Cities to live or to work in: an input-output model of migration and commuting

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Abstract

Madrid and Barcelona have traditionally been recipient provinces for in-migration in Spain. Since mid 1990s the inflows of workers into the two main Spanish cities have increased dramatically reinforced by the arrival of immigrants. These inflows should have affected the original distribution of population and labor force within the city itself and its surrounding areas, i.e. the metropolitan area. Two opposite forces are at play: the existence of agglomeration economies suggests a concentration of economic activity -and therefore jobs- in the city, while the agglomeration diseconomies associated with the arrival of new workers suggest a runaway of residents to some other places more attractive to live in but still close to the city.

Using the latest Spanish Census available -from 2001- and working at municipal level, this paper explores the effects that the arrival of new workers (either nationals or foreigners) has had *within* Madrid and Barcelona metropolitan areas. The input-output model suggested includes both migration and commuting flows, which allows us to analyze the displacement effect -and its subsequently distribution of workers- as well as the commuting patterns, i.e. distribution of residents, within the two main Spanish metropolitan areas.

Keywords: input-output, migrations, commuting, regional and urban structure, agglomeration economies.

Topic: 09. Applications of input-output tables

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1. Introduction

The intensity of in-migration flows, both from abroad and from other regions, to the provinces of Madrid and Barcelona (the most populated Spanish provinces) has been growing since the beginning of the 1990s (see Table 1). In the period that goes from 1991 to 2001, Spain registered around 3,000,000 migration movements of workers, being the destination of more than 35% the provinces of Madrid and Barcelona (Barcelona received 15.91% and Madrid 20.51%). Our hypothesis is that these inflows have affected somehow the original distribution of population and labor force within the municipalities that respectively compose these provinces.

When some migration inflows are received, two opposite forces are at play: it enhances city size, which can trigger the agglomeration economies leading to a concentration of economic activity -and therefore jobs- in the city. On the other hand, the arrival of new workers can generate diseconomies associated that pushes previous residents to some other places more attractive to live in.

Using the latest Spanish Census available -from 2001- and working at municipal level, this paper explores the effects that the arrival of new workers (either nationals or foreigners) has had *within* Madrid and Barcelona metropolitan areas. The input-output model suggested includes both migration and commuting flows, which allows us to analyze the displacement effect -and its subsequently distribution of workers- as well as the commuting patterns, i.e. distribution of residents, within the two main Spanish metropolitan areas.

The paper is organized as follows: Section 2 describes the bases of a multiregional model that studies the effects of immigration from the periphery to the core by means of a multipliers matrix. The proposed methodology is based on the input-output migration model developed in Fernandez-Vazquez et al (2010). This model analyzed the effect on internal migration patterns as a consequence of immigration. Section 3 explains how the model can be extended to the study of the distribution of jobs across the set of regions, by incorporating information of commuting flows. In section 4, a typology of cities is suggested by means of an indicator that combines the two models introduced in the previous sections. Section 5 presents an empirical application of the methodology proposed to the provinces of Madrid and Barcelona using microdata from the most recent Census. Finally, Section 6 presents the concluding remarks of the paper.

2. An input-output model of migration flows

From the assumption that foreign immigration affects internal mobility by displacing population (national in-migration), the multiregional input-output model proposed on Fernández-Vázquez *et al*. (2010) quantifies the effects that these arrivals generate on the migration patterns in the core itself. It is important to note that this methodology is not an attempt to investigate the causal relationships between internal migrations and some explanatory variables. Instead, we suggest a type of analysis that shares many common points with the so-called Garin-Lowry models. Originally proposed by Lowry (1964) and Garin (1966), these models have been frequently used to explain the allocation of population and labour among different locations from an initial push of basic employment, see for example, McGill (1977), Batty (1983), Guldman and Wan (1998), Jun (2005).

The point of departure for the analysis will be to consider a set of N geographical units that experience the spatial re-allocation of some part of their workforce in a given period of time. For the sake of simplicity, in this chapter we will specifically consider a set of N cities (C), where some inter-city migration flows are observed. In this situation, the following table reflects the migration flows among these cities where a typical element m_{ij} denotes the number of workers that migrate from city *i* to another city *j*.

<< Insert table 1 about here>>

For any city *j* considered, the net inflow of migrants (nm_j) received will be:[1]

$$nm_j = [ic_j + p_j] - [oc_j + a_j] \quad (1)$$

Equation (1) defines the net inflow of workers for each type of city. In other words, this variable is defined as the difference between the arrival of new workers - consisting of the in-migration coming from other cities (ic_j) plus the workforce coming from the periphery (p_j), i.e., either peripheral citys or from another country - and the outflows of people given by the out-migration to other citys located into the core (oc_j) as well as the out-migration to other cities (a_j). Note from Table 2 that it is possible to obtain ic_j as the column sum $\sum_{i=1}^{N} m_{ij}$. Likewise, the out-migrations from city *i* to other cities (oc_i) can be obtained as the row sum $\sum_{j=1}^{N} m_{ij}$. Conversely, the migration flows to and from other cities (p_j and a_i, respectively) do not appear in Table 2 but they can be included in it jointly with net migration (nm_j) in order to construct a new table that fulfils the demographic identity (1), and where the row sums equal the column sums. With this purpose in mind, let us define a N×1 vector $\boldsymbol{x}$, where a typical element x_j shows the inflows arriving to municipality *j*. Note that the elements of this vector can be defined as the sum $x_j = ic_j + p_j$, or alternatively as $x_j = nm_j + [oc_j + a_j]$, from equation (1).

This equivalence holds also when considering the whole vector:

$$\boldsymbol{x}' = \boldsymbol{ic}' + \boldsymbol{p}' \quad (2a)$$

$$\boldsymbol{x} = \boldsymbol{nm} + [\boldsymbol{oc} + \boldsymbol{a}] \quad (2b)$$

Consequently, Table 1 can be modified in the following way in order to verify that the row and column sums are both equal to vector **x**.

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[1] The traditional matrix algebraic notation is applied: bold uppercases denote matrices, bold lowercases (column) vectors and italic lowercases scalars. A prime indicates transpose.

<< Insert table 2 about here>>

Some assumptions are required in order to explain $\boldsymbol{x'}$ through an input-output model. One basic assumption is that the arrival of new workers from the periphery (vector $\boldsymbol{p'}$) is something exogenous to the set of N cities analyzed. Additionally, from Table 3 we will define a coefficient $b_{ij} = \frac{m_{ij}}{x_i}$. These b_{ij} coefficients measure the number of workers that move from city *i* to city *j* relative to the total number of workers received in *i* (including those coming from other cities out of the system). If, for instance, $b_{ij} = 0.15$, this would imply that for each 100 workers received in city *i*, this city "pushes" 15 to city *j*. The coefficients b_{ij} are a sort of "rate of displacement" that defines the reaction of city *i* when it receives new workers. The basic idea behind these b_{ij} is that the arrival of these new workers to one city produces some "diseconomy" (e.g.: rises in housing prices, traffic congestion, etc.) that encourages some of the previous residents to migrate.

Another essential assumption of the model is that the b_{ij} coefficients are assumed to be fixed in the short run. The matrix $\boldsymbol{B}$ contains all the b_{ij} coefficients for the N citys included in the model:

$$\boldsymbol{B} = \begin{bmatrix} b_{11} & b_{12} & \cdot & b_{1N} \\ b_{21} & b_{22} & \vdots & b_{2N} \\ \vdots & \vdots & & \vdots \\ b_{N1} & b_{N2} & \cdot & b_{NN} \end{bmatrix} \quad (3)$$

As a result, the vector of workers coming from other cities ($\boldsymbol{ic'}$) can be expressed as:

$$\boldsymbol{ic}' = \boldsymbol{x}'\boldsymbol{B} = [x_1 \quad \dots \quad x_N] \begin{bmatrix} b_{11} & b_{12} & \cdot & b_{1N} \\ b_{21} & b_{22} & \vdots & b_{2N} \\ \vdots & \vdots & & \vdots \\ b_{N1} & b_{N2} & \cdot & b_{NN} \end{bmatrix} = [ic_1 \quad \dots \quad ic_N] \quad (4)$$

and equation (2a) can be rewritten in terms of $\boldsymbol{B}$ as:

$$\boldsymbol{x}' = \boldsymbol{ic}' + \boldsymbol{p}' = \boldsymbol{x}'\boldsymbol{B} + \boldsymbol{p}' \quad (5)$$

Suppose that the group of N cities receives in a given period a vector of new workers $\boldsymbol{p'}$. However, this initial inflow of $\boldsymbol{p'}$ new workers will "push" some of the labor out to another one of the N cities. This will generate a new round of movements in the system equal to $\boldsymbol{p'B}$, which will further displace a part of the workers equal to $\boldsymbol{p'BB}$, and so on. The expression that describes the overall process of obtaining the new vector of incoming workers $\boldsymbol{x'}$ is:

$$\boldsymbol{x'} = \boldsymbol{p'} + \boldsymbol{p'B} + \boldsymbol{p'B}^2 + \boldsymbol{p'B}^3 + \cdots = \boldsymbol{p'}[\boldsymbol{I} + \boldsymbol{B} + \boldsymbol{B}^2 + \boldsymbol{B}^3 + \cdots] \qquad (6)$$

where **I** is the identity matrix. Under certain mathematical conditions, (6) can be written as:

$$\boldsymbol{x'} = \boldsymbol{p'}[\boldsymbol{I} - \boldsymbol{B}]^{-1} \qquad (7)$$

Equation (7) explains how the arrival of new workers to the cities ($\boldsymbol{x'}$) changes due to variations in the vector of workers coming from peripheral citys ($\boldsymbol{p'}$). The idea underlying equations (3.6) and (3.7) is that any increase in the movement of workers from the periphery to a city situated in the core, apart from the direct impact that it has on this specific city, generates a set of indirect effects on the entire system of N cities that turns out to be larger than the initial shock.[2]

In the framework defined by the previous model, the elements of the matrix $[\boldsymbol{I} - \boldsymbol{B}]^{-1}$ play a crucial role. The structure of this matrix is:

$$[\boldsymbol{I} - \boldsymbol{B}]^{-1} = \begin{bmatrix} \beta_{11} & \beta_{12} & \cdot & \beta_{1N} \\ \beta_{21} & \beta_{22} & \vdots & \beta_{2N} \\ \vdots & \vdots & & \vdots \\ \beta_{N1} & \beta_{N2} & \cdot & \beta_{NN} \end{bmatrix} \qquad (8)$$

2 Readers accustomed to the input-output literature will easily see the analogy of this proposal with the so-called Gosh input-output model (see Dietzenbacher, 1997).

where the element β_{ij} shows the variation in the number of workers that arrive to the city *j* due to the arrival of one additional worker to the city *i*.

This means that β_{ij} can be interpreted as an approximation to the following derivative:

$$\beta_{ij} = \frac{dx_j}{dp_i} \tag{9}$$

It is important to note that even if there are no direct migration flows between cities *i* and *j*, β_{ij} might still be different from zero given that it also measures the indirect effects. For example, the migration from the periphery of workers to city *i* displaces part of the workforce to the city *h*, and consequently some workers from *h* move to the city *j*.

The previous model (7) explains how workers allocate and reallocate their place of residence across the system of N cities (vector $\boldsymbol{x}$) given the initial stimulus of new entries of workers. It is important to highlight that it models the choice of residence of the workers, which may not be the same place where they have their jobs. This is a significant difference because while it is possible that a city *i* displaces workers to another city *j* as a consequence of the diseconomies produced by additional dwellers which turn city *i* into a less attractive place to live in, these workers might keep their jobs in the original city *i* because it is still attractive to work there. In other words, the model allows the possibility of commuting given that the location of homes and jobs might not be in the same city.

3. The role of commuting

In a fashion similar to the previous section, the commuting flows between the N cities can be represented in the following table (Table 3), where the cities of origin are displayed by rows and the destinations are shown by columns.

<< Insert table 3 about here>>

f_{ij} stands for the flow of workers in a given period of time that arrived to live in the city *i* but commute to the city *j*. The main diagonal elements represent the workers that live and work in the same city. Note that $\sum_{j=1}^{N} f_{ij} = x_i$ and that $\sum_{i=1}^{N} f_{ij} = l_j$, where l_j is the total number of jobs occupied by the vector of workers $\boldsymbol{x}$ that are allocated in city *j*.

For the sake of convenience, we will work with proportions of commuters instead of working directly with flows. These proportions will be defined as $c_{ij} = \frac{f_{ij}}{x_i}$ and measure the fraction of workers who live in city *i* but work in city *j*. For example, $c_{ij} = 0.25$ means that 25% of the workers who migrated to city *i* commute to city *j*. If $\boldsymbol{C}$ denotes the $\boldsymbol{N} \times \boldsymbol{N}$ matrix of proportions c_{ij}, it is straightforward to see that:

$$\boldsymbol{l}' = \boldsymbol{x}'\boldsymbol{C} \qquad (10)$$

Equation (10) links the entries of workers that live in the system of N cities ($\boldsymbol{x}'$) with the distribution of their jobs across the same N cities ($\boldsymbol{l}'$). Note that this equation is simply a mathematical expression that relates the place of residence to the location of the jobs. However, by combining equations (7) and (10) we can construct the following model that explains the spatial allocation of the new jobs from the exogenous shock produced by the arrival of workers from the periphery to the core ($\boldsymbol{p}'$):

$$\boldsymbol{l}' = \boldsymbol{x}'\boldsymbol{C} = \boldsymbol{p}'[\boldsymbol{I} - \boldsymbol{B}]^{-1}\boldsymbol{C} \qquad (11)$$

Equation (11) models the spatial location across the core of the economic activity (new jobs) generated as a consequence of new workers coming to live in the set of cities. The idea is that workers from the peripheral citys ($\boldsymbol{p}'$) arrive to the cities, which produces a sequence of indirect effects through migrations - matrix $[\boldsymbol{I} - \boldsymbol{B}]^{-1}$ - that subsequently implies a specific distribution of jobs - matrix $\boldsymbol{C}$. The whole sequence of multiplier effects on the generation of jobs is given by the product of the matrices $[\boldsymbol{I} - \boldsymbol{B}]^{-1}$ and $\boldsymbol{C}$. Letting $\boldsymbol{M}^* = [\boldsymbol{I} - \boldsymbol{B}]^{-1}\boldsymbol{C}$, equation (11) can be written as:

$$\boldsymbol{l}' = \boldsymbol{p}'\boldsymbol{M}^* \qquad (12)$$

where:

$$\boldsymbol{M}^* = \begin{bmatrix} \mu_{11} & \mu_{12} & \cdot & \mu_{1N} \\ \mu_{21} & \mu_{22} & \vdots & \mu_{2N} \\ \cdot & \cdot & \cdot & \cdot \\ \mu_{N1} & \mu_{N2} & \cdot & \mu_{NN} \end{bmatrix} \tag{13}$$

and a typical element μ_{ij} shows the variation in the number of jobs in the city *j* given by the arrival of one additional worker to city *i*. Note that these elements are given by the sums $\sum_{h=1}^{N} \beta_{ih} c_{hj}$, so that in more detail we have:

$$\mu_{ij} = \sum_{h=1}^{N} \beta_{ih} c_{hj} = \sum_{h=1}^{N} \frac{dx_h}{dp_i} \frac{f_{hj}}{x_h} = \frac{dx_1}{dp_i} \frac{f_{1j}}{x_1} + \frac{dx_2}{dp_i} \frac{f_{2j}}{x_2} + \cdots + \frac{dx_N}{dp_i} \frac{f_{Nj}}{x_N} \tag{14}$$

The idea underlying the μ_{ij} elements is that they comprise a two-stage process: the entries of workers from the periphery to city *i* generate a variation - through the whole round of indirect effects captured in β_{ih} - in the inflows of labour to city *h*, a proportion $c_{hj} = \frac{f_{hj}}{x_h}$ of which are going to commute to city *j*. When considered together and summed across all the citys *h*, μ_{ij} can be taken as an approximation to the derivative:

$$\mu_{ij} = \frac{dl_j}{dp_i} \tag{15}$$

We may be interested in studying the capability of each city of getting the jobs that are generated by the entrance of new workers in the cities. In other words, we could be interested in estimating how many jobs will locate to city *j* when all the cities receive one additional worker coming from the periphery. Note that this number can be obtained by the sum $\mu_{.j} = \sum_{i=1}^{N} \mu_{ij}$ and it can be written as:

$$\mu_{.j} = \sum_{i=1}^{N} \mu_{ij} = \sum_{i=1}^{N} \frac{dl_j}{dp_i} = \frac{dl_j}{dp_1} + \frac{dl_j}{dp_2} + \cdots + \frac{dl_j}{dp_N} \tag{16}$$

Relatively large values of $\mu_{.j}$ would indicate that city *j* attracts comparatively more jobs than the average city when workers coming from the periphery migrate to the core.

4. Classifying the cities: places to work or to live in?

The elements of matrices (8) and (13) remark the effect that the arrivals of workers from out of the system (vector $\boldsymbol{p}$) have both on the residential (vector $\boldsymbol{x}$) and job location (vector $\boldsymbol{l}$) patterns. It seems logical to expect that along the set of N cities, some of them experience a relatively larger effect on one of the two possible effects. For example, the new workers might decide to live in some specific location i but commute to a different one because there are better opportunities to work there. This would turn out in a large effect on x_i but a small effect on l_i. Conversely, in one city i we could observe a huge generation of jobs as a consequence of the exogenous shock of vector $\boldsymbol{p}$, but the number of workers who have their residence there might be small –because of high prices of housing, for example- and consequently we would have big effects on $\boldsymbol{l_i}$ but smaller on $\boldsymbol{x_i}$.

From this simple idea, we can define a measure of "net demand of commuters" for a city i as the difference $\boldsymbol{d_i} = (\boldsymbol{l_i} - \boldsymbol{x_i})$, which compares the number of jobs that are located in that city with the number of workers that live there. If this difference is positive, this means that the city i would require commuters from other areas in order to fill the jobs that are not taken by the local workers. In other words, this would be a signal that would indicate that city i is attractive for working but not for living. The opposite would happen if this difference is negative.

If we compute this difference for the whole set of N cities, we would have:

$$\boldsymbol{d'} = \boldsymbol{l'} - \boldsymbol{x'}, \tag{16}$$

and taking into account the equations (11) and (7):

$$\boldsymbol{d'} = \boldsymbol{l'} - \boldsymbol{x'} = \boldsymbol{p'}[\boldsymbol{I} - \boldsymbol{B}]^{-1}\boldsymbol{C} - \boldsymbol{p'}[\boldsymbol{I} - \boldsymbol{B}]^{-1} = \boldsymbol{p'}[\boldsymbol{I} - \boldsymbol{B}]^{-1}[\boldsymbol{C} - \boldsymbol{I}] \tag{17}$$

If we denote with $\boldsymbol{\Delta}$ the matrix obtained by the product $[\boldsymbol{I} - \boldsymbol{B}]^{-1}[\boldsymbol{C} - \boldsymbol{I}]$ the previous equation can be written as:

$$\boldsymbol{d'} = \boldsymbol{p'}\boldsymbol{\Delta} \tag{18}$$

Where:

$$\mathbf{\Delta} = \begin{bmatrix} \delta_{11} & \delta_{12} & \cdot & \delta_{1N} \\ \delta_{21} & \delta_{22} & \vdots & \delta_{2N} \\ \vdots & \vdots & & \vdots \\ \delta_{N1} & \delta_{N2} & \cdot & \delta_{NN} \end{bmatrix} \tag{19}$$

And a typical element δ_{ij} shows the variation in the requirement of commuters in the central city j produced by one additional worker migrating to city i. Considering that each element δ_{ij} comes from the product given by $[\boldsymbol{I}-\boldsymbol{B}]^{-1}[\boldsymbol{C}-\boldsymbol{I}]$, its expression is:

$$\delta_{ij} = \sum_{h \neq j}^{N} \beta_{ih} c_{hj} + \beta_{ij}\left(c_{jj} - 1\right) \tag{20}$$

Note that the element δ_{ij} will be positive if:

$$\sum_{h \neq j}^{N} \beta_{ih} c_{hj} > \beta_{ij}\left(\frac{x_j - f_{jj}}{x_j}\right)$$

i. e., if the arrival of new workers to city i produces an increase in the commuters to j larger than the increase in the number of workers that commute from j $(x_j - f_{jj})$. Oppositely, the variation in p_i could cause an increase in the workers that have their residence in other city h and commute to work in j smaller than the growth in the workers living in j but commuting to anywhere else. In such a case, δ_{ij} would be negative, which would indicate that the rise in the immigrant workers form the periphery arriving to city i produce an increase in the residents rather than in the jobs in j. If, on the contrary, δ_{ij} is positive, the additional workers coming from the periphery to city i would enhance the jobs located in j to a greater extent that the workers residing there.

From these δ_{ij} multipliers it would be possible to classify the cities in two different types: those that are capable to attract comparatively more jobs than residents -job attracting- when new workers enter in the system of N cities and those where the opposite happens –resident absorbing-. This information can be obtained by the sum

$\delta_{.j} = \sum_{i=1}^{N} \delta_{ij}$. In general terms, the following vector contains these sums for all the cities:

$$\boldsymbol{\delta}' = \boldsymbol{e}'\boldsymbol{\Delta} \tag{22}$$

When an element $\delta_{.j}$ of the vector $\boldsymbol{\delta}'$ is positive, it would indicate that the city j can be classified as "job attracting". If, on the contrary, $\delta_{.j}$ is negative then the city j would be "resident absorbing".

5. The case of Madrid and Barcelona: an empirical application for 1991-2001.

This section applies the aforementioned methodology to develop a model of migration and commuting flows between 1991 and 2001 for Madrid and Barcelona using the data from the last National Census. As explained above, in Spain internal mobility has traditionally not been very high, but it has recently experienced a considerable increase together with a remarkable rise in the reception of immigrants.

The data required for the model have been obtained taking a sample of microdata extracted from the most recent *Censo de Población y Viviendas* - Population and Housing Census (PHC) - compiled by the Spanish National Statistical Institute for 2001. The sample comprises approximately 5% of the whole census, corresponding to a sample size of around two million people. The information contained in the survey includes the part of population who were working in 2001, the municipality where they were working and the municipality where they were living. Moreover, information about the municipality where they lived in 1991 is also available. From the data observable, we can identify 27 municipalities in Madrid and 39 in Barcelona. Some of the municipalities (those smaller than 20,000 inhabitants) are not identifiable since they are too small and data for them are not disclosed in the Census for privacy reasons.[3]

Tables 4a and 4b show the cities included in both models ranked according to their population in 2001:

<< Insert tables 4a and 4b about here>>

We have applied the three previous input-output models to the municipalities of both provinces. Firstly, from the tables of migration flows, we have divided these flows by the respective vector of total inflows $\boldsymbol{x}^{'}$ to compute the coefficient matrix $\boldsymbol{B}$. This allows obtaining the inverse $[\boldsymbol{I}-\boldsymbol{B}]^{-1}$ composed by the β_{ij} multipliers. They quantify how many workers municipality i displaces directly and indirectly to city j as a consequence of the arrival of new workers from outside of the province to city i. If we calculate the sums $\beta_{i\cdot} = \sum_{j\neq i}^{N} \beta_{ij}$, we will have an indicator that measures the amount of workers displaced from region i to other central regions. Figures 1a and 1b show these indicators for both provinces:

[3] We suspect that the impact of the no consideration of these municipalities in our study is limited for the case of Madrid, since they represent less than 9% of population. In the case of Barcelona, however, it could be more problematic because the population living in these municipalities represent around 20% of the population in 2001.

<< Insert figures 1a and 1b about here>>

The charts above show that there seems to pattern relating city size and the number of workers that each city displaces to other locations. We can see how for middle-size cities like *Móstoles*, *Leganés* and *Aranjuez* we estimate larger multipliers than for the city of Madrid itself. Something similar happens for the province of Barcelona, where municipalities like *Hospitalet* and *Santa Coloma* present larger estimates than the city of Barcelona. Apart from these cases that can be considered as exceptions, the graphs suggest a general negative relationship between the value of the $\beta_{i\cdot}$ multipliers and the size of the municipalities studied,

Besides the data on residence mobility between 1991 and 2001 the microdata in the census also informs about the commuting patterns in 2001, because for each person included in the sample, the municipality of residence and also the location of the job was registered. This allows us to obtain a matrix that contains the commuting trips among the N cities, with the same structure as the previous Table 3. This way, the proportions of commuters defined as $c_{ij} = \frac{f_{ij}}{x_i}$ will be computed to obtain the matrix C. This matrix will be used to replicate the equation (11) for our study case and compute the multiplier matrix $M^* = [I - B]^{-1}C$, where a typical element μ_{ij} quantifies the variation in the jobs located in j generated by the arrival of one additional worker to city i. Now, we will focus our analysis in the number of jobs located on city j when all the municipalities in the province receive one additional worker coming from outside. Figures 2a and 2b show the sums $\mu_{.j} = \sum_{i \neq j}^{N} \mu_{ij}$. As explained in section 3, large values of $\mu_{\cdot j}$ indicate that city *j* attracts comparatively more jobs than the average.

<< Insert figures 2a and 2b about here>>

The results in the previous graphs highlight the relevance of the big cities regarding the number of new jobs they are able to attract. In this two provinces characterized by two enormous cities surrounded by other municipalities much smaller in size, the arrivals of new workers displaces more residents than the average from these big municipalities but they manage to keep on them most of the jobs. All in all, a general idea would be that the immigration of labour force pushes workers from living in big cities to reside in the smaller locations situated in the province. However, the large metropolises manage to keep inside of them the jobs filled with these workers by means of commuting.

In order to investigate with more detail the different effects on the distribution of jobs and residences across the municipalities studied in both cases, we will focus now on vector $\boldsymbol{d}$. The basic idea is that along the entire period 1991-2001 the municipalities considered in each one of the two models have received workers who can come either from other city within the system of N locations or from outside (the elements of vector $\boldsymbol{p}'$ on Table 4). The sum of both types of inflows ($\boldsymbol{x}'$), equals the number of jobs, but the distribution of these two variables is different depending on the type of region. Matrix $\boldsymbol{\Delta}$ provides more information in this respect, given that its δ_{ij} coefficients quantify the variation in the net requirement of (jobs filled by) commuters in city j caused by one additional worker migrating from an origin outside the set of N cities to city i. If the sum $\delta_{.j} = \sum_{i \neq j}^{N} \delta_{ij}$ for city j is positive, this means that this city can be classified as net "job attracting" because it attracts comparatively more jobs than residents. On the other hand, if $\delta_{.j}$ is negative then city j could be classified as "resident absorbing" (there are more homes than jobs re-allocated to j when new workers enter into the system of N cities). Figures 3a and 3b show the $\delta_{.j}$ indicators for the municipalities of Madrid and Barcelona:

<< Insert figures 3a and 3b about here>>

Figures 3a and 3b show some common pattern between the two provinces and other results that are more specific. Something common to both cases is that the big cities are the municipalities that can be by far classified as much more capable of attracting new jobs (not surprisingly according to the results already presented in figures 2a and 2b) than new residents. As expected, new workers coming to live in these two provinces have their homes in smaller cities in the surroundings of the capital (those characterized by negative $\delta_{.j}$ indicators), but their jobs are located in the urban agglomeration of these two big cities.

In spite of this general picture for both provinces, it is also true that the above pattern is clearer for the case of Madrid than for the case of Barcelona. In this last case, we detect more cases of municipalities (*Vic* and *Martorell*, for example) that could be classified as net receiver of jobs (even when the quantitative difference in the $\delta_{\cdot j}$ indicators is still huge). Probably the differences in the industry specialization between these two provinces help to explain such a result: the comparatively larger share of manufacturing companies in the province Barcelona, which are located in this type of middle-size cities, is the key factor that accounts for this difference between both cases.

6. Some conclusions

Spain has experienced over the last two decades an intense arrival of immigrants and in-migrants to its central regions. The arrival of population has effects on the recipient regions through internal migrations and/or commuting to some areas that might be more attractive.

Using and extending the input-output model suggested on Fernández-Vázquez et al. (2010) to include the possibility of commuting, this paper has assessed the effects that the arrival of new workers have in the most populated Spanish provinces. Using the last available Census, estimations show that the arrival of in- and im-migration to Madrid and Barcelona generates a set of direct and indirect effects induced by the redistribution of population among other regions.

The arrival of workers provokes reallocations of residence. However, the intensity of these reallocations seems to be correlated with size, which indicates the existence of agglomeration diseconomies associated with big cities. At the same time, when the possibility of commuting is considered the arrival of workers generates both the reallocation of jobs (economic activity) and also of residences. The larger municipalities are the ones pushing out more residents to other areas while keeping most of the jobs. In other words, they are becoming attractive areas to work in (economies of agglomeration), but not to live in (high housing costs, congestion or some other negative externalities). The opposite is true for the smaller cities, which are resident-absorbing but not job-attracting. Thus, the distribution pattern of residences proves to be different to the distribution pattern of jobs.

Even more, these results highlight the idea that the effects of the arrival of population are not only felt in the recipient city but might also generate comparatively far larger effects on other cities in terms of internal migration and the location of economic activity.

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Table 1. Matrix of migrations among N cities.

	C_1	C_2	…	C_N
C_1	m_{11}	m_{12}	…	m_{1N}
C_2	m_{21}	m_{22}	…	m_{2N}
…	…	…	…	…
C_N	m_{1N}	m_{2N}	…	m_{NN}

Table 2. Migration flows in an inflow-outflow table.

	C_1	C_2	…	C_N	oc	a	nm	x
C_1	m_{11}	m_{12}	…	m_{1N}	$oc_1 = \sum_{j=1}^{N} m_{1j}$	a_1	nm_1	x_1
C_2	m_{21}	m_{22}	…	m_{2N}	$oc_2 = \sum_{j=1}^{N} m_{2j}$	a_2	nm_2	x_2
…	…	…	…	…	…	…	…	…
C_N	m_{1N}	m_{2N}	…	m_{NN}	$oc_N = \sum_{j=1}^{N} m_{Nj}$	a_N	nm_N	x_N
ic'	$ic_1 = \sum_{i=1}^{N} m_{i1}$	$ic_{12} = \sum_{i=1}^{N} m_{i2}$	…	$ic_N = \sum_{i=1}^{N} m_{iN}$				
p'	p_1	p_2	…	p_N				
x'	x_1	x_2	…	x_N				

Table 3. Matrix of commuting flows among the N cities.

	C_1	C_2	…	C_N	x
C_1	f_{11}	f_{12}	…	f_{1N}	x_1
C_2	f_{21}	f_{22}	…	f_{2N}	x_2
…	…	…	…	…	…
C_N	f_{1N}	f_{2N}	…	f_{NN}	x_N
l	l_1	l_2	…	l_N	

Table 4a. Municipalities for the province of Madrid included in the model

City	Population	City	Population
Madrid	2,938,723	Majadahonda	50,683
Móstoles	196,524	Collado Villalba	47,001
Fuenlabrada	182,705	Aranjuez	40,797
Alcalá de Henares	176,434	Tres Cantos	36,927
Leganés	173,584	San Fernando de Henares	36,244
Alcorcón	153,100	Rivas-Vaciamadrid	35,742

Getafe	151,479	Colmenar Viejo	35,181
Torrejón de Ardoz	97,887	Arganda del Rey	33,432
Alcobendas	92,090	Valdemoro	33,169
Parla	79,213	Pinto	31,340
Coslada	77,884	Boadilla del Monte	27,443
Pozuelo de Alarcón	68,214	Galapagar	25,559
Las Rozas de Madrid	63,385	Villaviciosa de Odón	22,564
San Sebastián de los Reyes	61,884		

Table 4b. Municipalities for the province of Barcelona included in the model

City	Population	City	Population
Barcelona	1,503,884	Sant Feliu de Llobregat	40,042
Hospitalet de Llobregat (L´)	239,019	Gavà	39,815
Badalona	205,836	Igualada	33,049
Sabadell	183,788	Vic	32,703
Terrassa	173,775	Sant Adrià de Besòs	31,939
Santa Coloma de Gramenet	112,992	Vilafranca del Penedès	31,248
Mataró	106,358	Ripollet	30,235
Cornellà de Llobregat	79,979	Sant Joan Despí	28,772
Sant Boi de Llobregat	78,738	Montcada i Reixac	28,295
Manresa	63,981	Barberà del Vallès	26,428
Prat de Llobregat (El)	61,818	Premià de Mar	26,334
Rubí	61,159	Sant Vicenç dels Horts	24,694
Sant Cugat del Vallès	60,265	Sant Pere de Ribes	23,134
Viladecans	56,841	Martorell	23,023
Vilanova i la Geltrú	54,230	Sant Andreu de la Barca	21,933
Cerdanyola del Vallès	53,343	Pineda de Mar	21,074
Granollers	53,105	Masnou (El)	20,678
Mollet del Vallès	47,270	Molins de Rei	20,639
Castelldefels	46,428	Santa Perpètua de Mogoda	20,479
Esplugues de Llobregat	45,127		

Figure 1a. Population displacement multiplier ($\beta_{i\cdot}$) for the province of Madrid

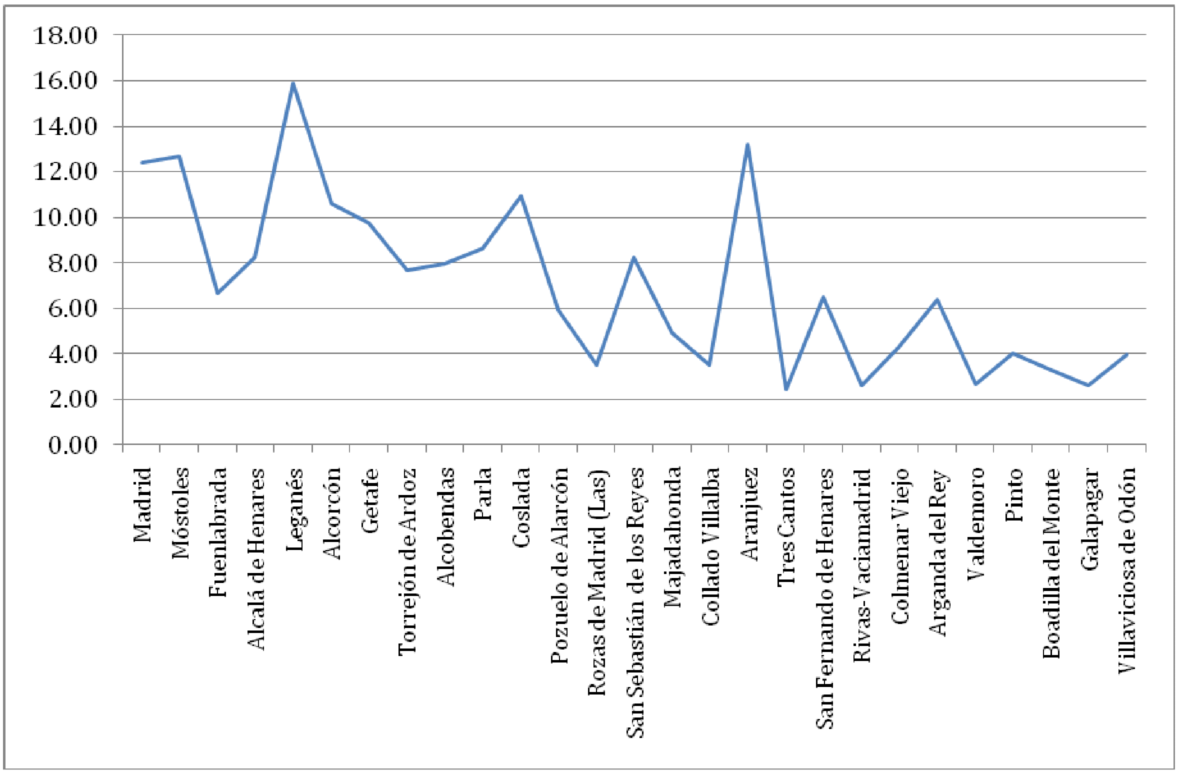

Figure 1b. Population displacement multiplier ($\beta_{i\cdot}$) for the province of Barcelona

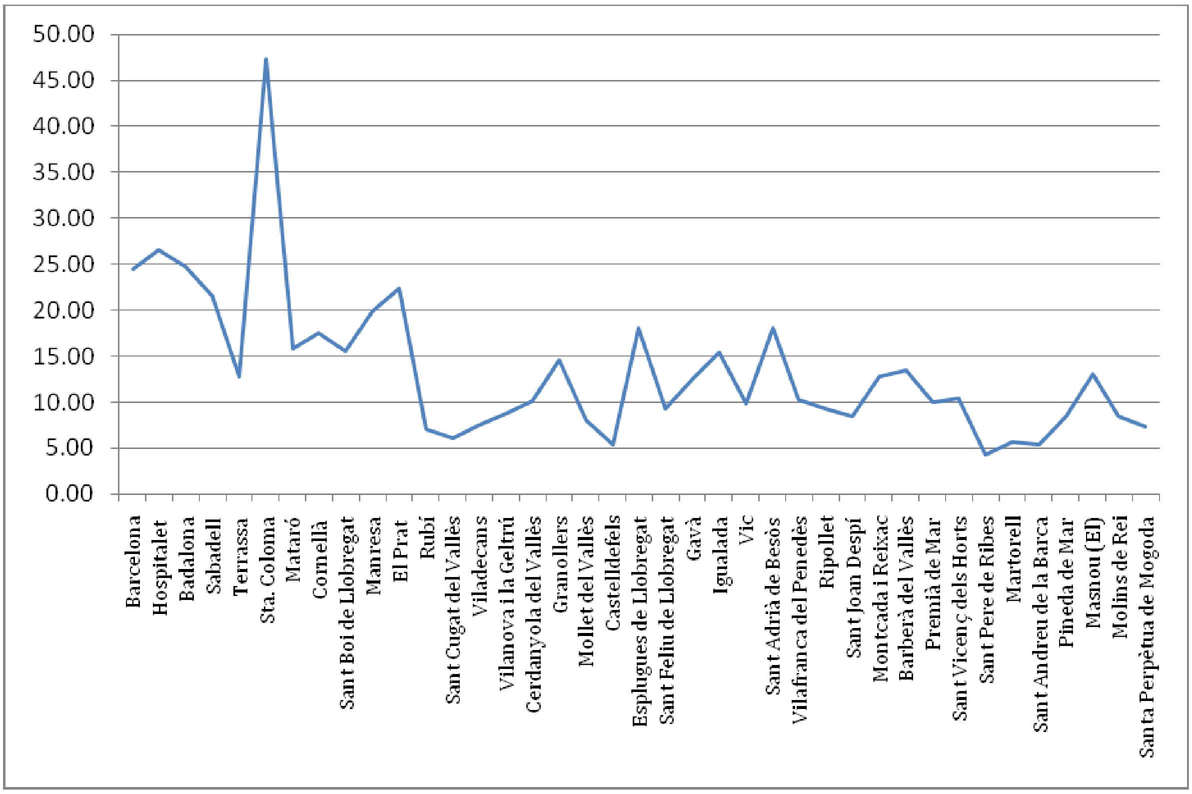

Figure 2a. Job location multiplier ($\mu_{.j}$) for the province of Madrid

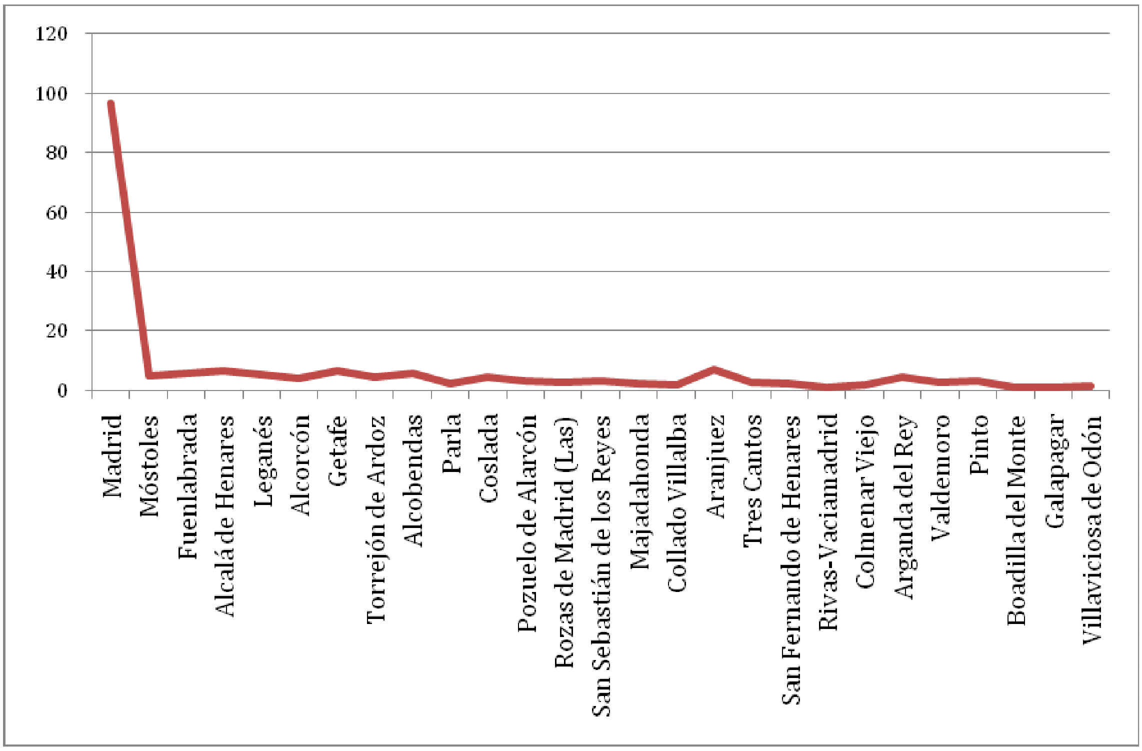

Figure 2b. Job location multiplier ($\mu_{.j}$) for the province of Barcelona

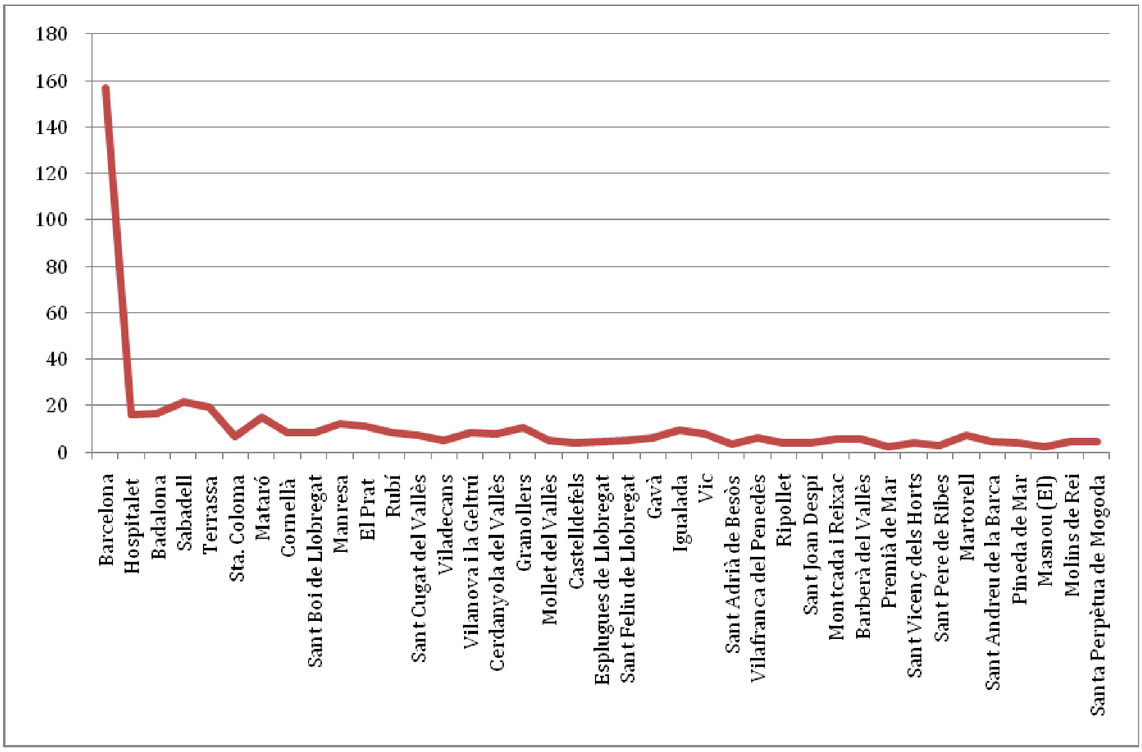

Figure 3a. $\delta_{\cdot j}$ coefficients for the province of Madrid

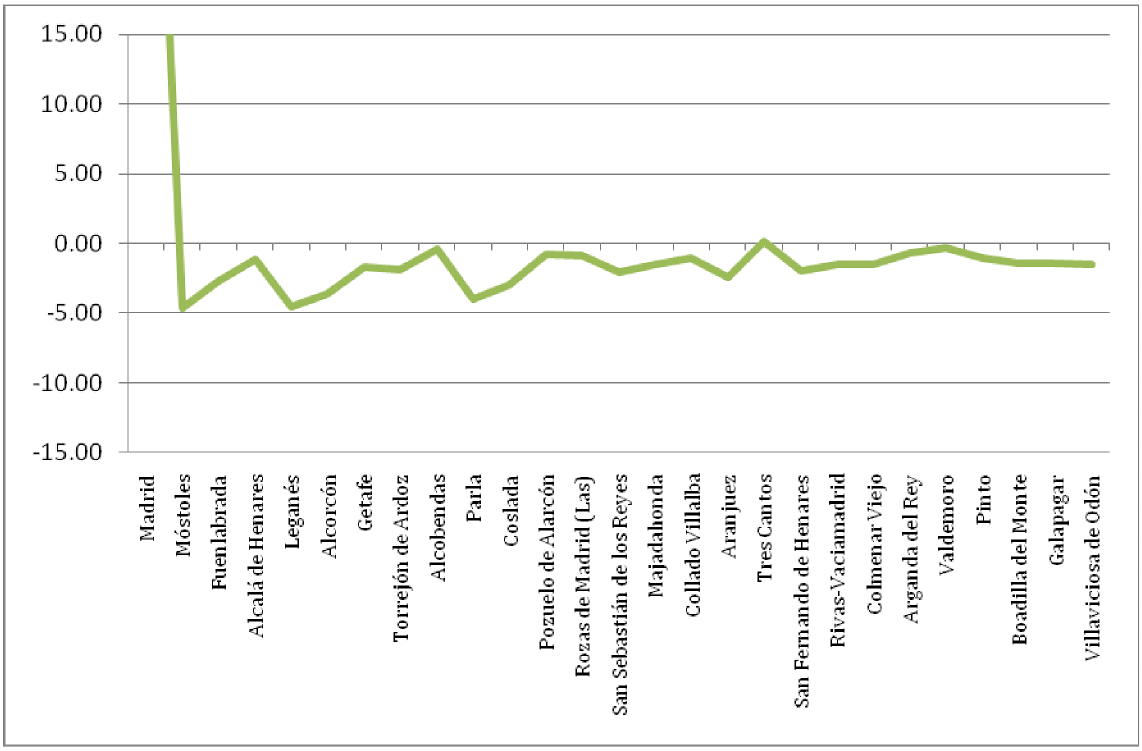

Figure 3b. $\delta_{\cdot j}$ coefficients for the province of Barcelona