household status and corresponding behaviors include an expansionary effect on the national economy, i.e., the total impacts are positive. This positive effect is mainly associated with the commuting-related consumption structure changes, as in the previous section. Once again, the contribution of changing the commuters to non-commuters contributes to the growth of the total national GVA. Indeed, the induced changes in demand account for an important share of the gains from reducing "wasteful commuting".

This particular scenario does not consider an exogenous change in Greater Lisbon region rent prices (although this model is able to accommodate real estate rental changes, as considered in the last section). However, it is important to note that such population reallocation from the suburbs to the Lisbon municipality benefits the landlords living in Greater Lisbon (as they own an important share of the available houses now occupied by former commuters). Accordingly, this mechanism reinforces income distribution in favor of households in the Greater Lisbon region. Once again, the environmental results are positive for the society with a reduction in energy consumption (except in the case of coal due to the existence of an expansionist movement in the economy) and in CO_2 emissions.

As this scenario does not involve direct changes either in the overall economic patterns or in regional production exogenous demand, the results corroborate the results of the last section and the existence of a critical impact of commuting in metropolitan areas. This more 'realistic' application shows that if a proportion of workers who commute daily to the Lisbon municipality were to change their area of residence and become non-commuters, this would generate an overall expansionary economic effect and reduce the energy consumption and CO_2 emissions in this economy. In spite of being merely illustrative, the empirical approach suggested here may provide an important insight into the impacts that might result from the application of a centralizing urban strategy and adequate urban planning.

4.10. Applying a CSA modelling framework: 'commuting embodied' in product production

In this section, the main aim consists of demonstrating other potential applications that can be performed through the implementation of a CSA modelling framework. This framework has a set of potential applications that is naturally dependent on the scope and subject to be studied, as well as on the geographical configuration and characteristics of the data provided. Some of the possible applications are similar to those that have been deeply explored by Miller and Blair (2009) and in many of the already quoted MRIO derived frameworks.

Multipliers composing the **D** matrix (the Leontief Inverse or total requirements matrix) can be transformed from output multipliers into other multipliers. Miller and Blair (2009: 244) refer to other types of multipliers that are often used: (a) income earned by households in each sector because of the new outputs, (b) employment (jobs, in physical terms) that is expected to be generated in each sector because of the new outputs and (c) the value added that is created by each sector in the economy. These kinds of multipliers have also been applied in the works developed during this research, and were used more specifically to provide Tables 32 and Tables 32 in sections 4.8. and 4.9., respectively.

Notwithstanding, it is important to analyze the employment and commuting embodied in product production for a given region studied in this work. Indeed, in a paper first presented at the 22nd International Input-Output Association Conference (Lisbon, Portugal) and then improved and presented at the 6th SHAIO Conference (Barcelona, Spain), the number of commuters incorporated into a given vector product productions, which contributes to exacerbating traffic, congestion, energy consumption and, consequently, CO_2 emissions was estimated with regard to their specific housing location.

In the specific case of this work, it was only estimated the commuting 'embodied' in Greater Lisbon product production.

So, as stated, the **D** matrix presented in section 4.7., representing the Leontief inverse matrix, is divided into four different quadrants. In this particular work, the main objective consisted of estimating the effects of product production on employment in each industry. So, sub-matrix $\mathbf{D_3}$ deserves special attention as this sub-matrix specifically depicts the relations between each product's production and the effects on each industry's output, which generates employment. At the regional level, the $\mathbf{D_3}$ matrix is a 'rectangular' matrix combining different sub-matrices.

$$\mathbf{D_3} = \left[\begin{array}{c:c:c} D^{GL,GL} & D^{GL,PS} & D^{GL,RC} \\ \hdashline D^{PS,GL} & D^{PS,PS} & D^{PS,RC} \\ \hdashline D^{RC,GL} & D^{RC,PS} & D^{RC,RC} \end{array}\right] \qquad (13)$$

The sub-matrices $\mathbf{D^{ij}}$ represent the output generated in industries located in region *i* incorporated into a unitary product demand in region *j* and households' income is considered in the endogenous part of this 'core' matrix (in the bottom rows and columns of each sub-matrix, as this is a 'closed' I-O model). In this case, it is considered that in this particular example *j* is Greater Lisbon. This means that if there is an increase (or decrease) in product production in Greater Lisbon, impacts are to be felt in all of the industry outputs located in the three regions. $\mathbf{D^{GL,GL}}$, $\mathbf{D^{PS,GL}}$ and $\mathbf{D^{RC,GL}}$ deserve specific attention in this research. The sum of the cells in each column of each sub-matrix, except the ones that refer to the impact on households' income, gives the total output in the industries of each region incorporated into an unitary product production for a given product in the Greater Lisbon region, *ceteris paribus* (e.g. the industries' output incorporated into one monetary unit in telecommunications or health services product production, in Greater Lisbon).

Considering that the Greater Lisbon region is specialized in different products, it was considered relevant to attribute different weights to each product production in Greater Lisbon in order to accurately mirror its regional economic base. So, in order to estimate 1% of each product production in Greater Lisbon, *ceteris paribus*, a vector ($\mathbf{\Delta 1\%}$) representing this specific demand and production is defined (the bottom cells associated with the endogenous household income were equal to zero). So, three new sub-matrices can be computed, as follows:

$$\begin{bmatrix} \boldsymbol{\Delta x^{GL,GL}} \\ \boldsymbol{\Delta x^{PS,GL}} \\ \boldsymbol{\Delta x^{RC,GL}} \end{bmatrix} = \begin{bmatrix} \mathbf{D^{GL,GL}} \\ \mathbf{D^{PS,GL}} \\ \mathbf{D^{RC,GL}} \end{bmatrix} \cdot \ \boldsymbol{\Delta}\ \mathbf{1\%} \qquad (14)$$

Each $\mathbf{\Delta x^{i,GL}}$ is a (I+H)x1 vector, being I the number of industries and H the number of endogenous household types considered, that gives the change in the output in region *i* resulting from an increase in fin final demand equal to a 1% change in product production. The bottom cells correspond to the same impact on households' income. Then, if each cell is divided by the labor-productivity (as defined in section 4.8.), the result is:

$$\boldsymbol{\Delta e} = \begin{bmatrix} \boldsymbol{\Delta e^{GL,GL}} \\ \boldsymbol{\Delta e^{PS,GL}} \\ \boldsymbol{\Delta e^{RC,GL}} \end{bmatrix} \qquad (15)$$

Each $\mathbf{\Delta e^{i,GL}}$ being a Ix1 vector representing the variation in employment embodied in each industry located in a specific region *i* and resulting from a variation of 1% in product production. In this case, the bottom cells of the former sub-vectors, corresponding to the inputs or households columns, were suppressed since, there are any direct employment requirements associated with the household income.

Consider a new matrix $\mathbf{\Delta e^*}$ represented as follows:

$$\boldsymbol{\Delta e^*} = \begin{bmatrix} \boldsymbol{\Delta e^{*GL,GL}} & 0 & 0 \\ 0 & \boldsymbol{\Delta e^{*PS,GL}} & 0 \\ 0 & 0 & \boldsymbol{\Delta e^{*RC,GL}} \end{bmatrix} \qquad (16)$$

This new matrix is a diagonal matrix that can now be applied to estimate the commuting embodied. For this, a matrix representing the travel-to-work journeys by each industry in each region is defined as:

$$\mathbf{G} = \begin{bmatrix} \mathbf{G}^{GL} \\ \mathbf{G}^{PS} \\ \mathbf{G}^{RC} \end{bmatrix} \tag{17}$$

Each $\mathbf{G}^{\mathbf{i}}$ represents a 134x4 matrix, where each row represents the industries located in region *i*, and the first column represents the share of non-commuters, the second column represents the commuters living in the Greater Lisbon, despite the region where they work, and the other two columns represent the commuters living in the Peninsula de Setubal and in the Rest of the Country. As each column represents a share, then the sum of all of the columns in each row must be equal to 1.

Then,

$$\mathbf{\Delta W} = \mathbf{\Delta e^*} \times \mathbf{G} = \begin{bmatrix} \mathbf{\Delta W}^{GL} \\ \mathbf{\Delta W}^{PS} \\ \mathbf{\Delta W}^{RC} \end{bmatrix} \tag{18}$$

Where each $\mathbf{\Delta W}^{\mathbf{i}}$ is a 134x4 matrix that gives the employment variation in the 134 industries of region *i*, splitting non-commuters and commuters by their place of residence (concerning the three regions considered in this model). Finally, the estimated employment by industry can be estimated by:

$$\mathbf{\Delta W}^{T} = \mathbf{\Delta W}^{GL} + \mathbf{\Delta W}^{PS} + \mathbf{\Delta W}^{RC} \tag{19}$$

As this research considers the commuting ‘embodied’ in 1% of each product production, the values corresponding to the non-commuters in each of the three regions (represented in the first column of each matrix) are neglected. So, in this particular case, only the values described in the second, third and fourth columns are considered. Moreover, in this specific work, the commuting among workers that travel between municipalities located in the ‘Rest of the Country’ is also considered. In other words, as production in Greater Lisbon has impacts in other regions, there is also an effect on commuting in the ‘Rest of the Country’ due to changes in production in Greater Lisbon.

Table 39 illustrates the data concerning the products produced in Greater Lisbon that incorporate more commuting in 1% of their production, in absolute values, including the direct, indirect and induced effects, and the regional structure of these flows. It is important to note that in the columns that display the number of commuters, that work in the Peninsula de Setubal and the Rest of the Country, are considered those that commute inside those regions and also those that come from other regions, including the ones that come from the Greater Lisbon itself.

Table 39: Commuting 'embodied' in 1% of product production in Greater Lisbon: Top 6 products

Number (%) of FTE jobs	Working in the Greater Lisbon						Working in other regions				TOTAL
	Living in other municip. of Greater Lisbon		Living in Peninsula Setúbal		Living in the Rest of the Country		Peninsula de Setúbal		Rest of the Country		
	N.	%	N.	%	N.	%	N.	%	N.	%	
Wholesale trade	503	64	119	15	50	6	18	2	90	12	*780*
Human health activities	491	68	131	18	37	5	12	2	52	7	*723*
Retail trade	451	69	104	16	38	6	10	1	48	7	*650*
Building projects and construction	338	59	91	16	47	8	10	2	85	15	*571*
Education	359	70	75	15	35	7	8	2	38	7	*515*
Foreign affairs, security, order and protection	299	62	101	21	41	8	9	2	33	7	*482*

Source: Own calculations

Table 39 shows how the production of each of these products in the Greater Lisbon area contributes to the commuting activity in Greater Lisbon, the Peninsula de Setubal and the Rest of the Country. It is clear that different products 'embody' different levels of commuting. For example, 1% of "Wholesale trade" products production generates 780 FTE commuters, of which 672 work in the Greater Lisbon region (503 live in the Greater Lisbon region, 119 in Peninsula de Setubal and 50 in the Rest of the Country). Additionally, there are also 108 commuters that work in the Peninsula de Setubal or in the Rest of the Country regions. So, the production in Greater Lisbon contributes to exacerbating the commuting phenomenon in other regions and, consequently, reinforces the environmental externalities.

In absolute terms, the product that generates more commuting proceeding from the Peninsula de Setubal is "Human health activities", whereas Wholesale trade" is the one that generates more commuting of workers living in Greater Lisbon or in the Rest of the Country. It is also interesting to observe that "Human Health" is the second activity that generates more commuters working in the Peninsula de Setubal region and only the fifth that embodies more commuters working in the Rest of the Country.

One unique characteristic strictly associated with the application of this methodology allows for a new remarkable perspective of 'commuting spillovers'. For example, 1% of "Health Activities" production 'embodies' 131 commuters from the Peninsula de Setubal to Greater Lisbon, but only 90 of these work directly in this industry, while the remaining 41 correspond to the 'embodiment' of commuters who live in the Peninsula de Setubal and work in other industries located in the Greater Lisbon region. This outcome specifically comes from incorporating the indirect and induced effects.

As the commuting intensity by industry, and by region, varies significantly, this implies that each product's production has the potential to affect commuting differently. Thus, commuting resulting from indirect and induced effects should not be neglected. There is a major reason for this conclusion: a significant share of the commuting flows resulting from the production of a specific product can be linked to the industry and the region that produces the inputs needed to satisfy the production.

To sum up, this research adds to the existing literature as it uncovers the commuting effects associated with sectoral and interregional interdependencies, thereby opening up new avenues for improving policy and decision-making processes in highly urbanized regions and improving the impact assessment application to metropolitan regions.

4.11. Final Comments

The main goal of this PhD dissertation consists of transforming/adapting an MRIO framework to assess the economic, social and environmental impacts of commuting. The transformations include the introduction of regional distribution of income, the explicit split of final household consumption into commuters and non-commuters, a specific development of the real estate rental activity and the distribution of income that arises from this economic activity, and, finally, the extension of the model to an energy and environmental satellite account. All of the steps were described in this chapter.

The application of this advanced model in two 'extreme' scenarios allowed us to better understand the consequences and impacts of commuting in a metropolitan setting. Indeed, commuting by itself induces an important loss in economic activity. This outcome and also the intensity of the effect may be different in other metropolitan areas located in countries with a different economic structure, particularly when the commuting-related products are mainly domestically produced. However, it is our belief that that this result is remarkable to the Lisbon Metropolitan Area but also to the majority of metropolitan areas in Western countries, particularly in Europe but also in other economies as Japan and China. This mostly results from the different consumption structure between commuters and non-commuters, since commuters have a consumption pattern that is more intensive in products with a large share of international inputs embodied in their production or inclusively that are almost exclusively imported. On the other hand, commuting as part of a more embracing phenomenon has a relevant role in potentiating the agglomeration economies in a given region, since it contributes to maintaining the proximity of firms within a given CBD.

Additionally, the results in terms of real estate rents matter in macroeconomic terms. However, this effect may be considered a small one, taking into account the size of regional or national economies. Nevertheless, it can also imply an important distribution of benefits/losses according to each type of economic agent located in the region/country. In other words, landlords would be important beneficiaries of a situation where real estate rents increase, following an agglomeration of the economic activity.

Moreover, the CSA modeling framework was also applied in a more 'realistic' scenario in which the 'vacant' houses located in the Lisbon municipality were occupied by commuters. This also underlines a possible future use of this tool: applying it to real-case studies in order to understand the additional cost/benefits of changes in commuting patterns. The results of this empirical approach shed some light on the impacts that result from promoting urban recentralization and the adoption of adequate tools and urban planning strategies. Indeed, with this innovative modeling framework, commuters and economic activity are integrated in the same framework and, as shown, the economic multipliers can be converted into 'commuter multipliers'.

Finally, the results obtained from the hypothetical scenarios and the hypothetical reduction of 'wasteful' commuting point to important significant gains in terms of the environment. Comparing all of the scenarios examined, the current situation is the one where energy consumptions and CO_2 emissions have the most important negative effects at the environmental level.

“For many people, commuting is the worst part
of the day, and policies that can make commuting shorter
(...) would be a straightforward way to
reduce minor but widespread suffering.”

Daniel Kahneman, 2012

“Buy land,
They don’t make it anymore”

Mark Twain

CHAPTER 5 – CONCLUSION

This PhD dissertation assumed the ambition of addressing one of the most globalized urban phenomena, which determinately forges the lives of millions of human beings. Commuting is more than simply travel, repeated every day, and usually taking a certain amount of time and money, which, on a less fortunate day, can completely ruin someone’s mood. An average commuter in the Lisbon Metropolitan Area spends approximately 10 months of their life travelling to work, by the time of his retirement. This is probably more than the time consumed by other more ‘rewarding’ activities. Indeed, commuting is one of the most important activities in the contemporary world, for three major reasons: first, it is a vital ‘cost’ tolerated by households, as it allows them to earn their income; second, it is crucial to the society as it provides the necessary workforce for the production activity; and, finally, most of the time it is the byproduct of two of the most difficult decisions made by households - the choice to buy/rent a house and the option to have a certain job. So, commuting usually emerges as an undesirable consequence of these meaningful dimensions.

Moreover, commuting has a key role in regional and urban economies. Commuting affects the economy as much as (or even more than) other interregional economic flows or possible external shocks. Commuting shapes the CBDs and defines their relationship with neighboring regions. It changes households’ consumption patterns and exacerbates fuel consumption and greenhouse gas emissions. As shown, the dialectical relationship between commuting, territorial dimensions and economic activity raises the importance of the marriage between urban modeling and more realistic frameworks that incorporate (multi-dimensional) interdependencies. Society, academia and people demand advances capable of shedding some light on these difficult but inspiring challenges. Accordingly, in this dissertation several contributions were made.

5.1. Methodological and empirical contributions

Chapter 2 described several dimensions of the Lisbon Metropolitan Area (LMA). This region comprises two NUTS III regions. Greater Lisbon is characterized by the location of Lisbon, the Portuguese capital, while the other region – Peninsula de Setubal – is typically referred to as a suburban region. Some demographic and economic indicators were presented highlighting the unique characteristics of Greater Lisbon, as a region that concentrates many productive industries (mainly services) and an important concentration of several headquarters of national and multinational firms. Thus, the analysis highlights an important trade balance surplus in the Greater Lisbon region (mostly due to interregional trade). On the other hand, the trade balance of the Peninsula de Setubal presents a large deficit that accounts for almost 30% of its GDP. This significant deficit is (at least) in part balanced by the income resulting from commuting. Indeed, an important share of commuters that live in the Peninsula de Setubal have their salaries paid by the industries located in the Greater Lisbon region and "transfer" that money to the Peninsula de Setubal region. Finally, the commuting activity in Portugal and in the LMA was characterized. The LMA is the region where commuting is more intensive, with 47% of the workers traveling to other municipalities in order to work. This intensive commuting also occurs between municipalities located in the two margins of the Tagus River. The large distances traveled by an important share of the commuters contribute to the impressive amount of kilometers traveled by commuters every day in the LMA (more than 35 million). As highlighted, different industries incorporate a significantly distinct share of commuters among their workers. Indeed, while for some industries around 70% of their workforce is composed of commuters (e.g. "Water Transport", "Air Transport", "Computer Programming, Consultancy and related activities"), for others the figure is less than 30% (e.g. "Agriculture", "Fishing" and "Manufacture of basic metals"). Furthermore, despite the relatively higher use of public transportation in the LMA than in the 'Rest of the Country', it is very significant that most of these workers commute by car.

Next, Chapter 3 was specifically devoted to the methodology used in the development of the MRIO framework applied to the LMA. It started by presenting an overview of the characteristics and procedures applied to compile the Input-Output (I-O) data at national level. The official data provided by the National Statistical Institute provided the Use Table at "purchasers' prices" and "total flows". So, the first step consisted of transforming our national table to "basic prices" and "domestic flows". According to the MULTI2C practice, the procedures to 'close' the model to households living mainly on labor income (employees and self-employed workers) were applied. So, the household consumption was split into five different household types and the income paid by each industry as compensation for employees and mixed-income was estimated. Next, from the national table, 30 I-O regional tables were estimated, each one corresponding to a Portuguese NUTS III region. These regionalization procedures made good use of detailed information from several sources to estimate, on the one hand, the product supply at the regional level and, on the other, the specific "use" of products (both as Intermediate Consumption or Final Demand) in each of the regions. In the Intermediate Consumption case, the consumption of industries was generally made applying the equal industry technology assumption. Then, to derive the LMA MRIO model, the interregional trade estimation was performed through the application of a pragmatic methodology, according to products' specific characteristics (tradable, non-tradable or others).

Chapter 4 was devoted to the conceptualization and then to the application of the 'Commuting Satellite Account' (CSA) framework. First, the process of estimating the elements that integrated the CSA was explained, involving three particular features on which that framework particularly focused: first, the interregional distribution of labor income by region and household type, according to the journey-to-work data; second, the distinct consumption structures of commuter and non-commuter households; and, finally, the real estate rental activities considered in the endogenous part of the model (a share of the income originated by this activity represents a transfer directly benefiting households, particularly landlords but also, more marginally, those living mainly from labor income and pensions). Next, all of these components were integrated together with an energy and environmental extension, which allowed for assessing the impacts of certain shocks in the (physical) quantity of primary energy used by each industry or household type, in each region. These energy uses were then "converted" into corresponding CO_2 emissions.

After that, the CSA framework was applied to estimate hypothetical scenarios, considering changes in the commuting patterns of those that live and work in the Lisbon Metropolitan Area. First, two 'extreme' scenarios were applied in order to assess the opportunity costs of commuting. One scenario admitted the end of commuting, by considering that workers change their place of residence to the municipality where they work. The other scenario also admitted the hypothesis of commuting ceasing, but through the increased dispersion of economic activities to the places where commuters live. These scenarios demand a specific set of transformations in the input coefficients matrix and, consequently, in the Leontief inverse. These modifications and algebraic procedures were deeply explored in this chapter.

According to the results of the first scenario, if the current LMA commuters could live closer to their workplace, important savings would emerge in terms of economic, social and environmental (opportunity) costs. In this scenario, where agglomeration forces are strengthened and density increases, the end of commuting flows and, consequently, a change in households' consumption structure, contributes to an expansion of the national economy. So, for the LMA, the GVA loss in the suburbs (216 million Euros in the Peninsula de Setubal and 43 million Euros in the 'Rest of the Country') is more than offset by an increase in Greater Lisbon GVA (921 million Euros). The difference between the benefits in Greater Lisbon and the losses in Peninsula de Setubal and the 'Rest of the Country' indicate that the Portuguese GVA would increase by 0.5%. This is even more relevant as energy consumption and CO_2 emissions should simultaneously decrease (about 0.7% of the national emissions). This is exclusively due to the reduction in the consumption of "Oil and its derivatives", as the economy expansion would lead to an increase in the consumption of Natural Gas and Coal.

On the other hand, if commuting vanishes due to the economic activity dispersion towards the suburbs, the economic consequences would be likely to be globally negative, despite the increase in the suburbs' economic production. So, the Peninsula de Setubal and the 'Rest of the Country' GVAs would increase by more than 4,159 and 883 million Euros, respectively. However, the decline in Greater Lisbon would be much more significant leading to a 1.5% loss in national GVA. In terms of employment, the national decrease would be less significant (approximately 0.5%) as the economy would be more concentrated in less productive regions (and so, more workforce would be needed for the same amount of Output). Thus, for the LMA case study, the results indicate that the dispersion would imply a reduction in economic productivity that would overwhelm the benefits of ending commuting. This scenario highlights an important trade-off between economic and environmental effects, since it was estimated that national greenhouse gas emissions would fall by almost 3%, thus indicating a substantial positive environmental impact. Although an important share of this effect would result from the decline in the economy, another part would result from a shift towards more 'environmental friendly' consumption.

As changes in urban density may affect real estate rental activities, the results of both scenarios were tested through a sensitivity analysis. Accordingly, it was assumed that, in the scenario where households change their place of residence, housing rents in the Greater Lisbon region would increase. Alternatively, in the scenario where firms reallocate to the suburbs, the rents supported by industries in the Peninsula de Setubal would rise. Despite the substantial changes in the real estate rental effort, the results broadly confirm the findings highlighted above and produce a relatively small change in macroeconomic indicators. The main reason is that while rents are considered a cost supported by households or firms, they are also an income that favors some economic agents that provide this specific service. Thus, in macroeconomic terms, this specific expenditure does not represent such a significant burden on the economy. Nevertheless, the macro analysis conceals the fact that changes in real estate rental activity may unbalance the income distributed among households or firms. Indeed, if higher real estate rental prices are an outcome of the agglomeration process then it is predictable that landlords and financial institutions (who are also major producers of the rental services) are the ones that would obtain the major benefit from this side-effect. Finally, the comprehensive analysis of both scenarios indicates dichotomous, yet complementary, conclusions: commuting, by itself, induces significant economic, social and environmental costs, and commuting as one of the many elements arising from the agglomeration phenomenon is undoubtedly linked to processes of increasing productivity and economic expansion. Additionally, commuting imposes important environmental costs. These important conclusions have major relevance and should materialize in a more adequate set of policies and recommendations that can accurately contribute to accomplishing the 11st Sustainable Development Goal of the UN 2030 Agenda (UN, 2015).

In a second application, the CSA framework was applied to assess a 'more realistic' scenario. It was considered that a share of the 'unoccupied' houses in the Lisbon municipality would be inhabited by commuters (who, therefore, would become non-commuters). So, the simple reallocation of 4% of the LMA commuters (about 25 thousands persons) would generate a total gain of 0.04% of national GVA. This redistribution of people would be (basically) from the other regions to Greater Lisbon, which would result in its economic expansion, while this declined in the others. Additionally, the major share of the reallocation would be within the Greater Lisbon region, which justifies why its benefits would exceed in a widespread manner the other regions' losses. In a similar mode to the first 'extreme' scenario of a commuting opportunity costs appraisal, two main reasons explain the national expansion in GVA. First, when commuters become non-commuters this implies changes in the consumption demand composition, from products with larger imports content (vehicles, fuel, etc.) to others comprising a larger share of nationally generated value added. The second reason is that when ex-commuters change their place of residence to the Greater Lisbon region, they are deemed to behave as Lisbon residents. This means that, for example, they demand more services, which have a higher average GVA/Output ratio, while adopting the 'propensity to consume' of their new region. Once more, the results of this more 'realistic' scenario reinforce the conclusion that commuting has important costs that must be addressed by decision-makers at the local and regional levels.

Finally, the CSA is a suitable tool to assess the impacts of multiple changes in the exogenous final demand. In the latest application presented in Chapter 4, an increase of 1% in the demand directed towards product production in the Greater Lisbon region was considered. In this application, the proposed CSA multipliers matrix was different from the one that would result from a more 'traditionalistic' approach, as it included a broader set of income flows. Ultimately, this also resulted in distinct income and employment multipliers matrices. Actually, one important step forward presented in section 4.10 comprised the estimation of a so-called 'commuter multipliers matrix' and the estimation of the 'commuting embodied' in the production in Greater Lisbon.

This work sets out an innovative approach to study the complexity of commuting flows and their impacts. The proposed CSA framework is expected to be a decisive step in this direction. For this, the CSA has been specifically designed to assess changes in workers' commuting patterns that affect the regional distribution of labor income, household consumption patterns and real estate rental activities. The integration of a CSA into the mainstream multi-regional input-output framework allows for the study of a wide range of interactions anchored in the specific reality of a given geographical territory. Thus, while deviating from more 'theoretical' approaches it makes an important contribution through the application of a more 'down-to-earth' framework in the field of urban studies. Moreover, the CSA takes a step forward with regard to traditional sectoral interdependencies by modeling the income sprawl throughout the territory, taking into account commuting flows and rental activities. The CSA application to the Lisbon Metropolitan Area illustrates the contribution of commuting patterns to shaping urban, regional and even national economies.

The framework developed opens up new research avenues to assess structural changes in urban tissues, commuting patterns and housing or workplace locations. Indeed, the outcome of this PhD dissertation sheds light on some possible policy designs that would encourage economic growth, and simultaneously increase well-being and a more sustainable urban environment. This work integrates (and reinforces) a set of works that have stated the importance of implementing coherent and effective urban planning that on the one hand, acknowledges the opportunity costs of commuting (and, consequently, of urban sprawling), and, on the other hand, does not ignore the benefits of economic agglomeration. Ceasing commuting is an unreachable and, even, undesirable accomplishment, but to manage commuting and reduce sprawling looks possible and is dependent on of our capability to implement the proper changes. Of course, in historical CBDs, such as the one located in the Lisbon municipality, the increasing agglomeration must also look to protect historic buildings and cultural heritage. This 'will' to change our cities will definitely require a considerable break with past and current practices, imposing the application of specific measures, as advanced below.

5.2. Policy Recommendations

Next, some policy recommendations are addressed and some critical findings are analyzed, to reach conclusions at a more general level and others focusing more specifically on the Portuguese reality.

1. Urban and regional planning matters. Despite the fact that the decision to buy a house with certain characteristics, in a specific location, should belong to the personal sphere of every household, the urbanization process produces 'winners and losers'. Moreover, the trillions of variables weighted billions of times to support the decision of millions of households living in a given city (may) actually

not lead to the best societal outcome. As commuting will continue to exist in modern societies, it cannot continue to be ‘swept under the carpet’ and more active policies should be applied to reduce it, in order to minimize its negative consequences. So, it is our belief that active planning (correctly performed and applied) may improve life in urban spaces. Ewing (1997: 118) considers that “the posture usually assumed by local governments (…), waiting for property owners to come forward with rezoning requests is not planning but reacting”. Moreover, Hamilton and Röell (1982) had already stated several ‘market failures’ that generate ‘wasteful’ commuting and that justify public regulation. So, the role of planning arises as a mechanism to intervene in the market processes to achieve broader aims that should be clearly stated and widely acknowledged.

2. Planning should be made at the correct level of governance. According to Brenner (1999) the political-regulatory institutions of urban regions are often fragmented into multiple agencies and departments with distinct jurisdictions and tasks. So, contemporary discussions on regional governance must emphasize the need for administrative flexibility and regionally coordinated economic development strategies as a way to minimize some cases of interspatial competition. In Portugal, urban policies have been mostly outlined at the municipal level. This is even more problematic, as it often results in different actors defining policies that in the end lead to contradictory results. The most striking point is that some suburban municipalities actively compete to attract inhabitants and determinately contribute to enhancing the cost of commuting. For example, Almeida et al. (2013) reported the case of a Portuguese municipality where policy makers considered that higher tax rates (despite their value is well below the effective cost supported by public authorities) may constitute a relevant loss in regional competitiveness and reduce its attractiveness. Accordingly, many local policy makers admit to often comparing their tax rates with the ones practiced in their neighboring regions. In fact, the policy makers ‘rational’ option is very often to promote extensive land-use, settling new suburban neighborhoods, and in this way increasing their budgets and political influence. This may be even truer in the suburbs, where land is abundant and relatively cheap and many of the investments and infrastructures required to sustain this new construction (e.g. water, road, public facilities) are financed by the central government. This highlights the fact that the attribution of wider

responsibilities, concerning urban and regional planning, to inter-municipal and/or regional authorities, will definitely contribute to reducing the competition between municipalities and increase the potential benefits of a coherent urban policy.

3. Land-use Policy can favor less sprawled regions and, consequently, less commuting. One must be aware that the national legal background in Portugal is different from that prevailing in most European countries. According to Newman and Thornley (1996), for historical reasons the Portuguese case represents one of the most underdeveloped urban planning systems. Carvalho and Oliveira (2015) also consider that the Portuguese municipalities benefit from a large (and discretionary) margin to state that a certain area of land as urban or available for future construction. Moreover, due to the "fragmented and sprawled infrastructural occupation in Portugal, during the last decades, the zones classified as urban (or where building is admissible) correspond to very extensive areas" (Carvalho and Oliveira, 2015: 3)[69]. This had already been acknowledged in the National Program for Territorial Planning and Management (PNPOT, 2007), as it refers to the need to reduce the urban areas in Portugal. The extension of land that has been classified as "urban" or "passible for being constructed" is so much sprawled that Mateus (2007) considered that the urban perimeters in Portugal could accommodate more than 30 million inhabitants (three times more the Portuguese population). So, building construction and, consequently, the urbanization process become exclusively dependent on private initiatives, implying in many cases that the 'rational and individual' decision of the investor leads to the use of the 'unoccupied' lands located in the suburbs (since they are less expensive). From this political and institutional framework an additional problem arises. As most of the land is privately owned and the initiative to build belongs to property owners, the 'rational' decision of the landowner of more central places can be simply to maintain the land as vacant and sell it in the future, independently of the costs supported by the society (inclusively the commuting costs). Although this question seems to have been largely ignored (at least in Portugal), two important pieces of work addressed this issue decades ago. Bahl (1968) considers that if a city is

[69] A new Law (31/2014) and a Decree-Law (80/2015) have recently been approved and new restriction to the (re)classification of soil was imposed on municipalities. However, it does not directly imply the significant reduction of the zones already classified as urban.

expected to grow and there are expectations that the land value will continue to increase, then the landowner will continue to keep (and eventually add) his stock of land until an increasing expected future return from an alternative investment emerges. On the other hand, Clawson (1962: 108) has a more straightforward view of the landownership problem in central cities and considers that "land speculation, sprawl and intermingled idle land are all natural outgrowths of economic and institutional forces (…). Policies should be applied to minimize the impact of land speculation". In practical terms, the differences between the Portuguese institutional framework and other European frameworks can be easily observed. Taking the Netherlands as an example Van der Krabben and Jacobs (2013) describe the land development strategy. The process begins by involving public purchase, ownership and active planning for land use before a certain parcel is released for actual development to the private sector. They argue that this guarantees building developments according to public policies, while ensuring full cost recovery for all public works (through the sale of building plots). Simultaneously, at least part of the surplus value of the land is captured by the public sphere. Otherwise in Portugal, urban growth has been left to private initiatives. Land is private from the beginning until the end of the process. The application of more restrictive regulatory legislation could have reduced the construction of new building lots in the suburbs and redirected some of the investment made in new construction to the refurbishment of old city areas and a downtown renaissance. So, commuting expansion could be (to a certain point) avoided.

4. Transport Policy is a central issue in urban governance. The decision to become a commuter is to a large extent dependent on transportation costs. When local, regional or federal governments decide to build a new highway or a bridge or to finance public transportation, in fact they are using taxes to favor those that will use such infrastructures more intensively. On the contrary, when the burden falls on the commuter (at least in the long term) commuting is discouraged. So, in a more sprawled city, where car commuting prevails, one may have a case to implement measures that can condition car use. Indeed, the recent decrease in oil prices, which could lead to important and sustained deflation in fuel prices, has reduced the costs supported by those that commute by car and contributed to

increasing commuting attractiveness. Accordingly, the argument runs that national governments should mitigate this recent decrease in fuel prices and maintain the prices at a significant level. This can be done through fiscal policy on “oil and its derivatives” or through the introduction of taxes or fees that are in turn applied to improve the quality of life of those living in the CBD. These measures can be complemented by, for example, the introduction of congestion tolls (already applied, with different specifications, in London, Singapore, Durham or Milan). As introducing congestion tolls is often politically difficult, alternatively, parking policies could be applied to reduce traffic in the city center (Verhoef et al. 1995; Barata et al., 2011). In this case, the recommendation would be to give priority to non-commuters living in the CBD, in occupying the limited number of parking places available there. Initiatives such as park and ride (Mingardo, 2013), car-sharing and car-pooling (Correia and Antunes, 2012) can also be encouraged among those that live or travel to the CBD. A collateral or even the main purpose of this type of policy usually consists of triggering a change in the means of transportation used in commuting and it is not so much directed to reduce commuting as argued in this thesis (although a non-explored topic is that different commuting modes imply different costs). Without doubt, while roads and highways are built to reduce congestion, it seems that these infrastructures also contribute to exacerbating commuting. Indeed, Carvalho et al. (2013) consider that the process of building new roads should be globally suspended or else sprawling will continue to increase.

5.3. Limits and Future Research

Throughout this study it has become clear that the lack of statistical data requires making several (yet, as we believe, feasible) assumptions. Some examples concern the regionalization of the I-O tables and the estimation of interregional trade between Greater Lisbon, the Peninsula de Setubal and the ‘Rest of the Country’. Moreover, it would certainly be preferable to have used more detailed information concerning the commuter and non-commuter households’ consumption structures and data regarding the regional distribution of real estate rental income flows. Of course, these information gaps have limited the analysis, restricting not only the quantity, but also the quality, of the information provided for policy purposes. Unquestionably, Portuguese National and (mostly) Regional Accounts need to continue to improve with regard to the quality of data, in order to allow for more accurate specification of the intricate complex interactions between geography and the economy in Portugal. The same applies to the data (un)availability concerning regional primary energy consumption and CO_2 emissions.

Nevertheless, future work can be performed using the 'Commuting Satellite Account' framework either based on the LMA tri-regional model or by adapting the procedure to other metropolitan regions, as many research topics still remain unexplored. On the one hand, this could imply some refinements and methodological advances applied in the context of the CSA framework, such as:

- Extension of the model to incorporate other satellite information of major importance to assist policy-makers on an urban scale, namely e.g. water, waste disposal, land-use.
- Extension of the model to embrace a higher number of regions. Moreover, it is the author's belief that the estimation of international and interregional trade and the comprehensive analysis of the corresponding results would largely benefit from detaching the Lisbon municipality from the Greater Lisbon region and from its consideration as an independent region.
- A higher level of households demand disaggregation. Namely, commuters' consumption patterns could be split according to the means of transportation used or according to other social or demographic characteristics (e.g. age, number of members in the household, housing type).
- To perform the analysis for more recent years and assess the structural changes (through some form of structural decomposition analysis and/or disaggregation techniques), which might have occurred in the Greater Lisbon region.
- To incorporate this model into an even more comprehensive framework, making use of the sophisticated techniques associated with Geographical Information Systems, allowing for the integration of transport networks, traffic simulation and mixed land-uses.
- To consider the existence of non-linear relations between land availability, commuting and housing prices. This will certainly demand much more data availability and/or the assumption of additional hypotheses concerning the relations and elasticities affecting these dimensions, but it would certainly

improve the richness of the analysis addressed. This would also be a step forward for a discussion of the optimum level of commuting.

On the other hand, the CSA modeling framework could also be applied to perform other empirical assessments of national and/or regional impacts resulting from, for example:

- A disruption in commuter flows in the Lisbon municipality due for example, to a disaster on one of the two bridges crossing the River Tagus at Lisbon or a persistent strike in the boat transportation services).
- The introduction of traffic and transport demand management constraints and/or technological changes in private transportation and/or an increase in the public transport network, which would induce changes in the modal split.
- The computation of high-order economic costs or benefits that might result from an expansion in the road, train or underground network.

5.4. Final Words

To conclude, decisive changes from the *status quo* are required to contain sprawling in most of the large metropolitan areas worldwide, as in the Lisbon case. The author of this dissertation definitely believes that the existing reality has harmed the economy, the environment and the lives of millions of workers, who, every day, spend an important share of their time inside their car or on public transportation. As cities are increasingly the 'home' of more and more humans, it is time to move towards a new institutional and legal framework to allow for living in a human settlement that:

- Provides shelter for all its inhabitants;
- Provides jobs and employment at an acceptable distance;
- Allows for substituting the time spent commuting with more interesting and rewarding activities;
- Provides access to affordable, accessible and sustainable transport systems;
- Reduces the environmental impact of its activities and addresses air quality issues;
- Provides universal access to safe, inclusive and accessible green and public spaces.

- Supports positive economic, social and environmental links between urban, peri-urban and rural areas through the implementation of regional and urban development planning.

Such prosperous, culturally intense, healthier and sustainable cities would not be easy to raise. However, mankind is continuing to evolve and it has been capable of many astonishing achievements. In a period where the economic challenges seem to circumscribe to uninspired goals such as austerity and a reduction in public spending, society needs to step forward and assume that a better future must galvanize more efforts, more involvement and audacity.

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