SKILLED LABOR MOBILITY AND INNOVATION: A STUDY OF BRAZILIAN MICROREGIONS[1]

Eduardo Gonçalves[2]
Danielle Reis de Souza Ribeiro[3]
Ricardo da Silva Freguglia[4]

A stylized fact in the labor mobility literature, especially for skilled workers, is that they are characteristically a means of knowledge transfer from one region to another. However, research on innovation has hardly explored the role of skilled human capital mobility. This paper mainly aims to verify the extent to which innovation in the Brazilian microregions is related to skilled labor migration, as well as to know how attracting qualified labor is influenced by innovation levels. For this, estimates were performed by means of simultaneous equation systems using the SUR, 2SLS and 3SLS methods. Two innovation measures were then used: patents *per capita* and industrial manufacturing value. The results suggest that there was simultaneity between innovation and skilled labor migration. This paper also presents an Exploratory Spatial Data Analysis (ESDA) on migration and innovation, which show the existence of spatial clusters.

Keywords: skilled labor mobility; innovation; endogeneity.

MOBILIDADE DE MÃO DE OBRA QUALIFICADA E INOVAÇÃO: UM ESTUDO PARA AS MICRORREGIÕES BRASILEIRAS

A mobilidade de trabalhadores, em especial dos qualificados, é um meio bem conhecido pelo qual o conhecimento pode ser transferido de uma região para outra. Contudo, as pesquisas sobre inovações tendem a desconsiderar o papel da mobilidade de capital humano qualificado. O objetivo principal deste artigo é verificar até que ponto a inovação das microrregiões brasileiras está relacionada à migração de mão de obra qualificada e, ao mesmo tempo, verificar como a atração de mão de obra qualificada é influenciada pelo nível de inovação. Para tanto, as estimações foram feitas por sistemas de equações simultâneas, utilizando-se os métodos SUR, 2SLS e 3SLS. Foram testadas duas medidas de inovação: patentes *per capita* e valor de transformação industrial. Os resultados indicam que há simultaneidade entre inovação e migração de mão de obra qualificada. O artigo apresenta também uma análise exploratória dos dados espaciais (Aede) de migração e inovação, o que indica a presença de *clusters* espaciais.

Palavras-chave: mobilidade de trabalho qualificado; inovação; endogeneidade.

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2. Associate professor, Department of Economics, Federal University of Juiz de Fora, Brazil. E-mail: <eduardo.goncalves@ufjf.edu.br>.

3. MSc. in Economics Federal University of Juiz de Fora. E-mail: <danireisufv@yahoo.com.br>.

4. Associate professor, Department of Economics, Federal University of Juiz de Fora, Brazil.

E-mail: <ricardo.freguglia@ufjf.edu.br>.

1 INTRODUCTION

This paper recognizes that there is a mutual influence between skilled labor mobility and regional innovation in Brazil. If, on the one hand, labor mobility is a means of transferring technological knowledge from a region to another, contributing in this way toward regional innovation capacity, a regional territory, on the other hand, may become attractive to skilled workers looking for promising job opportunities in innovative industries, in a self-sustained process.

Theoretical arguments linking qualified people migration and regional innovation capacity can be found in authors that relate technological knowledge accumulation and diffusion to productivity increase in firms, institutions and regions. Human capital mobility plays a crucial role in knowledge diffusion as it allows individually incorporated tacit knowledge to be conveyed from an institution/firm to another, in this way leveraging productivity in other institutions/firms. It was also in such a context of externalities generation that authors, highlighting skilled labor mobility as a means of interregional technological knowledge spillover, have turned their attention to. Such authors have in mind that a region is a social milieu that shares and spreads knowledge through an interactive process, which is characterized by a network of personal and institutional linkages (Feldman, 1999; Breschi and Lissoni, 2001). However, a region's capacity to attract skilled labor is dependent on the dynamism of its development that can be tied to its innovation capacity, allowing the emergence of a vigorous local labor market in which new job opportunities are created. Thus, innovation and skilled labor migration would occur simultaneously and there would not be a prevailing causality between these two variables (Faggian e McCann, 2009).

Therefore, this paper intends to explore the empirical literature gap on regional mobility and innovation in Brazil. Studies of these two subjects in this country have focused separately on the determinants of regional innovation or regional labor mobility as can be seen in several contributions (Gonçalves and Fajardo, 2011; Gonçalves and Almeida, 2009; Montenegro *et al.*, 2011; Sabbadini and Azzoni, 2006; Da Mata *et al.*, 2008). Therefore, studies considering a possible endogenous relation between skilled labor migration and innovation are missing. It is worth knowing to what extent highly innovative regions preserve such a condition due to net entry of human capital or whether such inflows result from the fact that other regions are more dynamic and highly innovative.

For this purpose, data used here refer to the 558 Brazilian microregions. Microdata from Rais-Migra (data on geographical mobility of labor from the annual report on social information – the Brazilian Ministry of Labor and Social Security) were used to measure skilled labor mobility of individuals having complete higher-learning education who moved from their native microregions in the years 1999, 2000 and 2001. Authors like Docquier and Marfouk (2006), Özden (2006), Accioly (2009), and Da Mata *et al.* (2008) adopt such skilled labor concept. Two measures are used here with the purpose of evaluating innovation, namely patents *per capita* and industrial manufacturing value (VTI) of innovative firms as well as their premium-price exports.[5]

The regression equations were estimated by means of simultaneous equation systems with the use of econometric methods that take endogeneity between dependent and explaining variables into account. The results suggested that skilled people mobility and innovation were simultaneous as measured by the VTI of innovative firms.

The present work is organized as follows: in section 2, a review of the literature on innovation, migration and the relation between these two factors are presented; section 3 shows the data used in this paper and each variable construction. Section 4 constitutes an ESDA designed to verify whether skilled labor and innovation follow spatial patterns, i.e., whether the value of these variables in one microregion is influenced by its value in neighboring regions. Section 5 discusses the methodological aspects where tests and models used here can be found. The following section presents estimate results and finally the conclusion.

2 REGIONAL INNOVATION CAPACITY AND SKILLED LABOR MOBILITY

Regional innovation capacity has been explained as a concentration of several factors, such as: existing skilled labor (Audretsch and Feldman, 1996), existing universities and university R&D (Feldman and Florida, 1994; Varga, 1998), urban density (Carlino *et al.*, 2007), concentration of firms as to input-output, professional services in support of innovation and industrial R&D (Feldman and Florida, 1994) and spatial knowledge spillovers from universities (Anselin and Varga, 1997) or from innovation accomplished in neighboring regions (Moreno, Paci and Usai, 2005; Usai, 2011).

Professional concentration in the labor market has been considered as an important factor in the literature, since Marshall (1985) suggested that the secret of certain professions was made available in a region as an element "in the air", which could be easily absorbed by firms belonging to this industrial agglomeration. The circulation of qualified people among firms is a factor conferring economic advantage to a region, once its local labor market has been established, which reinforces its capacity for attracting and agglomerating other firms and workers. Increasing returns to scale as to even further productive activity in that space would be acting from then on (Krugman, 1991).

5. According to De Negri (2005), premium price is an extra gain of at least 30% due to that a firm's product is differentiated from others in a given time span.

In fact, as knowledge may have been internalized by scientists and skilled workers and is not exactly "in the air", Feldman (1999) asserts that it can be transmitted to others somewhere else, provided that workers are inclined to geographical mobility. Labor mobility is a literature track that attempts to identify the mechanism through which tacit knowledge is transmitted between firms and regions (Zucker and Darby, 1996; Feldman, 1999; Almeida e Kogut, 1999; Rosenkopf and Almeida, 2003; Dahl, 2004; McCann and Simonen, 2005; Audretsch and Keilbach, 2005).

Mobility of skilled labor may impact human capital stock in a given region. As for receiving regions, the relevance of skilled workers for innovation and economic performance is usually encompassed in theoretical and empirical studies assessing human capital impacts on their economic performance. In this perspective, some authors have stated that the highest the average level o human capital, the highest the ability of developing and implementing new technologies locally (Lucas, 1988; Bartel and Lichtenberg, 1987). Other studies relate skilled workers' density in local labor market to urban economic growth (Ciccone and Hall, 1996).

These studies refer to Lucas (1988). This author points to two possible human capital effects; the first is directly related to increased productivity per worker and the second, to the external effects that such productivity brings for the economy. Therefore, the highest the human capital level, the highest the level of input growth rate and input remuneration level would be.

Although initially conceived for closed economies, using such models for analyzing regional economies is quite possible. Regional economies are open and interaction between them is achieved through different channels, such as: flows of goods, people and information. The smallest the regional space, the highest is the importance of such flows. As for migration flows, regional impacts are related with the effects that such flows cause on human capital redistribution among regions. Lucas (1988) affirms that human capital redistribution may bear a variety of growth paths in different regions in a given country. However, the kind of path would depend on the geographic mobility pattern and the regional capacity to retain, maintain and increase human capital stock.

According to Faggian and McCann (2009), results accruing from flows of people for the regions can be analyzed through several perspectives. Generally speaking, immigration tends to reduce growth rate according to the neoclassical analytical framework. However, this is not the case for qualified immigrants who are not subject to decreasing returns to scale.

The multiplier effects of highly endowed human capital stock on regional economies may be lessened when these workers migrate to other regions showing better opportunities. According to migration literature, this happens because propensity to migrate is directly dependent on the level of human capital incorporated by the individual. In this case, two scenarios appear as possible.

In the first scenario, processes of circular cumulative causation may occur as described by Myrdal (1957), in which regions receiving net flows of skilled workers would show continued productivity gains and, conversely, declining regions would undergo the consequence of decreasing productivity. However, such processes are not endless as a result of diseconomies of scale that would be effective in a given point in time, giving rise to congestion and increased prices in the target region (Faggian and McCann, 2009).

In the second scenario, outflows and inflows followed by small net results would characterize some cities or regions. According to Faggian and McCann (2009), this is the case of metropolises like London. Large-scale migration flows constitute a combination of human capital that brings new abilities, ideas and original knowledge to London. Power and Lundmark (2004), based on Sweden experience, asserted that labor mobility acts as channels transferring knowledge and new influences and that innovative and growing clusters show higher rates of labor mobility than other regions.

It is precisely on the effects accruing from the skilled labor mobility that lays the literature track treating people mobility as a mechanism through which knowledge spillovers occur (Feldman, 1999). The theoretical rationale underlying this argument is based on the idea that skilled people bring with them a kind of knowledge that – due to its tacit nature – is only effectively transmitted via face-to-face contacts.

As a matter of fact, Faggian and McCann (2009) go further in understanding such mechanisms as they distinguish spillover sources. Face-to-face conversations between interfirm employees of different business firms and interfirm labor mobility, both representing transference of incorporated human capital, are two kinds of spillover mechanisms. The difference between these two mechanisms lies on their occurrence frequency and amount of information transferred through them. Face-to-face interactions are more common, although they allow access to only a small amount of given subjects. As for transference of interfirm personnel, frequency is smaller. However, it gives room for access to all individual incorporated human capital for the receiving firm.

As for empirical evidence, Zucker and Darby (1996), in a pioneer study, focused on the development of biotechnology brought about by some outstanding scientists that had generated externalities located nearby their local of residence. Following this path, other studies highlighted the role of professionals' mobility. Almeida and Kogut (1999) emphasized the role of engineers in regional networks of semiconductor industry in Silicon Valley. Rosenkopf and Almeida (2003) pointed out the role of inventor's mobility in semiconductor industry for accessing relevant knowledge in order to offset restrictions imposed by technological and geographical distance. McCann and Simonen (2005) stated that face-to-face contacts improve innovation in Finland high-tech industries. According to these authors, R&D cooperative relationship initially involves informal contacts and interactions, which later lead to more formal transfer mechanisms among firms. Lenzi (2010) found evidence that innovation and knowledge diffusion have increased in firms employing Italian inventors with at least one patent acknowledged in the pharmaceutical industry.

All arguments and evidence presented here account for the effects of labor mobility and the concentration on regional innovative performance of skilled workers in local labor market. However, there are arguments and evidence that may pose an opposite questioning: to what extent innovative performance in a region explains skilled labor mobility? And this is important to the extent that innovative performance in a region creates job opportunities for qualified individuals. In other words, a latent endogeneity between innovation and mobility of skilled workers becomes clear.

Part of migration literature highlights the fact that qualified people move in search of better labor opportunities (Sahota, 1968) or urban centers growing faster that offer higher wages, salaries and labor positions (Pekkala, 2003). Such opportunities are liable to be derived from innovations that create more qualified jobs attracting better professionals, which may give rise to the phenomenon called brain drain (Kuwok and Leland, 1982; Portes, 1976). In the Brazilian case, some works have focused on this subject, which concluded that such a phenomenon is linked to reasons such as: prosperity, greater labor market dynamism and population density (Mata *et al.*, 2007; Sabbadini and Azzoni, 2006; Silva, Freguglia and Gonçalves, 2010); follow-up academic education and better salaries and work conditions in the case of researchers (Guimarães, 2002), smaller social inequality (Mata *et al.*, 2007) and higher number of graduate programs (Sabbadini and Azzoni, 2006).

On the other hand, arguments supporting the idea that knowledge clusters with a great number of highly skilled workers are attractive to more of this kind of labor due to agglomeration effects can be found in the international literature (Wolfe and Gertler, 2004; Florida, 2005). Faggian and McCann (2009) found evidence that in England innovation influenced regional innovative performance, in fact showing an endogenous and cumulative relation. The following sections aim to investigate the reciprocal influence between mobility and innovation, viewing to fulfill a gap in the Brazilian empirical literature.

3 DATA

Table 1 briefly describes all variables used in this paper.

In order to measure skilled labor migration, data from Rais-Migra[6] and Rais (annual report on social information) were used. Therefore, only individuals employed in the formal labor market – both public and private sectors – were considered here. The criterion used to define qualified individuals was that of workers having "complete higher-learning education".

The dependent variable measures the entry of skilled individuals in each microregion in 1999, 2000 and 2001, in relation to skilled labor average stock of the destination microregion in the period. A random sample of 15% of total population with complete higher learning included in Rais-Migra was carried out, which resulted in a panel of 404,558 individuals. After such a selection, dummies were created for which value 1 was attributed in case individuals had moved to another microregion in a year's time and 0, in case individuals had remained in the same microregion. The number of skilled workers was summed up for the years 1999, 2000 and 2001 for each microregion. The average stock of skilled workers was taken from the Rais data, based on which average values of people without and with formal jobs in December 31 of each year for the same period were obtained. Then, the dependent variable (MOBQ) was constructed, which represented the number of entrants in the microregion divided by the average stock of skilled workers in the respective microregion.[7]

In the present work, two innovation measures are to be tested, as follows: patents *per capita* (PAT/POP) and industrial manufacturing value of innovative industries (VTIAB/ABC). The PAT/POP variable was constructed based on patent data from the *Instituto Nacional de Propriedade Industrial* – INPI (the Brazilian national agency for industrial property rights) for the years 1999, 2000 and 2001 (a total of 16,884 patents) and census data as of 2000 of the *Instituto Brasileiro de Geografia e Estatística* – IBGE (the Brazilian census agency). Patents are most frequently used as a measure of innovation as – according to Pakes and Griliches (1984) and Griliches (1998) – they are a good indicator of inventive activities, since there is a strong relation between R&D and number of patents. However, it is not a perfect measure for innovation as not all inventions are patentable. Furthermore, patentable

6. Rais-Migra is a database derived from a federal government record called Relação Anual de Informações Sociais – Rais (an annual listing of social information of the Brazilian Ministry of Labor and Social Welfare –MTPS). The Rais-Migra database allows following a worker by means of a code called PIS (social integration program). The latter characteristic has motivated the use of this database.

7. The present work acknowledges the subtle difference between mobility and migration. As the latter refers to an individual's change of local of residence, the former refers to an individual's change of work place, which may be followed by the Rais-Migra database. As for long distances, both terms could probably be used as synonyms. However, as for short distances, people can more frequently trip between their local of residence and work place. On the other hand, for the purpose of this paper, such conceptual difference brings about no impacts, since it aims to capture a mutual effect between the entry of skilled labor force in a given microregion and its innovative capacity.

inventions vary greatly in quality. Additionally, there are inventions protected by several patents (Griliches, 1998; Link *et al.,* 2007; OECD, 1997).

TABLE 1
Description of variables

Variable	Description	Source
MOBQ	Number of entrants in the microregion divided by the average stock of skilled labor per 100,000 workers (1999-2001)	Rais-Migra and Rais
PAT/POP	Patents per 100,000 inhabitants (1999-2001)	INPI and IBGE, 2000 Demographic Census
Vtiab/ABC	Value of industrial manufacturing of A- and B-type firms in relation to total VTI for the microregion (2000)	Ipea
EMP/EST	Net admissions (admitted minus fired workers) in relation to labor force stock in the microregion (1999)	Caged and Rais
PIBPC	Variation of GDP *per capita* in 1999/2001	Ipeadata/ IBGE
IDH	Human Development Index (HDI) in 2000	Ipea
Crime	Murder rate per 100,000 inhabitants (2000)	Ipea
CTRSP	Distance of the biggest microregion city to the city of São Paulo	Ipea
INDTOT	Waged and salaried occupied people in industry in relation to total waged and salaried people (1998)	IBGE – *Cadastro Central de Empresas,* 1998 (Central Record of Business Firms)
H2DIND98	Industrial diversification degree measured by the Herfindhal-Hirschman index (1998)	Rais
PERGEMP	Registered acting firms with more than 500 employees in relation to total registered acting firms at the territorial unit (1998)	IBGE – *Cadastro Central de Empresas* – 1998 (Central Record of Business Firms)
POTEC	Occupied salaried people in technological areas in relation to total waged and salaried occupied people (1998)	Rais
EMP10PAT	Employment in the 10 sectors with higher propensity to patenting (1998)	Rais
E25	Percentage of people aged 25 or more who have completed at least a one-year university course (2000)	Ipea
Metroexp	Dummy for metropolitan area existence in the microregion	IBGE
N	Dummy for the Northern Region	IBGE
NE	Dummy for the Northeastern Region	IBGE
S	Dummy for the Southern Region	IBGE
SE	Dummy for the Southeastern Region	IBGE
CO	Dummy for the Center-Western Region	IBGE

Elaborated by the authors.

An innovation measure alternative used in this paper is the value added of manufacturing firms (VTI) classified as product innovative and exporters of premium-price goods. Gonçalves and Almeida (2009) asserted that a way to know a microregion's innovative potentiality is to use VTI by kind of business firm. The VTI data used here were obtained from a database by Ipea (a Brazilian official agency for economic research) that had been constructed from the *Pesquisa de Inovação Tecnológica* – Pintec (technology innovation research) and from *Pesquisa Industrial Anual* – PIA (annual industrial research). The Brazilian industries are ranked in three different categories according to their innovation strategies (Gonçalves and Almeida, 2009; De Negri and Salermo, 2005; Lemos *et al.*, 2005). Then, in order to measure innovation, the VTI of A and B-type industries[8] will be divided by total VTI (A,B,C), i.e., variable VTIAB/ABC.

Empirical studies show that yields, job opportunities and life quality are positively correlated with attraction of labor force (Faggian and Mccann, 2009; Pekkala, 2003; Golgher, 2008; Sabbadini and Azzoni, 2006).

Variable PIBPC – which is the variation of GDP *per capita* in the period 1999-2001 – was used here in order to capture income level in the microregion. Variable EMP/EST – based on labor admissions (admissions minus dismissals) in the microregion whose data were taken from *Cadastro Geral de Empregados e Desempregados* – Caged (record of general employed and unemployed labor force – was created aiming at capturing job opportunities divided by labor force stock in the same year[9] (Rais). Additionally, the microregion's IDH (Ipea) – the estimate of which is made using the simple arithmetic mean of three subindices that refer to Longevity (IDH-Longevity), Education (IDH – Education) and Income IDH – income) – was used in order to capture life quality in the microregion. These factors are expected to influence positively skilled labor mobility. The murder rate per 100,000 inhabitants (variable Crime) was used as a measure of amenity, which also represented life quality. Following the evidence found by Mata *et al.* (2008), which indicated that qualified migrants seek places with lower violence levels, variable Crime was expected to be negative.

As Gonçalves and Almeida (2009) did, the distance from the biggest microregion city to the city of São Paulo was considered here. In this study, variable CTRSP, whose data source for estimation is that of Ipea, is to be used for the mobility equation. Faggian and McCann (2009), for example, used the distance from each region to London as explaining variable of migration in a similar study for England. This variable, CTRSP, constituted a way to verify whether the distance to the major productive and financial center of the country affected skilled labor.[10] In order to

8. Category A: industrial units that innovate and differentiate their products, as well as have their premium prices 30% higher, whose larger portion is generated in their most dynamic segments. Category B: it is mostly comprised of firms producing homogenous goods, which – although eventually using innovative processes for innovative products – are not able to obtain premium prices (above 30%) in foreign markets. Such industries have lower capacity to develop R&D. Category C: this category represents the largest portion of Brazilian industries, which show low innovative capacity, do not export or differentiate their products and are less competitive and use disclosed technologies.

9. It takes into account people without formal employment and those formally employed on Dec. 31 of the respective year.

10. The MOBQ variable, spatially lagged by means of k-nearest neighbors (k19), was also tested instead of CTRSP variable in order to verify the effects of the neighbors on the worker mobility. The results were not statistically significant.

capture differences among regions, which could be important in attracting skilled labor, dummies for each mesoregion were included in the mobility equation.

The INDTOT variable was obtained by using data of occupied, waged and salaried employees in extractive and manufacturing industries divided by total occupied, waged and salaried employees (IBGE). This variable was used both in the mobility equation and the innovation equation, since a higher degree of industrialization was expected as indicated by the number of job opportunities in the regional industry. At the same time, innovation was also expected to increase due to the kind of industry considered.

As for verifying innovation determinants, the MOBQ variable (previously explained), waged and salaried employees in extractive and manufacturing industries (INDTOT), degree of industrial diversification (*H2DIND98*), proportion of big companies present in the economy (PERGEMP), proportion of occupied people in technology fields (POTEC), adult population proportion aged more than 11 years (E25), and dummies for the presence of metropolitan regions (METROEXP*)* were taken into account. In addition to these variables, a control variable of patenting degree by type of industry (EMP10PAT*)* was also included. Further details concerning to explaining variables are given below.

The variable INDTOT was explained before because is also used in the mobility equation. In addition to industrial degree (INDTOT), the article considers a measure to verify the industrial diversification impact on innovative activity, the H2DIND98 variable, which is the Herfindhal-Hirschman index. This index measured industrial diversity in microregions through employment data from Rais in 1998 in the industrial sectors listed in the three-digit *Classificação Nacional de Atividades Econômicas* – CNAE (National Classification of Economic Activities) of IBGE. It varies from 0 to 1: the nearer to 0, the higher the industrial diversity in the microregion and the nearer to 1, the higher the specialization is (Montenegro *et al.*, 2011; Gonçalves and Almeida, 2009). This variable was considered only when VTI was used to measure innovation. The estimation formula for this index is described as follows:

$$D_t = \sum_j (Emprego_{ij} / Emprego_i)^2$$

The more diversified the industrial structure, the more innovative it is (Jacobs, 1969). The expected empirical sign for this variable was negative, due to the method used to construct this indicator.

Variable PERGEMP represents the percentage of business firms with more than 500 employees in relation to total acting companies in the year 1998 (IBGE). Big companies were mostly accountable for more significant innovation processes, where the R&D activity was concentrated (Schumpeter, 1942; Cruz and Vermulm, 2011). Therefore, a positive sign of this variable in the regression was expected.

Variable POTEC was estimated from the amount of employees with education in physics, chemistry, engineering, system analysis and programming divided by total employed workers in the microregion in 1998. These data were obtained from Rais. The professions chosen for constructing this proxy were considered relevant in transferring new techniques for the production sector (Diniz and Gonçalves, 2005).

Variable EMP10PAT was used in order to capture the sectoral propensity to patenting. According to Albuquerque (2000), the sectors showing more patents were as follows: machines, rubber products, metallurgy, education activities (universities), chemistry, other business activities, furniture, motor vehicle manufacturing and assemblage, electrical and other electronic equipment, as well as petroleum and natural gas extraction. This variable is a percentage of jobs in these 10 sectors in 1998, whose data were taken from Rais, according to Gonçalves and Almeida (2009). EMP10PAT was used only when PAT/POP measured innovation.

The E25 variable represents people who have completed at least one year in a university course in each microregion. It was expected that the higher the level of education of individuals, the higher innovation was. Carlino *et al.* (2007) used a sample of 280 metropolitan areas in the USA and found inputs for local R&D (mainly human capital) which contributed to improve the innovation level. The higher the educational degree was, the higher the propensity to create and apply new knowledge with economic purposes. Gonçalves and Almeida (2009), in a study for Brazilian microregions, and Montenegro *et al.* (2011), in a study of microregions in the state of São Paulo, concluded that the schooling level in a region affected innovation positively.

A dummy variable (METROEXP) – in which value 1 was given if there was a metropolitan area effect on the microregion and 0 if there was not – was introduced in the equation. Gonçalves and Almeida (2009) utilized such a variable and found a positive and significant relation of this variable with innovative activity. According to IBGE, there were 26 metropolitan areas in Brazil in 2000.[11]

4 EXPLORATORY SPATIAL DATA ANALYSIS OF MOBILITY AND INNOVATION DATA

More self-connected regions are more interactive with less-connected regions and such connection degree is usually measured by means of proximity degree among regions. Therefore, this section makes use of an ESDA and spatial econometrics

11. The 26 metropolitan areas considered are as follows: Belém, Grande São Luís, Fortaleza, Natal, Recife, Maceió, Salvador, Belo Horizonte, Vale do Aço, Grande Vitória, Rio de Janeiro, São Paulo, Baixada Santista, Campinas, Curitiba, Londrina, Maringá, Joinville, Blumenau, Vale do Itajaí, Florianópolis, Tubarão, Criciúma, Porto Alegre, Goiânia and Distrito Federal.

in order to verify if skilled labor mobility and innovation follow spatial patterns, i.e., if these variables' values in a microregion are affected by such values in the nearest regions.

The Baumont (2004) procedure was used for choosing the spatial weight matrix[12] and queen, tower and k-neighbors matrices were generated nearer to 1 and up to 20, and that with higher significant Moran's I was chosen. As can be seen in Table 2, Moran's I and Geary's c statistics indicated a positive spatial autocorrelation for variables PAT/POP, VTIAB/ABC and MOBQ, i.e., similarity between values of such variables and geographical localization. Therefore, microregions showing high values of skilled "migrants" were surrounded by microregions also showing high values of skilled "migrants", as well as those microregions attracting few skilled workers were surrounded by microregions that attracted little skilled labor force. The same argument was valid for variables used as innovation measuring.

TABLE 2
Spatial autocorrelation statistics for mobility and innovation

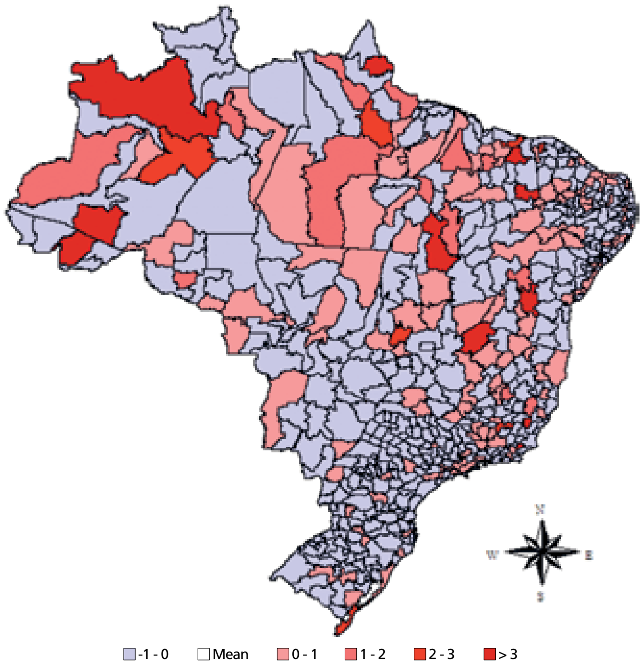
Variables	Weight matrix (W)	Moran's I	P-value	Geary's C	P-value
MOBQ	K19	0.05	0.00	0.91	0.00
PAT/POP	K6	0.44	0.00	0.61	0.00
VTIAB/ABC	K2	0.39	0.00	0.62	0.00

Elaborated by the authors using the Spacestat software.

Figure 1 shows the geographical distribution of the ratio between skilled labor mobility and total skilled labor force in the destination microregion as for the years 1999, 2000 and 2001. In the Northern region of the country some microregions appear with a high degree of skilled labor attraction in relation to the average stock of skilled labor force, which corroborates the study carried out by Ferreira and Matos (2004), such as Rio Negro (AM), Coari (AM), Alto Solimões (AM), Macapá (AP) and Boca do Acre (AM). Ferreira and Matos (2004) emphasized that the labor market was reorganized in the 1990s, due to the opening of the Brazilian market to foreign markets, which have resulted in a deconcentration of certain productive activities, notably industrial activities. And this was due to that new portions of the Brazilian territory had been incorporated into the dynamics of wealth generation. Therefore, migration flows were again dynamized. Ferreira and Matos (2004), in their study for the period 1995-2003, for example, highlighted that the Northern region has offered wage differentials to immigrants in the formal sector of the economy, in this way attracting labor force.

12. The spatial weight matrix (W) was an attempt to reflect a given spatial arrangement of interactions resulting from the phenomenon to be studied. Queen and Rook are matrices of contiguity, in which two regions are considered neighbors when they share a common physical boundary. The k nearest-neighbor matrices are those whose proximity convention is based on geographic distance (Anselin, 1999).

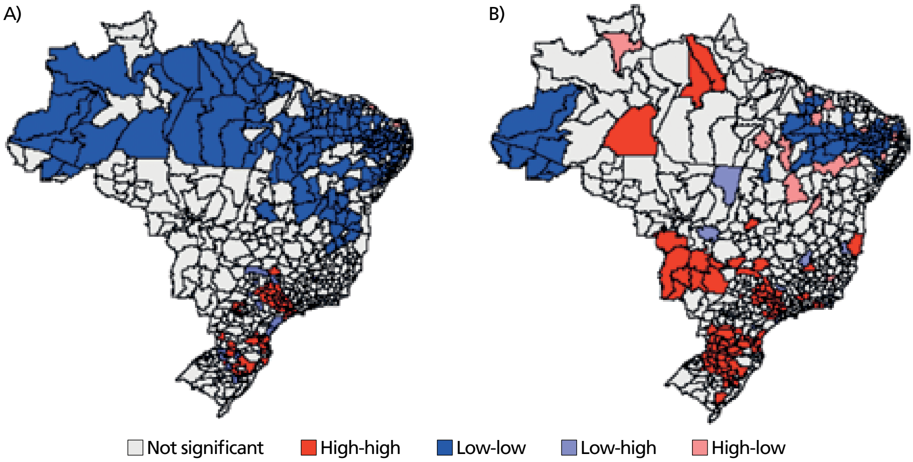
FIGURE 1
Attraction of skilled labor force as a proportion of skilled labor stock – 1999, 2000 e 2001



Elaborated by the authors using the Arcview software.

Figure 2 shows a spatial map of clusters, which was constructed based on local Moran's I as suggested in the literature by Anselin (1995), with the aim to capture local patterns of spatial autocorrelation. The portion 2A shows patent clusters as population ratio. Low-low clusters prevailed in the Northern and Northeastern regions, i.e., microregions with low innovation activities measured by number of patents, which are grouped in these parts of Brazil. High-high clusters can be found in the Southeastern, Center-Western and Southern regions, where microregions in the state of São Paulo, such as Araraquara, São Paulo, Piracicaba, Ribeirão Preto, Bauru, São Carlos are located; Uberaba can be seen in the state of Minas Gerais, and Joinville (SC), Caxias do Sul (RS) and Florianópolis (SC) are microregions included in the Southern region, according to the spatial pattern presented by Gonçalves (2007). Figure 2B shows the innovation map of clusters measured by industrial manufacturing value of firms belonging to the A and B categories. Here again, low-low clusters prevailed in the Northern and Northeastern regions, whereas microregions showing high innovation are grouped in the Southern, Center-Western and Southeastern regions, where high-high clusters are concentrated.

FIGURE 2
Spatial clusters of patents (A) and clusters of VTI (B)



Elaborated by the authors using the Geoda software.

Once the exploratory analysis of skilled labor migration and innovation data was completed, estimates of econometric models were carried out. The econometric methods used are presented as follows.

5 EMPIRICAL STRATEGY

As shown in section 2, Regional innovation capacity and skilled labor mobility, there is evidence that found in the international literature of migration and innovation the attraction degree of skilled labor force is a function of the degree of innovation in a region, while innovation seemed to be related to human capital entry. Therefore, given the hypothesis that there was a feedback relation between skilled labor migration and innovation, econometric estimates were carried out by taking recourse of a simultaneous equation system.

As the regional innovation capacity has been explained by spatial knowledge spillovers coming from innovation accomplished in neighboring regions (Moreno, Paci and Usai, 2005; Usai, 2011), a spatial lag of the variable representing innovation (W_PAT/POP and W_VTIAB/ABC) was taken into account.

When PAT/POP is used as a measure of innovation, the structural form of equations is as follows:

$$MOBQ = \alpha_0 + \alpha_1 pat/pop + \alpha_2 empest + \alpha_3\, PIBPC + \alpha_4 ctrsp + \alpha_5 idh + \alpha_6 crime + \alpha_7 indtot + \alpha_8\, dummies\ for\ regions + \eta\,; \quad (1)$$

$$pat/pop = \beta_0 + \beta_1\ MOBQ + \beta_2\ indtot + \beta_3 metroexp + \beta_4 pergemp + \beta_5 e25 + \beta_6 emp10pat + \beta_7 potec + \beta_8\ W\_PAT/POP + \varepsilon\ . \quad (2)$$

When the measure of innovation used is VTIAB/ABC, the equations are:

$$mobq = \gamma_0 + \gamma_1 vtiab/abc + \gamma_2 empest + \gamma_3\ PIBPC + \gamma_4 ctrsp + \gamma_5 idh + \gamma_6\ CRIME + \gamma_7 indtot + \gamma_8\ dummies\ for\ regions + \xi\ ; \quad (3)$$

$$vtiab/abc = \phi_0 + \phi_1 mobq + \phi_2 indtot + \phi_3 metroexp + \phi_4 pergemp + \phi_5 e25 + \phi_6 h2dind98 + \phi_7 potec + \phi_8\ W\_VTIAB/ABC + \mu\ . \quad (4)$$

First of all, the system was estimated by means of the SUR (Seemingly Unrelated Regressions) method, which takes into account possible existing correlations between errors in the several equations in a system, but neglects possible endogeneity among variables. SUR consists in estimating equations by OLS (Ordinary Least Squares) that are equivalent to estimating by OLS of equation by equation, when there are no restrictions in the parameters (Wooldridge, 2002). Estimators by OLS are inconsistent in the presence of endogeneity.

In order to verify the existence of multicollinearity, a correlation matrix of variables was elaborated and the *Variance Inflation Factor* test was applied, which led to the intuition that, when a regressor is not orthogonal to other regressors, the variance of the respective parameter remains inflated.[13] We present these results in the appendix.

The Durbin-Wu-Hausman test was performed so as to verify the existence of endogeneity, the null hypothesis of which, however, was that there was no endogeneity. The method of tool variables was used to treat the problem of endogeneity between mobility (MOBQ) and innovation (PAT/POP or VTIAB/ABC). In the equation where MOBQ is the dependent variable, the PAT/POP variable is considered as endogenous and also being intrumentalized by INDTOT, METROEXP, PERGEMP, E25, EMP10PAT and POTEC, i.e., by all exogenous variables. The same procedure was adopted for the MOBQ equation, where the VTIAB/ABC equation was taken as an innovation measure, i.e., VTIAB/ABC was instrumentalized by INDTOT, METROEXP, PERGEMP, E25, H2DIND98 and POTEC. In equations where MOBQ was an explaining variable, which was considered endogenous, the set of instruments, containing all exogenous variables,

13. According to Gujarati (2000), when a simple correlation is higher than 0.8, it can be considered a serious correlation problem. Still according to this author, in case the variance inflation factor of a given variable is VIF > 10, it can be taken as a highly collinear variable.

proved to be feeble. Following removal or recombination of instruments used in the tests, as suggested by Cameron and Trivedi (2005), INDTOT and EMPEST variables were chosen to instrumentalize MOBQ both in the equation where VTIAB/ABC is the dependent variable and in equation PAT/POP.

According to Wooldridge (2002), the chosen variable should fulfill two conditions so as to be taken as a good instrument. First of all, instrument (z) cannot be correlated with the error term in the equation: *i)* Cov(z, u)= 0. That is, the instrument must be exogenous in the equation in which it is being used and not determined in the equation context. Secondly, the instrument must be partially correlated with to the variable being instrumentalized: *ii)* Cov(z,x) ≠ 0. Wooldridge (2002) highlighted that these two conditions are equally important in identifying the estimator. However, condition (i) is not testable as it refers to the covariance between z and a nonobservable error.

Based on Cameron and Trivedi (2005), when more than one instrument is used in estimating by using instrumental variables, a joint correlation of the endogenous regressor with such instruments – in order to verify if the latter are feeble – can be considered. A common diagnosis is to verify F statistics for the joint significance of instruments in the first stage of the regression. Cameron and Trivedi (2005) still assert that a rule proposed by Staiger and Stock (1997) establishes that the instruments would be feeble, if the statistics F value is below 10.[14] These tests were carried out according to that carried out by Fallah *et al.* (2011). Besides, we did a test suggested by Sotck and Yogo (2005) in which the null hypothesis represents weak instruments, i.e., the instruments are not enough to explain a reasonable fraction of that endogenous regressor's variability due to a weak correlation between Z and X variables.[15]

The equation system was estimated by means of 2SLS (Two-Stage Least Squares) that treats one of the equations isolatedly. The first stage consists in making the endogenous variable to regress in relation to the instruments in order to obtain the variable's adjusted value; in the second stage, y is regressed in relation to the adjusted value of the endogenous variable and in relation to the exogenous variables, thus obtaining the estimator β (Cameron and Trivedi, 2005). The estimate obtained by OLS, for the first stage regression, provides the optimum linear combination for the instruments taken into account, i.e.,

14. Wooldridge (2002, p. 104-105) also suggests to verify the validity of instruments by using statistics F in the first regression stage. A value below 5 indicates the presence of an extreme bias in finite samples.

15. Stock and Yogo (2005) suggest a test in which the null hypothesis is that the bias of the 2SLS estimator be less than a certain required percentage, such as 5%, 10% or 20%, of the OLS estimator. Under null hypothesis, the estimator is weakly identified due to the size of the bias. The Stock-Yogo test is calculated based on the F-statistic from Cragg and Donald (1993). However, if there was an unique endogenous regressor, such statistic becomes the first stage F-statistic. The Stock-Yogo test maintains the robustness properties even in the situations where the hypothesis that the errors are independent and identically distributed is violated.

among all possible linear combinations that can be used as instruments for the endogenous variable, the 2SLS chooses the one showing the higher correlation with such a variable (Wooldridge, 2002).

The 2SLS method will provide inefficient estimators for α and β (γ and ϕ) if the error terms in the equation system η and ε *(*ξ and μ*)* are correlated. Therefore, as in Faggian and McCann (2009), there is no theoretical reason to exclude the possibility of correlation in the model. In this case, the most efficient estimator would be 3SLS (Three-Stage Least Squares*)* proposed by Zellner and Theil (1962), which assumes that errors are homoscedastic, although correlated among equations (Cameron and Trivedi, 2005). Model 3SLS includes characteristics belonging to the two previous methods, by estimating each of the equations using the 2SLS method and then estimating the system as a whole in the same way as SUR does. 3SLS may be considered as an extension of 2SLS; in other words, as an extra stage consisting in estimating the covariance matrix of the error terms between equations, besides using it to correct the parameter estimates of α and β (γ and ϕ). The identification hypotheses of the model are as follows (Wooldridge, 2002):

- $E(Z_i'u_i)= 0$, exogeneity of the instrument;
- rank $E(Z_i'X_i)= K$, full rank, the number of instruments must be higher or equal to the number of explaining variables; e
- the estimated weight matrix converges in probability of being a real weight matrix.

The 3SLS estimator is consistent and asymptotically normal under these three hypotheses. The first two hypotheses avow the 2SLS consistence.

In the following section, the OLS, 2SLS and 3SLS estimates are shown, initially using patents as innovation measuring and then using industrial manufacturing value.

With the aim to verify if the spatial autocorrelation had been duly controlled, a test of regression residues was carried out, in order to guarantee the estimates' consistence after choosing the better adjusted models.

6 RESULTS

Table 3 shows the estimate results that used patents as innovation measure.[16] The Hausman test reveals existing endogeneity in the migration equation (MOBQ) when variable PAT/POP is the innovation measure, as the null exogeneity hypothesis is rejected at 5% significance. Therefore, using instrumental variable methods was

16. There is no evidence of multicollinearity in the estimation models among the variables, as attested by the correlation table and the Variance Inflation Factor test.

justifiable. Instruments have proved to play a robust role in this equation. As for the PAT/POP equation, the Hausmann test indicates that there was no endogeneity, which suggests that the OLS method would be preferable for such estimation.

The F statistics suggested that the instruments used in the PAT/POP equation were robust, in accordance with the criterion proposed by Staiger and Stock (1997). The Stock-Yogo test confirms that the instruments used here are not weak. As both SUR method and 2SLS method have estimated the equations separately, the best results for the MOBQ equation were those estimated by 2SLS, whereas the best results for the PAT/POP equation were those estimated by OLS. The residual tests in these regressions showed that both models have controlled the presence of spatial dependence.[17]

Results indicate that despite the fact that a microregion is innovative, i.e., showing high indices of patents *per capita* , this result is not a factor of skilled labor attraction, since PAT/POP was negatively associated with MOBQ. This result was compatible with that shown in the explanatory analysis, which highlighted the Northern microregions – showing low patenting levels – as receivers of qualified people in relation to the average stock of the labor force in microregions.

As expected, recently made admissions (EMPEST) positively affected skilled labor entry in the microregions. And this attested that people had taken notice of job opportunities before migrating. The coefficient of variable *INDTOT* was significant in the mobility equation, but negative, in such a way that a higher employment in industry seemed not to attract qualified migrants any more. Variable CRIME presented negative sign, which indicated that violence was a repelling factor of skilled labor migration. The coefficient of the variable dummy for the Northeast region was negative and significant, suggesting that microregions, in this portion of the country, were migration obstructive to skilled labor force as compared to the reference dummy (North). The distance of the microregion to São Paulo (*CTRSP*), GDP *per capita* and *HDI* did not show significant coefficients.

As for the innovation variable (PAT/POP), results signalled that it was positively affected by industrial employment (INDTOT), higher individual level of education (E25) and existence of a metropolitan area in the microregion (METROEXP). The employment percentage in the 10 sectors most producing patents (EMP10PAT) also affected innovation positively. Variable W_PAT/POP showed a positive and highly significant coefficient, confirming the hypothesis that innovations in a microregion positively affected the innovation level of neighboring microregions.

17. The Moran's I test was carried out for these regressions' residues, as proposed by Anselin (1992).

TABLE 3
Determinants of skilled labor mobility and innovation using patents as innovation measure (1999-2001)

	OLS		2SLS		3SLS	
Variables	MOBQ	PATPOP	MOBQ	PATPOP	MOBQ	PATPOP
Constant	415.2[3]	-0.313[3]	393.4[2]	-0.342[1]	407.4[3]	-0.353[3]
	(106.6)	(0.05)	(173.6)	(0.20)	(107.5)	(0.10)
PATPOP	-41.92		-137.6[3]		-122.8[3]	
	(27.36)		(35.24)		(46.58)	
EMPEST	481.6[2]		480.1[3]		480.4[2]	
	(200.5)		(144.2)		(202.0)	
PIBPC	6.708		17.75		13.73	
	(15.64)		(12.17)		(16.25)	
CTRSP	26.36		23.57		22.83	
	(21.76)		(30.17)		(21.95)	
IDH	1.42		3.90		2.41	
	(3.58)		(3.40)		(3.71)	
INDTOT	-240.7[2]	0.54[3]	-180.8[1]	0.56[3]	-187.5	0.57[3]
	(111.6)	(0.15)	(99.24)	(0.21)	(115.4)	(0.16)
CRIME	-2.87[2]		-2.34[2]		-2.43[2]	
	(1.15)		(0.94)		(1.18)	
SE	-55.88		-30.87		-31.17	
	(91.05)		(141.6)		(92.23)	
S	-149.0[1]		-112.0		-118.3	
	(90.50)		(128.10)		(92.30)	
CO	-118.3		-136.2		-124.4	
	(84.38)		(114.60)		(85.16)	
NE	-179.1[3]		-180.1[1]		-182.3[3]	
	(60.42)		(101.70)		(60.91)	
MOBQ		0.00		0.00		0.00
		(0.00)		(0.00)		(0.00)
METROEXP		0.73[3]		0.74[3]		0.72[3]
		(0.10)		(0.21)		(0.10)
PERGEMP		0.00		0.00		0.00
		(0.02)		(0.02)		(0.02)

(Continues)

(Continued)

	OLS		2SLS		3SLS	
Variables	MOBQ	PATPOP	MOBQ	PATPOP	MOBQ	PATPOP
E25		0.05[3]		0.05[3]		0.05[3]
		(0.01)		(0.01)		(0.01)
POTEC		-1.03		-1.07		-1.15
		(2.62)		(2.66)		(2.62)
EMP10PAT		0.99[3]		0.99[3]		0.99[3]
		(0.18)		(0.30)		(0.18)
W_PATPOP		0.41[3]		0.41[3]		0.40[3]
		(0.07)		(0.08)		(0.07)
R^2	0.08	0.55	0.05	0.55	0.06	0.55
F (First Stage)			21.35	10.14		
Hausmann (p-value)			0.00	0.94		
Stock-Yogo (p-value)			0.00	0.01		

Standard errors in parentheses.
Notes: [1] 10% significance.
[2] 5% significance.
[3] 1% significance.

In models in which the measure of innovation was VTI (Table 4), the Hausman test suggested endogeneity both in equation MOBQ and in equation VTIAB/ABC, i.e., when using measure VTI, simultaneity between skilled labor mobility and innovation was confirmed. Table 4 shows the results of estimation tests. In the estimation carried out by using 2SLS, results indicated a positive relation between skilled labor mobility and innovation, although its value was not so significant. When estimation was carried out by means of 3SLS, such a feeble causality between mobility and innovation became insignificant. Results of estimation using 3SLS suggested that, in Brazil, innovation affected mobility negatively, confirming what was previously observed in table 3, where innovation was measured by PAT/POP. It should also be noted that the negative relation between mobility and innovation was verified when the three estimation methods were used. The regression residual tests indicated that the models estimated by 3SLS have controlled the existence of spatial dependence.[18]

18. The Moran's I test was carried out for these regressions' residues, as proposed by Anselin (1992).

In the study by Faggian and McCann (2009) for the British case, results indicated that migration had affected innovation positively and significantly only when the authors had removed Scottish regions from the estimations. When all British regions were taken into account or when London regions had been removed, the results were not significant. As for the innovation impact on qualified people migration, a positive and significant relation was found by these authors when using all models. Such a result contrasts with the results found in this paper for the Brazilian microregions and this fact reflects differences between innovation systems in these two countries.

In the Brazilian case, the presence of innovative companies in relation to all industrial companies is significantly lower than those in Britain, which makes it weaker the ties between job opportunities in technology-intensive industries and skilled labor mobility. Furthermore, innovation is spatially concentrated in Brazil, especially in the capital of the state of São Paulo (Montenegro *et al.*, 2011). However, despite that this federation unit received a net skilled labor force in relation to others in the period 1995-2006, according to Silva, Freguglia and Gonçalves (2010), this was not sufficient to make it prevail in the skilled labor mobility pattern. In brief, the negative effect of innovation on skilled labor mobility may be related to the fact that innovation in Brazil is concentrated in most developed microregions, which generally also prove to have agglomeration diseconomies and labor repelling factors. Such a result signalled to that workers with higher learning education go to microregions whose job opportunities are not necessarily associated with the degree of innovation in the microregion's industrial tissue.

The results found for the mobility equation are in accordance with studies as those of Golgher *et al.* (2005), Netto Jr. and Moreira (2003), Sabbadini and Azzoni (2006), in which economic motivations are determinant of internal migration in Brazil. The results are also in accordance with those found in Da Mata *et al.* (2008), who concluded that qualified migrants had sought jobs in cities having better opportunities measured by variable EMPEST that, in Brazil, may not be associated with industrial innovation level.

TABLE 4
Determinants of skilled labor mobility and innovation using VTI as innovation measure (1999-2001)

	OLS		2SLS		3SLS	
VARIABLES	MOBQ	VTIABABC	MOBQ	VTIABABC	MOBQ	VTIABABC
CONSTANT	452.8[3]	0.04	646.4[3]	-0.17	561.9[3]	0.07
	(108.1)	(0.06)	(218.4)	(0.14)	(116.3)	(0.07)
VTIAB/ABC	-81.02[1]		-531.5[3]		-380.2[3]	
	(45.06)		(199.3)		(124.5)	
EMPEST	487.5[2]		571.2[3]		442.0[2]	
	(200.6)		(160.1)		(196.9)	
PIBPC	5.970		25.95		14.05	
	(15.48)		(20.73)		(15.76)	
CTRSP	25.72		8.493		18.42	
	(21.80)		(31.58)		(21.50)	
IDH	1.149		3.210		2.166	
	(3.53)		(3.57)		(3.47)	
INDTOT	-199.5[1]	0.69[3]	192.2	0.89[3]	44.19	0.69[3]
	(117.0)	(0.10)	(151.7)	(0.16)	(158.6)	(0.11)
CRIME	-2.94[2]		-1.75[1]		-2.42[2]	
	(1.14)		(1.02)		(1.15)	
SE	-64.39		-69.80		-24.75	
	(90.72)		(134.8)		(87.63)	
S	-159.0[1]		-154.2		-107.6	
	(89.85)		(121.2)		(87.45)	
CO	-113.2		-109.9		-101.2	
	(84.26)		(110.1)		(81.88)	
NE	-187.0[3]		-243.1[2]		-208.8[3]	
	(60.65)		(109.1)		(61.62)	
MOBQ		-0.00		0.00[1]		-0.00
		(0.00)		(0.00)		(0.00)
METROEXP		0.07		0.08		0.06
		(0.07)		(0.06)		(0.07)
PERGEMP		0.00		0.02		0.00
		(0.01)		(0.01)		(0.01)
E25		0.01[2]		0.02[3]		0.01[3]
		(0.01)		(0.01)		(0.01)
H2DIND98		-0.08		-0.17		-0.09
		(0.0636)		(0.111)		(0.06)
POTEC		7.06[3]		6.245[2]		6.09[3]
		(1.80)		(2.69)		(1.72)
W_VTIAB/ ABC		0.55[3]		0.48[3]		0.52[3]
		(0.08)		(0.09)		(0.08)
R^2	0.08	0.39			-0.01	0.39
F (First Stage)			23.97	10.52		
Hausmann (p-value)			0.00	0.08		
Stock-Yogo (p-value)			0.00	0.00		

Standard errors in parentheses.
Notes: [1] 10% significance.
[2] 5% significance.
[3] 1% significance.

In equation VTI, the proportion of industrial employment appeared with positive and significant coefficient, suggesting that a higher number of jobs in extractive and manufacturing industries had generated more innovation. Variable *E25* showed a highly significant coefficient, implying that the higher the individual education level, the higher the innovation in the microregion. Variable *POTEC* was also significant at 1%, suggesting that the business firms' capacity of generating R&D was positively correlated with innovation. It is also worth noting that the coefficient for variable H2DIND98 was negative, though not significant, which means that diversified regional environments were more important for innovation generation than specialized environments. This was in accordance with Jacobs (1969), what had been originally verified by Gonçalves and Almeida (2009). As expected, the spatial lag of the variable representing innovation (W_VTIAB/ABC) showed a positive and significant coefficient, confirming that innovation in a microregion has had a positive effect on innovation in neighboring microregions.

The percentages of big companies (PERGEMP), GDP *per capita* (PIBPC) and HDI were not significant when innovation was measured both by patents and by VTI.

7 CONCLUSION

This paper investigated the influence of innovation on skilled labor mobility in Brazilian microregions and, at the same time, the effect of skilled labor attraction on the innovation level. The entrance number of skilled workers over total skilled labor force in a microregion was the mobility measure used here. This variable was regressed in relation to innovation measured by patents *per capita* and then in relation to innovation measured by industrial manufacturing. Additionally, other factors were taken into account in the equation, which would be attractive to skilled labor force, such as region localization (North South, Southeast, Center-West), level of employment, GDP *per capita*, distance to the financial center of the country, HDI and level of violence.

Innovation measures were regressed against mobility, and other variables indicated in the literature as innovation determinants, such as education, percentage of big companies, level of industrial base diversification, have occupied people in technical and innovation areas in neighboring regions. The results found point to a feeble relation between mobility of skilled labor force and innovation. Besides, the results found here seems to indicate a negative relationship between innovation and mobility. The results suggested that being an innovative microregion did not constitute a factor attracting skilled labor force using both patents as innovation measure and the industrial value added of companies in the industrial tissue. This probably lies on that innovation in

Brazil is concentrated in well-developed microregions, which usually present agglomeration diseconomies and labor repelling factors. The results also suggest that workers with higher-learning schooling go to microregions whose job opportunities are not necessarily linked to innovation level in the industrial tissue of the microregion.

Policies viewing to improve innovation and reduce industrial and regional concentration should focus on employment generation. As demonstrated by the results of the present work, increasing industrial jobs in technological areas is crucial for innovation in microregions, an important activity to be set in motion. Furthermore, the most important factor of qualified people's decision to migrate seems to be job opportunities found in a microregion.

This article aims to contribute to the empirical literature on mobility and regional innovation in Brazil, opening further debate about this research topic. Future extensions could consider the use of the panel data as a mean of control possible fixed effects and the use of the other estimators that deal with endogeneity bias and heterocedasticity issues, such as Generalized Method of Moments and Two Stage Least Squares proposed by Kelejian and Prucha (2010). Besides, one could test the use of Census data instead of Rais-Migra database in order to compare the results.

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APPENDIX

TABLE A.1
Variance Inflation Factor (VIF) Test

Variábles	MOBQ		PAT/POP		MOBQ		VTIAB/ABC	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
MOBQ			1.06	0.947832			1.06	0.944633
PAT/POP	1.48	0.67509						
VTIAB/ABC					1.46	0.68273		
PIBPC	1.37	0.729296			1.34	0.744129		
EMPEST	1.05	0.948386			1.06	0.947106		
IDH	1.24	0.809359			1.2	0.830721		
CRIME	1.26	0.792962			1.25	0.798974		
CTRSP	4.29	0.233345			4.3	0.232389		
SE	8.19	0.122121			8.13	0.122955		
S	5.54	0.18048			5.46	0.182994		
NE	3.94	0.253902			3.97	0.251826		
CO	2.91	0.344111			2.9	0.344972		
INDTOT	1.25	0.799924	1.34	0.74488	1.37	0.728383	1.13	0.888674
H2DIND98							1.41	0.711268
PERGEMP			1.1	0.908014			1.07	0.930909
POTEC			1.2	0.831666			1.17	0.85579
E25			2.06	0.486274			1.82	0.550901
W_PAT/POP			2	0.501101				
METROEXP			1.32	0.756728			1.31	0.766202
EMP10PAT			1.28	0.778427				
MÉDIA	2.96		1.42		2.95		1.28	

Elaborated by the authors.

TABLE A.2
Correlation matrix

	MOBQ	PAT/ POP	VTIAB/ ABC	PIBPC	EMPEST	IDH	CRIME	CTRSP	INDTOT	H2DIND98	PERGEMP	POTEC	E25
MOBQ	1												
PAT/POP	-0.11	1											
VTIAB/ABC	-0.11	0.34	1										
PIBPC	-0.06	0.33	0.31	1									
EMPEST	0.07	0.02	0.06	0.01	1								
IDH	-0.04	0.28	0.18	0.03	0.02	1							
CRIME	-0.11	0.14	0.17	0.34	0.03	-0.14	1						
CTRSP	0.15	-0.40	-0.35	-0.26	-0.13	-0.34	-0.06	1					
INDTOT	-0.14	0.34	0.46	0.21	0.05	0.18	0.07	-0.32	1				
H2DIND98	0.15	-0.39	-0.32	-0.21	-0.02	-0.36	-0.12	0.56	-0.17	1			
PERGEMP	-0.10	0.06	0.08	0.03	-0.01	0.11	0.14	0.07	0.16	-0.00	1		
POTEC	-0.06	0.27	0.30	0.39	-0.05	0.05	0.18	-0.18	0.15	-0.25	0.13	1	
E25	-0.19	0.63	0.43	0.38	-0.01	0.23	0.26	-0.53	0.25	-0.53	0.04	0.34	1

Elaborated by the authors.