

Ferreira, Joao Pedro; Ramos, Pedro; Cruz, Luis; Barata, Eduardo

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Metropolitan Multiregional Input-Output Modelling Framework

João Ferreira¹, Pedro Ramos², Luís Cruz³, Eduardo Barata⁴

¹ joao.ferreira@fe.uc.pt, GEMF – Faculty of Economics, University of Coimbra

² pnramos@fe.uc.pt, GEMF – Faculty of Economics, University of Coimbra

³ lmgcruz@fe.uc.pt, GEMF – Faculty of Economics, University of Coimbra

⁴ ebarata@fe.uc.pt, GEMF – Faculty of Economics, University of Coimbra

Abstract

Urban population has been growing consistently worldwide, with large metropolitan areas experiencing expansion phenomena both in terms of population and extension. Naturally, these processes did not occur homogeneously throughout the territories. Through the last decade, population in suburbs has largely increased while the population living in Central Business Districts has generally shrunk in many of the European and American cities. Portugal is not an exception and several cities have been largely affected by this phenomenon, suffering significant changes in their economic structure and characteristics, particularly through residences and jobs “relocation” to the suburbs.

Our main aim is to establish the theoretical design of a modelling framework to assess social, economic, energy and environmental impacts of changes in urban forms and commuting patterns in the regions studied. Accordingly, we will use a multi-regional input-output model which considers the areas defined as the Central Business District (Lisbon municipality), the suburbs (North Lisbon metropolitan area and Setubal Peninsula) and the “Rest of the country”. The model will then be extended with satellite accounts regarding social, energy, environment and mobility issues, in order to assess the (direct, indirect and induced) multidimensional effects of commuting felt within each metropolitan region and the ones that leak to other regions. This model has as an innovative feature, the fact that it distinguishes the final consumption of three types of households: the ones which do not commute, the ones which commute to other regions, and the ones who are real estate owners. Finally, the model will comprise a commuting satellite account which will allow to deal with the impacts on income, employment, energy requirements and emissions among regions, as well as with resulting changes both in the consumption patterns and in the location/region where consumption actually takes place.

This modelling framework should allow for the assessment of the multidimensional impacts resulting from several scenarios reproducing real and/or hypothetical changes in commuters’ behaviour and in the policy measures, such as, e.g.: modifications in household location, changes in travelling patterns and commuting distances, external shocks in the economies of these regions, the delocalization of industries or headquarters between regions, the implementation of specific (local, regional or national) policy measures.

1. Introduction

Cities have largely grown outside their boundaries. According to UNEP (2012), since 2007 urban areas worldwide are the home place to 50 per cent of the world's population and this number is expected to grow to almost 70% in 2050. These changes in residential location have (differentiated) impacts in travel patterns but also in the economic characteristics of the areas that are abandoned or, in contrast, in the ones that have positive net migrations. Presently, the costs of sprawling and commuting are mostly considered to be supported by those which use the car - travel costs, time, congestion - but they imply costs to the rest of the society - loss in quality of life, accidents, expenditure in road infrastructures, greenhouse gas emissions - (Ewing, 1997; Gordon and Richardson, 1997; Verhoef, 1997; Small, 1997).

Several works have demonstrated that urbanization costs depend directly of the characteristics of each metropolitan area (Camagni et al., 2002; Travisi et al. (2010). UNEP (2012) and Newman et al. (1997) also identify several types of urban growing patterns that may decisively affect the economic and demographic structure of a certain metropolitan area, as well as energy consumption, travelling patterns or many others dimensions.

In the Portuguese case, Lisbon and Oporto municipalities have been losing population (since the 1970s), while their surroundings have largely increased. According with the last Portuguese Census, in the period of 2001-2011 the trend persisted (e.g., Oporto lost 6.5% of its inhabitants due to migrations, while Lisbon and other adjacent municipalities also consistently lost population to other municipalities farther way from Central Business District). Table 1 describes the population growth in Great Lisbon municipalities divided between natural increase and net migration. The average distance between each municipality and the Lisbon municipality is also presented. The last column refers to the percentage of working population in each of those municipalities that have their workplace in Lisbon municipality.

Table 1: Demographic indicators in Great Lisbon municipalities, 2001-2011

Municipality	Pop. Census 2001	Pop. Census 2011	%	Natural Increase	Net Migrations	Km to Lisbon municipality ¹	% of work. pop. that commutes to Lisbon
Amadora	175.872	175.558	-0,2	4.359	- 4.673	10,9	43%
Cascais	170.683	205.117	20,2	6.373	28.061	32,0	24%
Lisboa	564.657	545.245	-3,4	-17.434	- 1.978	--	--
Loures	199.059	205.577	3,3	7.022	- 504	21,1	40%
Mafra	54.358	76.749	41,2	3.253	19.138	43,8	18%
Odivelas	133.847	143.755	7,4	5.093	4.815	12,0	45%
Oeiras	162.128	172.063	6,1	5.825	4.110	18,6	37%
Sintra	363.749	377.249	3,7	24.869	- 11.369	27,0	29%
Vila Fr. Xira	122.908	136.510	11,1	6.561	7.041	33,9	31%
Alcochete	13.010	17.565	35,0	627	3.928	35,8	25%
Almada	160.825	173.298	7,8	1.582	10.891	12,1	34%
Barreiro	79.012	79.042	0,0	-558	588	39,6	31%
Moita	67.449	66.311	-1,7	1.596	-2.734	39,0	23%
Montijo	39.168	51.308	31,0	682	11.458	34,1	22%
Palmela	53.353	62.549	17,2	1.335	7.861	41,3	14%
Seixal	150.271	157.981	5,1	8.330	- 620	22,7	32%
Sesimbra	37.567	49.183	30,9	1.918	9.698	38,8	20%
Setúbal	113.934	120.791	6,0	2.471	4.386	49,3	10%
TOTAL	2.661.850	2.815.851	5,8	63.904	90.097		

Source: Census 2001 and Census 2011 – National Statistic Institute

Amadora, Loures and Sintra, located near the municipality of Lisbon, have lost population due to the exodus of inhabitants. Other municipalities in the surrounding of Lisbon have observed positive net migrations. Among these, the ones with relative major increase due to migrations are Mafra, Montijo, Sesimbra and Palmela. These municipalities distance more than 35 kilometres from the Lisbon municipality and were the less dense according with the 2001 Census. Actually, even in these municipalities an important percentage of the working population daily commutes to Lisbon (between 14% and 23%). To sum up, the Lisbon area is becoming more populated and more dispersed.

The primary goal of our modelling framework is to identify and accurately describe the localization of industries and household's consumption, as well as the economic interdependencies established within each region and between them. This goal is assumed with the objective of answering to the need of more realism, considered by Capello and Nijkamp (2004) as one of the major tendencies in the theoretical development of urban economics. The idea that urban models should be capable of better describing what happens

¹ Considering road distances by the fastest trip criteria (Ferreira et al., 2012a).

within a certain metropolitan area raises after “the break of the link between urban size and urban functions imposed by the Christallerian logic” (Capello and Nijkamp, 2004). Accordingly, the core functions do not depend exclusively of the urban size.

The methodology followed in this research is based in the application of Input-Output (I/O) models and extensions. This idea is based on the acknowledgment that I/O is one of the most widely applied methods in economics, capable of capturing the interdependence between the different sectors within an economy (Baumol, 2000). This technique was first applied by Wassily Leontief (1936; 1941). The I/O model is based on the assumption that exists a linear relationship between production and final demand. This relationship between different inputs and production can also be extended to other inputs or outputs of the productive structure, such as labour, use of resources, pollutant’s emissions (Cruz et al., 2005; Ramos and Sargento, 2011).

Multi-regional I/O models include the description of the interactions between different industries in different regions. Additionally, these models have the capability of presenting the results in terms of direct impacts but also give the chance to discriminate the indirect and induced impacts of a shock. For instance, if the automobile industry increases its production the energy consumed is expected to increase, simultaneously this also leads to additional increases in the production of components for those cars (indirect effects). Moreover, as the production expands, the household’s income also increases, leading to a subsequent increase in the household’s consumption (induced effects).

The next section offers an explanation of the design and structure of our proposed model – Metropolitan Multi-Regional Input-Output Model – MMRIO-Commuting. In the third section, some empirical applications are proposed to be addressed using the MMRIO-Commuting model. Finally, a conclusion regarding the expected outcomes and scientific contribution of the modelling framework are addressed.

2. MMRIO - COMMUTING MODEL

The main characteristics of the modelling framework are presented in this section. The starting point of the MMRIO-Commuting is the 2010 “Supply and Use Tables” produced by the National Statistical Institute (INE), and then corrected using the 2011 Population Census and 2011 National Accounts. The disaggregation level considers 431 products produced by 125 industries.

The MMRIO-COMMUTING is built at “domestic flows” meaning that the flows considered in the model represent exclusively the products produced in these regional economies and within the national borders. Therefore, the international imports are treated separately from the other economic flows. Another characteristic of this model is that it is presented at “basic prices”, i.e. the flows described are expunged from VAT and Other Taxes less Subsidies on Products. The commercial and transportation margins were also treated and are assimilated as inputs provided by retail and wholesale commercial services or transport services.

A simplified bi-regional scheme of MMRIO-COMMUTING model is presented in Figure 1.

		Products								Industries								Other Fin. Demand		Res	Total		
		Region 1 (1)				Region 2 (2)				Region 1 (1)				Region 2 (2)				Reg 1	Reg 2				
Products	Region 1 (1)	0								IC ¹¹	FC(NC) ¹¹	FC(C) ¹¹	FC(L) ¹¹	IC ¹²	FC(NC) ¹²	FC(C) ¹²	FC(L) ¹²	OFD ¹¹	OFD ¹²	R ¹	TPP ¹		
										HI(NC) ¹	0			0	0			0	0			HI(NC) ¹	
	0									HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(C) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹
	HI(L) ¹									HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	HI(L) ¹	
Region 2 (2)	Region 2 (2)	0								IC ²¹	FC(NC) ²¹	FC(C) ²¹	FC(L) ²¹	IC ²²	FC(NC) ²²	FC(C) ²²	FC(L) ²²	OFD ²¹	OFD ²²	R ²	TPP ²		
										0	0			0	0			0	0			HI(NC) ²	
	0									RF(L) ²	RF(L) ²	RF(L) ²	HI(C) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	
	HI(L) ²									RF(L) ²	RF(L) ²	RF(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	HI(L) ²	
Industries	Region 1 (1)	p ¹¹	0			0				0								0			TPI ¹		
		0	HI(NC) ¹	0	0															HI(NC) ¹			
	0	HI(C) ¹	0	0	HI(C) ¹																		
	0	0	0	HI(L) ¹	HI(L) ¹																		
Region 2 (2)	Region 2 (2)	p ²²	0			0				0								0			TPI ²		
		0	HI(NC) ²	0	0															HI(NC) ²			
	0	0	0	HI(C) ²	HI(C) ²																		
	0	0	0	HI(L) ²	HI(L) ²																		
Other Taxes less Subsidies - Products	0								T(CI) ¹	T(NC) ¹	T(C) ¹	T(L) ¹	T(CI) ²	T(NC) ²	T(C) ²	T(L) ²	T(OFD) ¹	T(OFD) ²		TT			
Intern. Imports	0								M(CI) ¹	M(NC) ¹	M(C) ¹	M(L) ¹	M(CI) ²	M(NC) ²	M(C) ²	M(L) ²	M(OFD) ¹	M(OFD) ²		MT			
IC / OFD, at Purchasers' prices	0								ICT ¹	FCT(NC) ¹	FCT(C) ¹	FCT(L) ¹	ICT ²	FCT(NC) ²	FCT(C) ²	FCT(L) ²	OFD ¹	OFD ²		ICT + PFT			
GVA not distributed to households	0								VNH ¹	0	0	0	VNH ²	0	0	0	0	0		VNHT			
Household savings and other transfers	0									S(NC) ¹	S(C) ¹	S(L) ¹		S(NC) ²	S(C) ²	S(L) ²				ST			
Total	TPP ¹	HI(NC) ¹	HI(C) ¹	HI(L) ¹	TPP ²	HI(NC) ²	HI(C) ²	HI(L) ²	TPI ¹	HI(NC) ¹	HI(C) ¹	HI(L) ¹	TPI ²	HI(NC) ²	HI(C) ²	HI(L) ²	OFD ¹	OFD ²					

Figure 1 - Legends:

1 – Region 1		NC – Non-Commuters Households'
2 – Region 2		C – Commuters Households'
		L – Landlord's Households'
IC ^{ij}	i, j = 1, 2	Intermediate consumption of products produced in i, and used by the industries of j
OFD ^{ij}	i, j = 1, 2	Other final demand of the products produced in i, and then used in j
R ⁱ	i = 1, 2	Residues in the demand by the products produced in i
FC(g) ^{ij}	i, j = 1, 2 g = NC, C, L	Final consumption of type g households that live in the region j of products produced in i
TPP ⁱ	i = 1, 2	Total production of products produced in region i, at basic prices
P ⁱⁱ	i = 1, 2	Products produced in region i by industry
TPI ⁱ	i = 1, 2	Total production of industries in region i, at basic prices
HI(g) ⁱ	i = 1, 2 g = NC, C, L	Income of type g Households, which live in region i
T(f) ⁱ	i = 1, 2 f=IC, FC(NC), FC(C), FC(L), OFD	Taxes Less Subsidies on Products focusing on f, in region i
TT		Sum of taxes less subsidies on products
M(f) ⁱ	i = 1, 2 f=IC, FC(NC), FC(C), FC(L), OFD	International imports to satisfy f, in region i
MT		Sum of international imports
ICT ⁱ	i = 1, 2	Sum of industries intermediate consumption, at purchasers price, in region i
FCT(g) ⁱ	i = 1, 2 g = NC, C, L	Total final consumption of type g Households in region i
OFD ⁱ	i = 1, 2	Other final demand in region i, at purchasers price
ICT + FDT		Total Intermediate and final demand, at purchasers price
VNH ⁱ	i = 1, 2	GVA not directly distributed to households in region i
VNHT		Sum of GVA not directly distributed to households in region i
S(g) ⁱ	i = 1, 2	Savings and net transfers to other institutional sectors by households of type g in region i
ST		Sum of Savings and net transfers to other institutional sectors by households

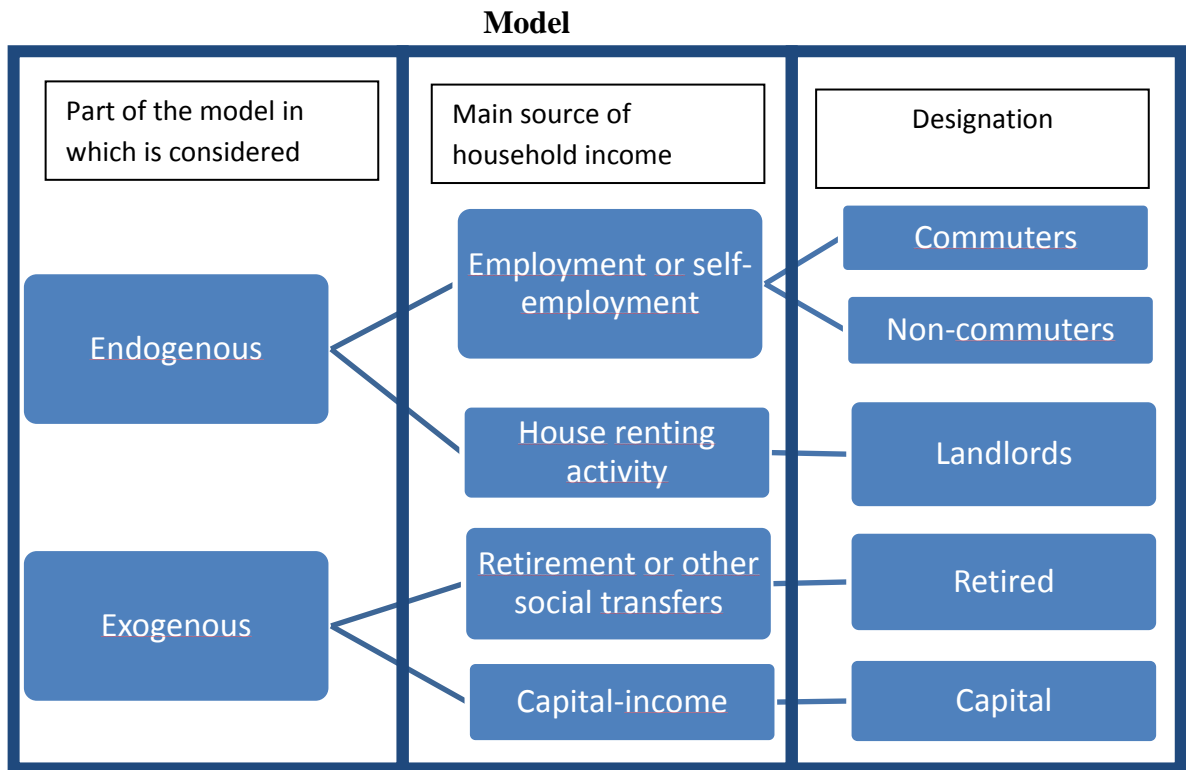
The MMRIO-Commuting modeling framework presented in Figure 1 is a “rectangular” I/O framework. As there are 431 products produced by 125 industries, each industry produces (one or) several main products and several other secondary products (corresponding to the main products of other industries). As an example, in the Portuguese economy the agriculture produces wine while the “wine industry” also produces some agricultural products. The lines of the matrices P^{ii} describe the products produced by each industry in the region.

As typical in I/O models, the columns of the MMRIO-Commuting model in the IC matrices describe the industry technology, in terms of the inputs needed to produce a certain amount of production. In our model, the products consumed by a certain industry may be produced in the same region or in another region of the national economy (Region 1 may use products produced in Region 1 or in Region 2) or even come from abroad (international imports). In this column, it is also represented the VAT and Other Taxes Less subsidies that were supported by the production, the income generated by each industry and the correspondent distribution by the different type of households and the GVA not directly distributed to the households.

In the MMRIO-Commuting the lines represent the products’ destinations. The destination can be the intermediate consumption by industries (in the same region where it is produced or in the other one), the households’ final consumption or other destinations considered in the Other Final Demand.

This MMRIO-Commuting framework distinguishes five different types of households according with the main source of household’s income and, in the case of employed households, if they commute or not. According with their dependency regarding the industries’ distribution of income, the households can be considered in the endogenous or in the exogenous part of the model. The households that directly depend of the production of the industries or on the behavior of the housing rent markets are considered in the endogenous part. This distinction is presented in Figure 2.

Figure 2: Different household's types considered in the MMRIO-Commuting



As represented in Figure 2, both commuters and non-commuters are those mainly living from the income of their employment or self-employment. The difference is that non-commuters households live in the same region where they work, while commuters households live in a different region of their workplace. The consumption of these households is presented in Figure 1 in columns $FC(NC)^{ij}$ and $FC(C)^{ij}$, respectively. The column described in Figure 1 as $FC(L)^{ij}$ refers to the consumption of households mainly living from housing rents (referred as Landlords). The products consumed by all households can be provided both by Regions 1 or 2.

In the Other Final Demand (OFD), considered in the exogenous part of the model, are described the other two types of households. One represents the consumption of the ones retired and of the households who live mainly from social transfers, while the other one represents the consumption of the households who live mainly from capital-income. These households consumption is considered exogenous because it is independent (in the short-term) from the economic activity and from the industries distribution of income. In addition the OFD also includes the consumption by Public Administrations, Non-profit organizations, Gross Capital Formation, Changes in Inventories, net acquisition of valuables, consumption of non-resident households in national territory and international exports.

In Figure 1, the MMRIO-Commuting main core is highlighted with a bolder border. After adequate mathematical manipulation, the elements inside this core are the ones which originate a Leontief type inverse matrix. This matrix has the potential to assess the economic impacts of changes in the final demand, both in the production of products or in the production of industries. This model can be generalized for ‘n’ regions. In the simplified scheme represented in Figure 1, the model considers a square matrix with 431 products, 125 industries and 6 lines (income of the three different types of households considered in the endogenous part of the model) multiplied by the 2 regions (in this case, the matrix has a dimension of 1124 x 1124; with three regions the dimension would be of 1686 x 1686).

2.1. Regionalization and Inter-regional Trade: Data sets and Calibration

The modelling framework schematically represented in Figure 1 involves the knowledge of the economic flows both within each region (intra-regional) and between the regions considered (inter-regional). For this, there is the need for information regarding the destiny of the products produced in each region. This can be a problem as often there is lack of data on inter-regional trade and this is also true on the Portuguese case. In such case, the application of statistical methods is required in order to estimate these flows consistently (Lahr, 1993; Hulu and Hewings, 1993; Eding et al., 1997; Schwarm et al., 2006).

Our option is to employ the procedure suggested by Ramos et al. (2013), where we start by applying the “residual method”. Accordingly, after estimating supply and demand components for each region, the difference between them is considered to be the total amount of net exports. Thus, if one region produces more of a certain product than the amount it consumes, it means that the “residual” is exported to the other regions of the country.

Firstly, in order to estimate supply, relevant statistical information for the Portuguese national economy is used. The information of 2009 Agricultural Census and 2010 National Forest Inventory are used to decompose the production of Agricultural and Forestry products² through the regions. To distribute the main production of other products, the main source of information used was the 2011 Population Census and the Employment Records of the Ministry of Solidarity and Social Security (MSSS). Moreover, as the secondary products are generally only a small part of the total production registered, this production was divided

² The use of this data is particularly relevant as the Agricultural and Forest workers are mostly not integrated in the Employment Records of the MSSS. Additionally, of the 431 products considered in the framework 63 are mainly produced by the “industry” of Agriculture and 11 by the Forest Activities.

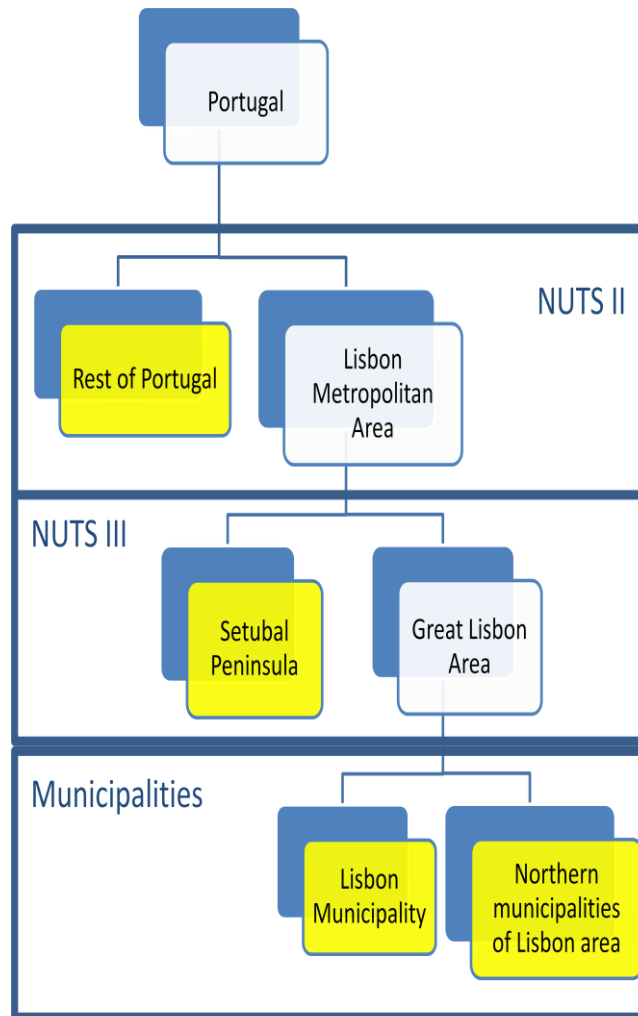
accordingly with the relative weight of the industry's output in each region in the respective industry's national output.

Secondly, to estimate the product demand in each region, the hypothesis of identical technology is assumed. This means that the structure of inputs used in each industry is the same independently of the region where they are located. Accordingly, only the relative weight of Gross Value Added and Intermediate Consumption is different through regions as there are available official data to differentiate such weights. Thus, each input represents a fixed percentage of the intermediate consumption of a specific industry independently of the observed region.

After the determination of product's supply and demand in each region, the total amount of net exports becomes available. Nevertheless, Multi-regional Input-Output models imply the use of information regarding each region's gross imports and exports (and not only the net exports) to accurately specify the intra and inter-regional flows. Therefore different hypothesis to each product according to its specific characteristics (tradable, non-tradable or others) are considered, as proposed by Ramos et al. (2012). After the determination of each product's gross imports and exports in each region, there is the need to estimate the origin of imported products and the destiny of exports. In a two-region model, this process is more straightforward as one is the region of destiny while the other is the region of origin. But, in a model with more than 2 regions there is the problem of determining which region(s) is the destiny and which one is the origin.

As our objective is the application of this modelling framework to the Lisbon metropolitan area, the consideration of only two regions is too restrictive. Our option is to consider a model with 4 regions - Lisbon municipality, Northern municipalities of Lisbon area, Setubal Peninsula and the 'Rest of Portugal'. In the estimation of the corresponding 16 (4 *per* region) intra and inter-regional flows matrices, a "cascade-stepwise procedure" is applied as represented in Figure 3. The 4 regions are highlighted in the Figure.

Figure 3: “Cascade-stepwise” derivation of The MMRIO flows and matrices



Firstly, from the national matrix we decompose the products’ supply and demand by two “regions “– Lisbon Metropolitan Area and Rest of Portugal – in order to estimate their inter-regional trade. Secondly, we split the Lisbon Metropolitan area matrix into two smaller sub-regions – Great Lisbon and Setubal Peninsula. At this point, the information on the inter-regional trade between the “Rest of Portugal” and these two sub-regions must be determined. For this we assume that, the imports are divided according with the weight of the products consumption in these two regions. On the other hand, each product exports are divided according with the weight of its production within these regions.

Finally, a similar procedure is applied to derive the inter-regional flows and the use matrices for the Lisbon municipality region and the Northern municipalities of Lisbon area from the matrix of the Great Lisbon region.

2.2. MMRIO – COMMUTING: a “closed” model applied to metropolitan areas

Most of I/O ‘closed’ models consider that household income is entirely distributed in the region where the industry is located, and therefore only the consumption of the households in the region is initially affected. Our option in this MMRIO-Commuting includes one innovative feature that can better represent the interactions in a metropolitan area. In these areas, the intensity of people travelling between municipalities and regions is much more common than in less dense areas. Indeed, due to commuting, if one industry in a certain region changes its production, as the income is distributed between non-commuters and commuters (those living in a different region) households, the direct effects will be felt differentially in the territory. As an example, closing a firm located in the Lisbon municipality, employing workers with residence exclusively in a different municipality implies that the initial economic impacts associated with the corresponding change in the household’s consumption will be felt in the municipality in which these workers live.

Therefore, the MMRIO is a “closed” model relatively to the consumption of the ones mainly living from their work or from house renting. In the first case, a distinction is made among the households which commute and the ones that do not. To sum up, the endogeneization of non-commuters and commuters households is intrinsically associated with the application of our Multi-regional I/O model to a metropolitan area. Accordingly, only the consumption of the households mainly living from retirement or other social transfers (retired) or from capital-income is considered in the exogenous part of the model. This option is based on the idea that these households income (and as a consequence, its consumption) is not directly associated with changes in the industries production of a specific region.

These types of I/O models extension is commonly designated as a “satellite account” as it has a strict relation with the economic tendencies of the industries in a certain region or nation. The OECD defines satellite accounts as “a framework linked to the central accounts and which enables attention to be focussed on a certain field or aspect of economic and social life in the context of national accounts” (OECD, 2013). There are number of satellite accounts applied to different areas, such as: energy, environment, water consumption, waste, tourism, unpaid work or fiscal revenues (European Commission, 2010).

Our goal is to derive a “commuting satellite account”. Firstly, by splitting the income distributed by industries (as wages and salaries) among two types of households: commuters and non-commuters, whose values are presented in lines $HI(C)^i$ and $HI(NC)^i$, respectively. Secondly, a third type of households - the ones that live from housing rents - is

included (Landlords). In this model the payment of rents is considered to be a transfer to these households. These households income is represented in the line referred as $HI(L)^i$. Further, it is worth to note that the “landlords” income has origin in the rents paid by “working” households, industries (office rents and others), and by other households (including the ones that have incomes from house renting activity). Accordingly, in theory, the $HI(L)^i$ line can be always different from zero in our matrices columns referring to industries and households consumption.

Another innovative feature concerns to the structure of consumption. The five types of households considered in our model have different consumption structures between them and between the different the region where they live. These different structures are estimated from information available on the 2010/2011 Household Budget Survey disaggregated by 199 products at regional level and on 2011 the Purchasing Power Index.

According with these different consumption structures, if households change their residence to a place that is more densely populated, the spending with housing rents will have a larger weight in their budget (Ferreira et al., 2012b). Contrarily, if they decide to live in less dense areas, the relative weight of household expenditures in fuel, other transportation services and other commuting related products will be more important in the total budget. This kind of change can be considered in the model regarding the household’s income distribution. Indeed, the initial values in vectors $HI(NC)^i$ e $HI(C)^i$ can be changed according with different hypothesis regarding income distribution between these households. In our case, the consumption (in absolute terms) of these two households type is changed, but the proportional weight of housing expenditures in their total budget remains the same, as this is considered to be a most suitable hypothesis in terms of short-term equilibrium.

The MMRIO-Commuting is also suitable for the assessment of circumstances where changes in the average value of housing and, consequently, in its weight in household’s total budget are considered. In such case, $HI(L)^i$ changes non-proportionally affecting all other input’s coefficients (when industries) or household expenditures. These non-proportional changes in housing rents are consistently with long-term assessments regarding the trends in terms of housing market.

3. Metropolitan demography and economy: a multi-dimension assessment

Input-Output models are commonly used for the estimation of impacts resulting from exogenous changes in the (national and/or regional) economies. In Multi-regional Input-Output models, the resultant impacts include spillover and feedback effects. Indeed, e.g.

the initial impact in one Region can affect industries in other Regions and, in return, affect again industries in the initial Region. Specifically, in our proposed MMRIO-Commuting model, changes in household's income directly affect not only the household's consumption in the region that felt the exogenous initial impact but also those living in other regions.

This, the proposed MMRIO-Commuting model can be used to assess impacts of other kinds of changes in the economy, or in the demography, of metropolitan areas. For example, this model is suitable to assess the impacts of two major changes in the territorial structure of economic activities and residences/industries location:

- changes in household's residential location;
- changes in the location of the economic activities (and therefore of the household's work-place).

Accordingly, this model is particularly appropriate to analyze the impacts that result from changes usually considered in policy-making and theoretical discussions on urban economies and their sustainability. For example, this model can be applied in of commuting patterns changes in metropolitan areas. For this, it is possible to assume several scenarios: e.g., persistence of the trend for movements of the residential location from the centre to the periphery; or, in contrast, situations where inhabitants return from the suburbs to the Central Business District.

This modeling framework is also suitable to assess the impacts of changes in the industries geographical distribution among regions. Indeed, this allows for the assessment of the impacts of advancing towards a more polycentric city, i.e. decentralizing industries (mainly services) which are often concentrated in the Central Business District. Further, the MMRIO-Commuting model has also the potential to reflect possible changes in the rents (commercial and housing) in the region(s) where inhabitants increase or decrease.

The assessments of such kind of changes in the territorial organization of economic agents and activities can also be complemented with the analysis of resource use and emissions' impacts, as suggested in Cruz et al. (2005) and Miller and Blair (2009: ch. 3.3). With this endeavor, the "commuting satellite account" is matched with other satellite accounts allowing the consideration of a modeling framework that considers the three fundamental dimensions of sustainability: economy, social and environmental. Thus, with such extensions the assessment of the impacts of changes in metropolitan regions can reflect multidimensional effects so diverse as: GVA; GDP, employment, primary energy consumption, CO₂ emissions, water use, generation of waste.

4. Conclusions

This work proposes a multi-regional modeling framework suitable to assess multidimensional impacts of changes in a metropolitan region. This is still work in progress. Indeed, after settling the design and structure of the modeling framework, the calibration and mathematical estimations are still ongoing, and the results of specific empirical applications will be presented in future work.

The first set of outcomes generated through this process regards the economic structure of the regions and their intra and inter-regional trade flows. This contributes to a better understanding of the interdependencies between major cities Central Business District, the suburbs of a metropolitan area and the ‘Rest of a country’.

This modeling framework is directed towards the assessment of multidimensional impacts of themes particularly relevant in terms of urban policy: e.g. changes in the residential location within a metropolitan area; or, changes in the location of the economic activities.

This MMRIO-Commuting model is being tested and calibrated to be applied to the Lisbon metropolitan area, but from it can be derived critical contributions to issues commonly identified in metropolitan areas worldwide. Accordingly, it is our conviction that the application of this modelling approach will contribute to a better (ex ante and/or ex post) assessment of multidimensional impacts, regarding actual or potential policy measures. Furthermore, this tool to support policy making is being designed with some degree of flexibility to be adapted for different scales, including the municipal, regional and/or national levels. Therefore, this research is expected to advance with contributes by Input-Output models to the study of sustainability in urban areas.

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