J Geogr Syst (2017) 19:301–317
DOI 10.1007/s10109-017-0250-5

ORIGINAL ARTICLE

Modeling commuting patterns in a multi-regional input–output framework: impacts of an 'urban re-centralization' scenario

J.-P. Ferreira[1] · P. Ramos[1] · L. Cruz[1] · E. Barata[1]

Received: 28 October 2015 / Accepted: 24 March 2017 / Published online: 6 April 2017

Abstract The paper suggests a modeling approach for assessing economic and social impacts of changes in urban forms and commuting patterns that extends a multi-regional input–output framework by incorporating a set of commuting-related consequences. The Lisbon Metropolitan Area case with an urban re-centralization scenario is used as an example to illustrate the relevance of this modeling approach for analyzing commuting-related changes in regional income distribution on the one side and in household consumption structures on the other.

Keywords Centralization · Commuting · Input–output analysis · Metropolitan areas · Multi-regional input–output models · Urban planning

JEL Classification J11 · R12 · R15

✉ J.-P. Ferreira
joao.ferreira@fe.uc.pt

[1] CeBER, GEMF, Faculty of Economics, University of Coimbra, Av. Dias da Silva, 165, 3004-512 Coimbra, Portugal

1 Introduction

Input-output (I/O) models have been widely used in economics to study the interdependencies between the different sectors within an economy (Baumol 2000) and to analyze the overall impact of given shocks, including their direct, indirect and induced effects (Leontief 1986; Miller and Blair 2009). Furthermore, the existence of interregional spillover effects, which can be particularly relevant when considering a regional economic system (Hewings et al. 2004), justifies the use of interregional I/O models. A multi-regional input-output (MRIO) framework extends the scope of I/O models by incorporating the interactions between industries (and households) in the different regions considered. This framework can incorporate other extensions as well, such as the impacts on employment and resource use, pollutant emissions and energy consumption (Cruz et al. 2005; Miller and Blair 2009). In this paper we propose an extension to the MRIO framework to improve the analysis of commuting flows in urban economies and for a comprehensive assessment of their effects.

The paper is organized as follows. The objectives of the study are described in Section 2. The general model structure and the data used are set out in Section 3, with particular emphasis on the novel components of the model developed to derive an application suited to Lisbon Metropolitan Area. Section 4 presents the main results from applying the model approach to the commuting analysis, within Lisbon Metropolitan Area, based on a scenario for urban population and economic activities recentralization. Section 5 concludes.

2 Commuting embedded in multi-regional input-output models

Commuting is a complex process. Hamilton and Roëll (1982) point out that, although households maximize their utility function with respect to the evaluation of opportunity (time and money) accessibility costs and housing prices, there are factors, such as market failures, that limit the maximum level of utility. Accordingly, commuting that actually occurs in a metropolitan region is far from what would be required if households could "freely" select jobs and housing locations that minimize the commuting costs. This excessive commuting is what Hamilton and Roëll (1982) define as "wasteful commuting". Moreover, Hamilton and Roëll (1982) consider that commuters within different urban regions tend to behave differently, entailing specific levels of 'wasteful commuting'.

Definitively, the commuting phenomenon in metropolitan areas contributes to exacerbating the regional income distribution flows within these regions. This topic has merited attention in regional economic studies, with important contributions by Geoffrey J. D. Hewings, relating particularly to the models derived for the Chicago Metropolitan Area. Hewings et al. (2001) use journey-to-work data to decompose the value-added coefficients associated with different income groups by county. They conclude that the greatest source of interdependency variation among regions is commuting (whether the focus is on production, employment, or income). The conclusions of this work also indicate the need to employ techniques that can help to trace the path of interregional (origin-destination) income. Sonis and Hewings (2003) suggest 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 consumption-expenditure patterns in metropolitan areas (in contrast to what we see in more aggregated interregional or international interdependency modeling).

The consideration of (commuting-related) regional income distribution in I/O frameworks was also proposed by Madden and Batey (1983) and deeply explored by Oosterhaven and Folmer (1985). Madsen and Jensen-Butler (2005) observed commuting as an activity involving a regional distribution of generated gross value added (GVA) outside the region and brought into the other regions as income. More recently, Aroca and Atienza (2011) examined long distance commuting in the Chilean mining industry and showed that commuting is an important mechanism for spreading the economic benefits of industries in one region to other regions, in particular through interdependency with (neighboring) regions where the workers live and consume.

These contributions highlight a mostly forgotten feature: commuting has a significant influence on household consumption. This is because households living near the most significant employment centers tend to spend relatively more on housing rent and local services (and less on fuel and other commuting related products), and also because commuters living outside their workplace region are expected to directly purchase certain products (e.g., housing, electricity, water) in the region where they live while other purchases are distributed between the living and working regions (Ferreira et al. 2014a). In short, a consistent specification of commuting economic significance

requires the separate treatment of households that (mainly) live from labor activities, and then, within these households, the separation of commuters from non-commuters. Thus, commuting is taken here as an activity performed exclusively by households living mainly from labor income.

Along with commuting, renting activities (due to demand for offices or other industrial buildings, and housing) should be incorporated into an MRIO modeling framework applied to metropolitan areas. Rents may be an important means (interconnected to commuting) of redistributing income within a metropolitan area. When commuting intensifies, more rents are paid in the new residential locations and received by agents living in different locations. Additionally, non-commuters living in those suburban regions are compelled to spend more on housing rents. In "National Accounts", renting real estate is usually considered as a productive service and not a monetary flow. Firms tend to demand offices (industrial buildings) while households demand housing. However, both office and housing rents can be paid either to firms or households. So, this research treats renting activities as monetary transfers,[1] between and within different economic sectors and regions.

On the other hand, commuting flows affect the various industries differently depending on the location of the firms. Moreover, Ferreira et al. (2014b) note the existence of relevant disparities between each industry commuter's 'attractiveness'.

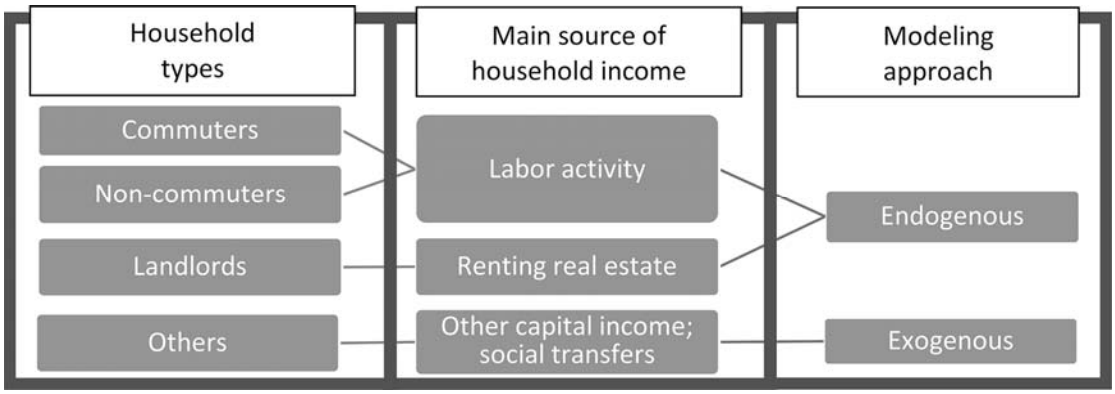
The literature suggests numerous explanatory variables to analyze these multiple influences, including housing prices (Malpezzi 1996; Cameron and Muellbauer; 1998), public transit systems (Elhorst and Oosterhaven 2006; Kawabata and Shen 2007), labor and residential accessibility (often decomposed into the attractiveness and impedance components) (Thill and Kim 2007; Alonso et al. 2014), education levels (Magrini and Lemistre 2013), gender (Kwan and Kotsev 2015), ethnicity (Williams et al. 2014) and lifestyle preferences (Walker and Li 2007). This paper does not aim to discuss the relative importance of these explanatory variables. Instead, our focus is on contributing to a better understanding of how different industries' commuting intensity affects urban economies.

Finally, the inclusion of all of these commuting-related components in the MRIO model must be addressed. Considering that most of the cited effects are associated with

[1] This means that the model deals with rents as income distribution, with no direct impact on GVA when households are the recipients. Figure 2, ahead, allows for a close inspection of how these rents are actually run in the model.

household expenditure, the assessment of the induced effects is essential, i.e., a 'closed I/O' model (at least for the consumption of some household types) must be used to analyze the interregional economic interdependencies underlying commuting activities. The closure of the model focuses on the households that live mainly from their (direct) contribution to the productive process, namely labor, both as employees and those working on their own account. Additionally, considering that an important share of the income generated by real estate renting is earned by households living mainly from renting activities (hereinafter called 'landlords'), their income (and therefore their expenditure) should also be treated separately from other sources of income and taken into account in the closure process; i.e. they are incorporated in the 'endogenous' components of the model. Thus, those living mainly from other capital income, pensions, and other social transfers are considered as "exogenous" households. Figure 1 illustrates the different household types considered within the proposed framework, by main income source, and indicates the respective modeling approach.

Fig. 1 Household types considered in the MRIO model



To take commuting specificities into account and promote a deeper understanding of metropolitan economies' complexity, we propose introducing a number of appropriate extensions into the 'standard' MRIO framework. In this paper, our analysis first considers the commuting effects on regional income distribution. Next, there is a reflection on the impacts on the consumption expenditure pattern of the parcel of households that commute. After that, we propose a way to model the interactions between economic agents and real estate renting. Finally, we explain how all of these model components can be integrated. This research highlights the need for a better understanding of how the impacts of income and consumption spread throughout a metropolitan region (and even from/to areas beyond it).

In brief, the proposed framework exhibits three novel features. The first is the discrimination of income generated by each industry according to different household types, including commuters and non-commuters. The second is consumption structure differentiation of commuters and non-commuters, among the labor income dependent households, besides the usual differentiation for the other sources of income. Finally, the third feature relates to renting activities that are treated as income distributed involving firms and households, which may vary when commuting patterns or their intensity change. So, the MRIO modeling framework requires the inclusion (in its endogenous part), for all of the regions it comprises, of extra columns and rows relating to the consumption of the household types seen as critical in the modeling context (including commuter and non-commuter types), and to the income distributed to each of these households.

The next section applies the MRIO modeling framework to the Lisbon Metropolitan Area (LMA) as an illustrative case study.

3 The Lisbon Metropolitan Area multi-regional input-output model framework

The proposed MRIO framework is based on MULTI2C, a multi-sectoral and multi-regional framework developed by a group of researchers from the University of Coimbra (Portugal) with critical input from Geoffrey J. D. Hewings, mainly in his capacity as a consultant on earlier R&D projects. This framework allows the adoption of different geographic configurations and empirical applications (Ramos et al. 2015). This particular application relies on the 2010 version of MULTI2C. The MULTI2C framework uses top-down non-survey methods to regionalize I/O tables (for the 30 Portuguese NUTS-3 regions), using detailed information provided by the Portuguese National and Regional Accounts, together with other detailed statistical information at the regional level from Statistics Portugal (INE) (population census, households expenditure survey, agricultural census and national forestry survey). The MULTI2C "Supply and Use Table" disaggregation specifies 431 products and 134 industries. The Portuguese Ministry of Employment and Social Security database is used as the main source for the determination of each industry's primary products supply, by region. The regional matrices are at "domestic flows", i.e., they concern the products produced within regional economies and national borders (international imports are treated separately). All transactions are at "basic prices", i.e., without value-added tax (VAT)

and other taxes, less subsidies, on products. Finally, trade and transportation margins are treated as inputs provided by retail and wholesale trade industries or transport services.

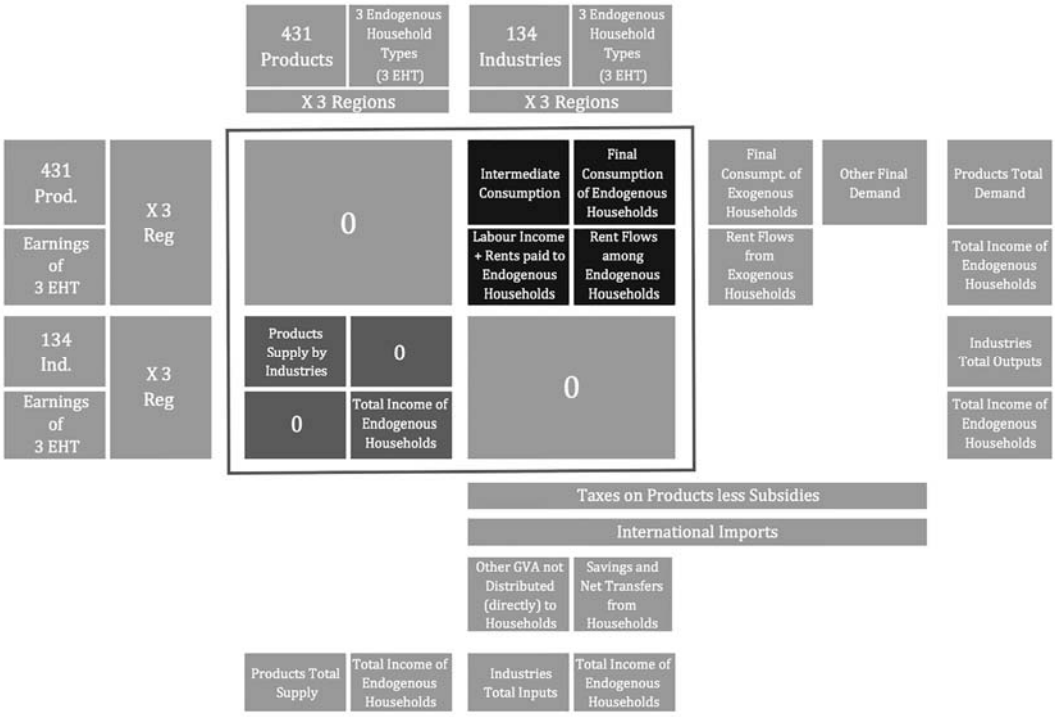
The interregional trade was also estimated according to the MULTI2C approach. The basic idea is that products have different levels of "regional tradability" (Ramos et al. 2015), and that the partition of each national input or other use, between regional imports and locally produced products, depends on a typology of tradability. This procedure led to estimates of gross interregional imports. As net interregional trade, by products, is determined by the commodity-balance method (Miller and Blair, 2009: 356), gross exports can also be estimated.

The supply and use format of MULTI2C is not transformed into a symmetric one, when the I/O model is implemented, preserving its rectangular type framework. This framework (of the kind developed in Miller and Blair 2009: Chapter 5) is kept to take advantage of the detailed information for the diversity of products produced by the same industry (which may be used as inputs by the other industries). Indeed, preserving the richness of the high level of product disaggregation is critical, as such products may have very different interregional and international trade coefficients.

Commuters are defined as all of the people living in one municipality and traveling daily to other municipalities for the purpose of working, as employees or on their own account (students are not included). As the MRIO model developed to LMA is based on NUTS-3regions, and each NUTS-3 region is composed of several municipalities, commuting occurs *between* and *within* NUTS-3 regions. There are two NUTS-3 regions inside Lisbon Metropolitan Area: Greater Lisbon (GL), which includes the Lisbon municipality, and Peninsula de Setubal (PS), comprising the southern region of the metropolitan area. The model also considers the remaining Portuguese NUTS-3 regions all merged into one additional region, termed 'Rest of the Country' (RC).

To incorporate the LMA commuting flows into the model framework we have to derive the (commuting induced) income distribution among the three regions (GL, PS and RC), and estimate the different household consumption structures, by household type. The procedures to endogenize the renting activities are also described below.

Fig. 2 The structure of the model focused on the commuting activity



The LMA MRIO model has a configuration as outlined in Fig. 2. The I/O model is of a rectangular (non-symmetric) type. Highlighted by the black border line is the core part of the model, which is a square matrix with dimension 1,713 (431 products, plus 134 industries, plus three types of endogenous households, considered twice in the use and supply matrices, multiplied by three regions). In the left bottom part of the core matrix, in dark grey, is highlighted the extended production matrix. In black, in the right upper part, is the extended use matrix. In fact, only the extended use matrix is fully regionalized, meaning that we know the region of origin of each product used in each region, as intermediate consumption or final consumption of endogenous households. This means that our regionalized extended use matrix (**U**) is composed by nine sub-matrices representing the flows between industries and households located in the different regions.

$$\begin{bmatrix} \mathbf{U}^{GL,GL} & \mathbf{U}^{PS,GL} & \mathbf{U}^{GL,RC} \\ \mathbf{U}^{GL,PS} & \mathbf{U}^{PS,PS} & \mathbf{U}^{PS,RC} \\ \mathbf{U}^{GL,RC} & \mathbf{U}^{PS,RC} & \mathbf{U}^{RC,RC} \end{bmatrix} \quad (1)$$

On the other hand, the extended supply matrix (**S**), corresponding to the lower left part of the core, is only partially regionalized, meaning that each cell of **S** is split according to the place of production, but no information on the destination of the

products is given in the regionalized supply matrix.[2] Then, in the LMA MRIO model, the supply matrix can be also divided in nine sub-parts, where only the diagonal ones are filled.

$$\begin{bmatrix} \mathbf{S}^{GL,GL} & 0 & 0 \\ 0 & \mathbf{S}^{PS,PS} & 0 \\ 0 & 0 & \mathbf{S}^{RC,RC} \end{bmatrix} \quad (2)$$

The application of this framework implies the assumption of fixed proportions in: i) the technical and trade structure of each industry production process; ii) the final consumption composition of each household group taken as endogenous in the model (including the interregional and international shares of origin of these consumptions); iii) the industries' contributions of each product supply. These assumptions are generally associated with the so-called "industry-based technology (IBT)" assumption,[3] which the model also adopts. The standard input-output procedure for calculating the total production needs, for a given final demand vector, is still valid in this model:

$$\mathbf{x} = (\mathbf{I} - \mathbf{C})^{-1}\,\mathbf{y} \quad (3)$$

where **y** is the 1,713 x 1 extended exogenous final demand vector, comprising the final consumption of the exogenous households and the other final demand, the 1,713 x 1,713 matrix **C** is the extended coefficient matrix (estimated by dividing each of the core cells of the regionalized matrices U and S by the bottom row of Fig. 2), and **I** is the 1,713 x 1,713 identity matrix. As a result, **x** is the extended total output vector of dimension 1,713 x 1.[4]

The derivation of a multi-regional supply and use table (MRSUT), such as the one proposed here, involves a two-step approach. This stepwise process is necessary

[2] This corresponds, according to Oosterhaven (1984) notation, to a "purchase-only interregional rectangular model". Actually, Oosterhaven (1984: 579) also argues that this type of model answers well the main questions regarding I/O models, and that a more elaborated model with full regionalization of both matrices is needless and not practical to build.

[3] IBT means that the production technology is the same for all of the products produced by each industry, even the secondary products that are typically produced by other industries. Part of the literature on rectangular input-output models (Oosterhaven 1984; De Mesnard 2004; Miller and Blair 2009) admits that this assumption may be less realistic than the alternative, more intricated, "commodity-based technology" assumption, where each product is produced by its own technology despite the industry that produces it. In fact, this discussion is beyond the scope of this paper. Furthermore, as explained before, the reason why the supply and use frame is kept in the model is the diversity of primary products considered, and not the secondary production. In Portugal, secondary production is, as a rule, a small share of the industry supply, making its discussion, to a large extent, a loaf one and justifying the adoption of the easier-to-implement IBT.

[4] **x** includes the total output of products and industries, and also some cells for the total income of endogenous households (its dimension is 1,713 x 1). **y** is also 1,713 x 1, but only products and rents payments from exogenous households have non-null values, while the remaining vector, corresponding to industries and households, is filled with zeros.

because of the interregional trade estimation. First, the country is split into "region A" (the Lisbon Metropolitan Area) and the "Rest of the Country". Region A is then split into A1 (Greater Lisbon) and A2 (Peninsula de Setubal), such that A1 and A2 exhausts A.[5] These steps to model the interdependencies between the industries within the regions are described in Ferreira et al. (2014b).

The share of commuters per industry is not homogeneous inside the LMA. Table 1 summarizes the residential location of the GL region's workers, by industry and by place of residence. In brief, only the top three industries that 'attract' more and less commuters are included in Table 1.

Table 1 Residential location of the Greater Lisbon region's workers, 2011

% of full-time equivalent jobs by industry (↓) satisfied by workers that live (→) in	**The same municipality where they work (non-commuters)**	**Other municipalities within Greater Lisbon**	**Peninsula de Setubal**	**Rest of the Country**
Top 3 industries attracting more commuters				
Water transport	29%	39%	25%	7%
Air transport	29%	49%	15%	7%
Computer programming, consultancy and related activities	32%	48%	16%	4%
Average	*49%*	*37%*	*10%*	*4%*
Top 3 industries attracting less commuters				
Fishing and aquaculture	64%	22%	10%	4%
Manufacture of basic metals	65%	26%	6%	3%
Agriculture, farming of animals, hunting and related service activities	74%	14%	3%	9%

Source: Adapted from Census 2011 (INE 2012a)

Table 1 relates only to people working in the Greater Lisbon area. However, the workers' area of residence influences the distribution of induced effects in all of the three regions concerned. So, a similar exercise was undertaken for the Peninsula de Setubal and the Rest of the Country regions. Ultimately, the wages and mixed-income earned by employees and self-employed workers are distributed among the three regions, according to the place of residence, taking into account the industries'

[5] 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. One major difficulty arises in an MRIO model with more than two regions: determining which region(s) is/are the destination and which one(s) is/are the origin of the interregional trade flows. The "cascade-stepwise procedure" was applied to solve this problem of the interregional trade, i.e. determining the origin and destination of domestic imports and exports between the two NUTS-3 regions within the LMA.

asymmetries and assuming homogeneous labor earnings within each industry in each region. These values are presented in Table 2.

Table 2 Income distribution by region (10^9 €), 2010

		Income distributed to non-commuters	Commuters area of residence		
			Greater Lisbon	Peninsula de Setubal	Rest of the Country
Place of work	Greater Lisbon	14.4	12.1	3.4	1.2
	Peninsula de Setubal	3.3	0.4	1.4	0.1
	Rest of the Country(1)	-	0.3	0.1	-

(1) Commuting within the 'Rest of the Country' region is not displayed as this study only focuses on the assessment of commuting flows in the Lisbon Metropolitan Area.

According to Table 2, it is possible to quantify how industries in the Greater Lisbon area increase the income sprawling effect to other regions and to commuters inside the same region. For example, the income distributed to households living in the Peninsula de Setubal but working in Greater Lisbon (3.4 billion Euros) exceeds the income distributed by the industries located in the Peninsula de Setubal either to non-commuters (3.3 billion Euros) or to commuters (1.4 billion Euros) within this region. In the sequel we describe the derivation of the different consumption structures for commuter and non-commuter households.

The households consumption structures

The MULTI2C framework covers five household types according to their main income source: i) labor; ii) real estate rents, iii) other capital income, iv) retirement, and v) other social transfers. At the starting point, the households supported mainly from working for a third party (employees) or on their own account are considered together, regardless of their commuting patterns.

In order to get a different consumption pattern for commuter and non-commuter households, we applied the methodology outlined in Ferreira et al. (2014a) to estimate the number of daily inter-municipality commuters that mainly use cars, by region and by industry, and used 2011 Census data (INE 2012a) to estimate the workers' origin-destination matrix by municipality and industry. We also estimated the daily fuel cost of inter-municipality commuting. Furthermore, as Ferreira et al. (2014a) demonstrate, commuters spend relatively more on "transportation products" and other products (such as insurance and car maintenance) related to commuting. As for other products, including spending on other means of transport, data from the Household Budget

Survey (INE 2012b) was used to identify the households' consumption structures for those living mainly from labor in the Lisbon Metropolitan Area, disaggregated by their commuting status. Due to the lack of statistical information, we assume a constant propensity to consume, in each region, for all of the households living mainly from labor (commuters and non-commuters). Table 3 shows the estimated commuter and non-commuter consumption structures in Greater Lisbon, Peninsula de Setubal and the Rest of the Country.

Table 3 Commuter and non-commuter consumption structures in Greater Lisbon, Peninsula de Setubal and the Rest of the Country (%), 2010

	Greater Lisbon		**Peninsula de Setubal**		**Rest of the Country**	
	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
Processed food industry	15.0	15.4	14.8	15.4	15.1	16.4
Other manufacturing and construction	29.4	27.7	29.4	26.2	33.2	30.2
Energy, water supply and sewerage	3.3	3.6	3.3	3.6	3.3	3.7
Accommodation, food serv., wholesale & retail trade, motor veh. & motorcycles	11.9	11.7	11.7	11.7	10.3	10.7
Transportation, storage; information, communication	9.8	7.7	9.3	7.5	9.8	6.5
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

Table 3 summarizes the different consumption structures according to the MULTI2C 431 products (classified here in 8 major sets of products, for reasons of clarity). These consumption structures are central in our model. Indeed, if a household were to change its residence and its status from commuter to non-commuter (or vice-versa), its consumption structure would also change, as would the region where a significant part of its income is spent (if applicable). This has important consequences at the regional and national level (e.g., in terms of national industries' output, international imports and taxes on products).

Renting of real estate

We continue to describe the main features of the process of endogenizing real estate rental. The assumed multi-regional supply and use table (MRSUT), at our starting

point, already includes a specific group for the households living mainly from real estate rents. This paper's model further assumes that all household types may have income from renting in addition to their main source of income. The share of rents for each household type is estimated taking into account the household budget survey (HBS).

Furthermore, the model framework incorporates the flows between the office (and other industrial buildings) and housing rents paid and the corresponding firm and household earnings, per region (i.e., a firm in region A1 can pay the rent for an office to a household that lives in region A2). The estimation of office rents paid (by firms) at regional level is derived from the MULTI2C database (Ramos et al. 2015). The housing rents paid by households in each region are estimated from the 2011 Census. The regional distribution of total rents received by firms is estimated based on the secondary production of other industries beyond the real estate renting industry itself (in the European System of National Accounts rents received are recorded as a service output). Regarding the households, the rents received are regionalized considering the Households Regional Accounts. Tables 4 and 5 show the estimations for these regional origin-destination matrices, specifically rents received by firms and received by households (see Table 4).

Table 4 Origin-destination firms' and households' rent flows (10^6 €), 2010

		Origin Location of the rented **office**			***Total***
		Greater Lisbon	**Peninsula de Setubal**	**Rest of the Country**	
Destination Location of the **firm** earning the renting income	**Greater Lisbon**	279	13	129	*421*
	Peninsula de Setubal	4	17	6	*26*
	Rest of the Country	63	8	275	*346*
	Total	*346*	*38*	*410*	*793*

		Origin Location of the rented **house**			***Total***
		Greater Lisbon	**Peninsula de Setubal**	**Rest of the Country**	
Destination Location of the **firm** earning the renting income	**Greater Lisbon**	186	42	160	*387*
	Peninsula de Setubal	0	6	0	*7*
	Rest of the Country	10	5	107	*122*
	Total	*196*	*53*	*267*	*526*

		Origin Location of the rented **office**			***Total***
		Greater Lisbon	**Peninsula de Setubal**	**Rest of the Country**	
Destination Location of the **household** earning the renting income	**Greater Lisbon**	615	19	208	*841*
	Peninsula de Setubal	50	53	42	*146*
	Rest of the Country	222	25	785	*1032*
	Total	*887*	*97*	*1,035*	*2,019*

		Origin Location of the rented **house**			***Total***
		Greater Lisbon	**Peninsula de Setubal**	**Rest of the Country**	
Destination Location of the **household** earning the renting income	**Greater Lisbon**	464	36	180	*680*
	Peninsula de Setubal	44	98	32	*174*
	Rest of the Country	168	45	682	*895*
	Total	*676*	*179*	*894*	*1,749*

The estimation of rental income by households and firms, per region, as well as the consumption structure for households living mainly from rental income provides the information required to close the model to renting activities. In the next section we present the results of a scenario involving a contribution to decrease 'wasteful commuting', based on population and induced economic activity re-centralization in the Lisbon municipality.

4 A 'wasteful commuting' reduction scenario

According to the 2011 Portuguese Census, there are 50,209 unoccupied houses in the Lisbon municipality. 39.7% of these were on the market, for sale or for rent, while some of the others (currently off-market) were also in a condition to be considered habitable homes.[6] So, in this section, we consider a scenario in which a portion of the households that currently commute to this municipality daily occupy 50% of these vacant houses. Nowadays almost 2/3 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 when determining the origin of the workers that are assumed to move their residence to half of Lisbon municipality's unoccupied houses, amounting to nearly 25 thousand household commuters.

Our research goal is to assess the potential impacts of this change without considering any further costs, i.e., the initial shock considered does not include any

[6] According to the 2011 Portuguese Census, only 2% of the houses in the Lisbon municipality are considered to be inhabitable or ready to be demolished.

other exogenous disturbances besides the shift in the household consumption patterns, induced by the hypothetical change in regional income distribution (e.g., the cost of refurbishing some deteriorated buildings is not taken into account). Note that we are considering 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 very significant part of their consumption products. So, it is assumed a new income distribution 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 households is offset by an increase in Greater Lisbon non-commuter households). While there are 25,105 new non-commuters households in Greater Lisbon region, there are less 17,222 commuters is this same region, minus 6,286 commuters in the Peninsula de Setubal and less 1,597 commuters in the Rest of the Country.

The scenario was implemented through changes in the coefficients of the matrix **C**, in the rows concerning the income distribution to "endogenous" households (in the use matrix). Some commuters became non-commuters (even within the Greater Lisbon region) and some households moved their residence to Greater Lisbon, so that more income was retained in this region (i.e. less is distributed to the others). In analytical terms, this means that the income distributed by industries located in Greater Lisbon will no longer be distributed to a parcel of the commuter households located in the three regions, but will remain with non-commuters. So, the cells in the (three) rows of the use matrix that correspond to commuters residing in Greater Lisbon, Peninsula de Setubal and the Rest of the Country, working in Greater Lisbon, are reduced by the same amount that is now distributed to households that do not commute and live in the Greater Lisbon region. So, Table 5 summarizes the "new" inter-regional income distribution and its comparison with the (original) situation presented in Table 2.

Table 5 New Income distribution by region (10^9 €), 2010

		Income distributed to non-commuters	**Commuters area of residence**		
			Greater Lisbon	Peninsula de Setubal	Rest of the Country
Place of work	Greater Lisbon	15.2 (+0.8)	12.1 (-0.5)	3.4 (-0.2)	1.2 (-0.1)
	Peninsula de Setubal	3.3	0.4	1.4	0.1
	Rest of the Country(1)	-	0.3	0.1	-

(1) Commuting within the 'Rest of the Country' region is not displayed as this study only focuses on the assessment of commuting flows in the Lisbon Metropolitan Area.

This new territorial income distribution leads to a new reallocation of the households' consumption between the regions. Moreover, the overall consumption structure is also affected, although there is no shock to exogenous final demand. So, the new output was estimated by multiplying the new inverse matrix $\mathbf{(I - C)^{-1}}$ by the same extended vector of exogenous final demand (**y**). This procedure led to multiple effects on the 134 industries located in the three regions. Table 6 gives a summary of these effects.

Table 6 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 (Full-time equivalent jobs)	1,716	- 617	- 37	**1,061**
Income				
Non-commuters (10^6 €)	856.8	- 7.4	- 1.9	**847.5**
Commuters (10^6 €)	- 553.5	- 215.5	- 53.7	**- 822.7**

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 changes in the consumption structure. Indeed, the induced changes in demand, from products with a large import content (vehicles, fuel, etc.) to others comprising a large share of nationally generated value added, account for an important share of the gains from reducing "wasteful commuting". Beyond this effect, another important reason for the 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 moreover having a higher propensity to consume. Through a *ceteris paribus* analysis, in which each one of these reasons is insulated, it is estimated that the conversion of the commuter consumption bundle into a non-commuter one contributes (alone) to 53.6% of the national gross value added impact, while the change in the place of residence of the former commuters (preserving their commuter-type consumption structure) corresponds to 42.0% of that total, the remainder being a combined effect. Of course the Greater Lisbon economy, whose population grows, catches the potential benefits of this scenario. The negative effects on the Peninsula de Setubal and 'Rest of the Country' regions result from the contraction of their economies due to lower (endogenous) final demand.

This particular scenario does not consider an exogenous change in the rent prices in the Greater Lisbon region (although our model is able to accommodate real estate rental changes). However, it is important to note that 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 occupied by former commuters). Accordingly, this mechanism reinforces the income distribution in favor of households in the Greater Lisbon region.

As this scenario does not involve direct changes either in the overall economic patterns or in regional exogenous demand, the results indicate a new dimension of the critical impact of commuting in metropolitan areas. Indeed, the industries seeing a relatively larger increase in their gross value added in the Greater Lisbon sub-region (and a larger decrease in the other regions) are those that offer goods and services that must be produced locally to satisfy the household demand (in particular "activities of households as employers of domestic personnel", "water collection, treatment and distribution" and "retail trade, except of motor vehicles and motorcycles").

5 Closing Remarks

Commuting affects the urban and regional economy as extensively as (or even more than) any other industry's economic flow. Commuting shapes urban regions and defines their relations with neighboring regions. It changes household consumption patterns. It affects local inhabitants' quality of life and exacerbates fuel consumption and greenhouse gas emissions.

In their standard configuration, multi-regional input-output models incorporate the intra-regional and interregional interactions between industries (and households). Through the simultaneous incorporation of a set of components, this paper proposed a framework that adds a specific design for regions with a wider range of commuting interactions to multi-regional input-output models. Furthermore, this modeling approach is an important tool for monitoring fast-changing complex metropolitan urban systems since it allows the assessment of either the impacts of external shocks or of policy induced structural changes. In spite of being merely illustrative, the empirical approach suggested in this paper provides important insights into the economic and social impacts that might result from the application of a centralizing urban strategy along the lines of those implemented in Chicago, Portland, or London (McMillen 2003; Kline et al. 2014; Nanda and Parker 2015). Our application shows that if a proportion

of the 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. Contrarily, a contractionary effect is embedded in the trend towards sprawling urban areas.

Summing up, this work establishes an alternative approach to studying the complexity of commuting implications in urban areas. Moreover, the proven dialectical relationship between commuting, the territorial dimension and economic activities can be integrated into a more comprehensive framework. As with other recent developments, the 'marriage' between more realistic models that incorporate multi-dimensional interdependencies and theoretical urban models is still a work in progress, and many ongoing (and future) debates are open or to be taken up. Society, academia and local populations are in need of advances capable of answering (some of) those difficult but inspiring challenges. This contribution is expected to be a significant step in the right direction.

Acknowledgments

This work has been framed under the *Energy for Sustainability Initiative* of the University of Coimbra and supported by the R&D Project *EMSURE - Energy and Mobility for Sustainable Regions* (CENTRO 07 0224 FEDER 002004). The authors would also like to thank the anonymous reviewers for their valuable comments and helpful suggestions to improve the quality of the paper.

References

Alonso M, Beamonte M, Gargallo P, Salvador M (2014) Labour and residential accessibility: A Bayesian analysis based on Poisson gravity models with spatial effects. J Geogr Syst 16(4):409–439.

Aroca P, Atienza M (2011) Economic implications of long distance commuting in the Chilean mining industry. Resour Policy 36(3):196–203.

Baumol W (2000) Leontief's great leap forward. Econ Systems Res 12(2):141-152.

Cameron G, Muellbauer J (1998) The housing market and regional commuting and migration choices. Scot J Polit Econ 45(4):420–446.

Cruz L, Proops J, Safanov P (2005) Input-output models. In: Proops P, Safanov P (eds.), Ecological economics. Edward Elgar Publishing, Cheltenham- UK, pp. 36-57.

De Mesnard L (2004) Understanding the shortcomings of commodity-based technology in input–output models: an economic-circuit approach. J Regional Sci 44(1):125-141.

Elhorst J, Oosterhaven J (2006) Forecasting the impact of transport improvements on commuting and residential choice. J Geogr Syst 8(1):39–59.

Ferreira J-P, Barata E, Ramos P, Cruz L (2014a) Economic, social, energy and environmental assessment of inter-municipality commuting: The case of Portugal. Energ Policy 66(1):411-418.

Ferreira J-P, Ramos P, Cruz L, Barata E (2014b) Spill-over effects in the Portuguese economy: Lisbon Metropolitan Area vs. Rest of the Country. 22th International Input-Output Conference Proceedings, Lisbon, Portugal.

Hamilton B, Roëll A (1982) Wasteful commuting. J Polit Econ 90(5):1035-1053.

Hewings G, Okuyama Y, Sonis M (2001) Economic interdependence within the Chicago metropolitan area: A Miyazawa analysis. J Regional Sci 41(2):195–217.

Hewings, G, Nazara S, Dridi C (2004) Channels of synthesis forty years on integrated analysis of spatial economic systems. J Geogr Syst 6(1):7–25.

Hewings G, Parr J (2007) Spatial interdependence in a metropolitan setting. Spatial Econ Anal 2(1):7–22.

INE (2012a) Census 2011. Database of the Official Statistics Portal, Statistics Portugal, Lisbon, Portugal.

INE (2012b) Household budget survey - 2010/2011 (in Portuguese). Statistics Portugal, Lisbon, Portugal.

Kawabata M, Shen Q (2007) Commuting inequality between cars and public transit: the case of the San Francisco Bay Area, 1990-2000. Urban Stud 44(9):1759-1780.

Kline J, Thiers P, Ozawa C, Yeakley J, Gordon S (2014) How well has land-use planning worked under different governance regimes? A case study in the Portland, OR-Vancouver, WA metropolitan area, USA. Landscape Urban Plan 131(1):51-63.

Kwan M, Kotsev A (2015) Gender differences in commute time and accessibility in Sofia, Bulgaria: A study using 3D geovisualisation. Geogr J 181(1):83-96.

Leontief W (1986) Input-output economics (2nd ed.). Oxford University Press, New York.

McMillen D (2003) The return of centralization to Chicago: Using repeat sales to identify changes in house price distance gradients. Reg Sci Urban Econ 33(3):287-304.

Madden M, Batey P (1983) Linked population and economic models: Some methodological issues in forecasting, analysis and policy optimization. J Regional Sci, 23(2):141–164.

Madsen B, Jensen-Butler C (2005) Spatial accounting methods and the construction of spatial social accounting matrices. Econ Systems Res 17(2):187-210.

Magrini M-B, Lemistre P (2013) Distance–income migration trade-off of young french workers: An analysis per education level. Reg Stud 47(2):282-295.

Malpezzi S (1996) Housing prices, externalities, and regulation in U. S. metropolitan areas. J Housing Res 7(2):209-241.

Miller R, Blair P (2009) I-O analysis: Foundations and extensions (2nd ed.). Cambridge University Press, New York.

Nanda A, Parker G (2015) Shared ownership and affordable housing: A political solution in search of a planning justification? Plann Pract Res 30(1):101-113.

Oosterhaven J (1984) A family of square and rectangular interregional input-output tables and models. Reg Sci Urban Econ 14(4):565-582.

Oosterhaven J, Folmer H (1985) An interregional labour market model incorporating vacancy chains and social security. Pap Reg Sci 58(1):141-155.

Ramos P, Cruz L, Barata E, Parreiral A, Ferreira J-P (2015) A bi-regional (rectangular) input-output model for Portugal: Centro and rest of the country". In: Godinho P, Dias J (eds.), Assessment methodologies: Energy, mobility and other real world applications. Coimbra: Imprensa da Universidade de Coimbra, pp. 265-286.

Sonis M, Hewings G. (2003) Miyazawa meet Christaller: Spatial multipliers within a triple decomposition of input-output central place systems. Discussion Paper 03-T-30, Regional Economics Applications Laboratory, University of Illinois, Urbana.

Thill J-C, Kim (2007) Trip making, induced travel demand, and accessibility. J Geogr Syst 7(2):229–248.

Walker J, Li J (2007) Latent lifestyle preferences and household location decisions. J Geogr Syst 9(1):77–101.

Williams E, Pollack S, Billingham C (2014) Measuring transportation equity: Commute time penalties by race and mode in Greater Boston. Transportation Research Board Annual Meeting 2014, Paper No. 14-4849. Washington, DC.