Determinants of university and industrial patents in Brazilian regions: a Spatial Panel Approach

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Abstract

Academia and industry have different norms and incentives to participate in the innovative process which reflects in different focuses and specializations. Considering the growing importance of university patents in great number of countries, we use a Regional Knowledge Production Function to analyze, not only patents as a whole, but to evaluate industrial and university patents separately for Brazil from 1998 to 2018 using a spatial panel for 133 regions. This work aims to define the role played by the different determinants cited in the literature on university and industrial patenting of innovation in developing countries with a broader and more recent panel using a hierarchical-functional regional cut. Our results include differences between academic and industrial innovations regarding R&D efforts, urban agglomeration and network connections. Also, we find a great source of heterogeneity and differences in innovation, like complementary technological profile. Moreover, we find specificities for the North and South regions of Brazil regarding innovation patterns and explore heterogeneity of patent data for international patents (PTC), co-invented patents and utility models. These results are important to understand the real effect of each type of patent, helping to direct public innovation policies specific to develop industries and university knowledge in peripheral regions.

Keywords: Regional Knowledge Production Function, Developing Countries, Patents, Networks.

JEL Code: C31, O31, O33, R1.

Introduction

Industrial and university R&D are closely related and this relationship involves formal and informal mechanisms as university-industry collaboration, training and knowledge spillovers. However, academia and industry are very distinguished worlds ruled by different norms and incentives to innovate (MERTON, 1973; PARTHA; DAVID, 1994) and it reflects on the patterns of patenting in both cases (LISSONI, 2012).

At its origin, the Regional Knowledge Production Function (RKPF) included the role of local private and universities R&D in the generation of patents (JAFFE, 1989) and, even recent works continue to evaluate this role (GONÇALVES; MATOS; ARAÚJO, 2019; KANG; DALL'ERBA, 2016; SANTOS; MENDES, 2021).

In fact, there is a growing literature on patents dealing with the differences between industrial patents (ADAMS, 2002; KIM; LEE; MARSCHKE, 2005) and patenting of academics and universities (DIAS; PORTO, 2018; GEUNA; NESTA, 2006; LISSONI et al., 2013) and how they changed in number and profile. There even

some studies that consider both patents (COWAN; ZINOVYEVA, 2013). However, the literature did not delve into the different determinants of industrial and university innovation and, above all, they did not seek to assess the specificities of innovation of industry or universities in regions.

In this context, it is expected that there would be an interest in the literature on Regional Innovation in analyzing not only patents as a whole, but in evaluating industrial and university patents separately and how the regional performance of both are affected differently by the innovation ecosystem but, as best as we know, this point was not yet addressed by the literature.

In this sense, the objective of this study is to analyze the different determinants of industrial and university patents in Brazil using an RKPF with a patent panel from 1998 to 2018. This aims to define the role played by the different determinants pointed in the literature such as R&D efforts, urban agglomeration and network connections for the generation of new industrial and university patents. Furthermore, using a single indicator such as total patents implies assessing the overall average effect, which could misdirect public innovation policies. Also, this paper aims to fill the gap in the RKPF literature for developing countries.

This paper is divided into 4 sections besides this introduction. In the first section, we present a literature review on Regional Innovation that adopts the RKPF as an analysis tool, focusing on literature for developing countries. In the second section, we present the model and the empirical strategy adopted. In the third section, we detail the variables used in this version and describe the methodological options for composing the spatial data. Finally, in the fourth section, we present the preliminary results.

Literature Review

In his seminal article, Jaffe (1989) established what became known as Regional Knowledge Production Function (RKPF). The author found that the regional innovation measured by patents was associated with local human capital and Industrial and University R&D. Since this study, there has been great interest in defining the determinants of local innovation.

The studies that followed it were progressively including to the RKPF more regional controls and adopting variables and models of spatial econometrics (ACS; ANSELIN; VARGA, 2002; VARGA, 2000). Among these elements, it is worth highlighting the effects of urban agglomeration (CARLINO; CHATTERJEE; HUNT, 2007; CRESCENZI; RODRIGUEZ-POSE; STORPER, 2012; LOBO; STRUMSKY, 2008), inter regional spillovers (CHARLOT; CRESCENZI; MUSOLESI, 2015; MIGUÉLEZ; MORENO, 2013), path-dependence (FLEMING; KING; JUDA, 2007; GONÇALVES; OLIVEIRA; ALMEIDA, 2020) and co-patent networks (**Miguelez2013b**; DE NONI; GANZAROLI; ORSI, 2017; STRUMSKY; THILL, 2013). These studies focus on developed countries, especially the United States and Europe, with a few on developing countries, generally, concentrated in China (WANG; ZHOU, 2013; YING, 2008), India Crescenzi, Rodriguez-Pose, and Storper (2012) and Russia (CRESCENZI; JAAX, 2017), in addition to Brazil.

At the same time, despite institutional and incentives differences, theres still a great relationship between university and industry regarding innovation and it is very relevant and has been the focus of extensive analysis. These studies analyze formal university-industry cooperation (ANATAN, 2015; PERKMANN et al., 2013; PÓVOA; RAPINI, 2010), informal channels as knowledge spillovers (**Petruzzelli2020**; BARRA; MAIETTA;

ZOTTI, 2019) and indirect relations such as the training of qualified personnel (ZUCKER; DARBY; BREWER, 1998; FLORIDA, 1999).

In addition, the university has increasingly assumed a direct role in innovation, especially in the generation of new patents. This change is associated with legal changes such as the Bayh Dole Act of 1980 in the USA (MOWERY et al., 2001), but also with the change in the view of universities as important players in innovation ecosystems and the increase in the number of Technology Parks or TTOs (ETZKOWITZ; LEYDESDORFF, 2000).

Despite this, the Regional Knowledge Production Function literature has not yet dealt with the heterogeneity of industrial and university patents. To the extent that the literature still does not address this, it is necessary to theoretically substantiate how each different dimension of the innovation ecosystem affects industrial or university innovation.

According to Jaffe (1989) RKPF proposition, Industrial and University R&D are the main input for the generation of patents and this fact is widely attested by the empirical literature. Therefore, industrial and university R&D is expected to have an effect on the number of industrial/university patents in a given location. However the relation between University/Industrial R&D and Industrial/University innovation is not totally straightforward. There are several reasons that University R&D complements industrial innovation such as the relationship between basic and applied research; university-industry collaboration, knowledge spillovers and staff training (PERKMANN et al., 2013; ZUCKER; DARBY; BREWER, 1998). However, with the exception of university-industry collaborations, there is little reason for a complementary relationship between Industrial R&D and more university innovations.

Regarding agglomeration effects on innovation, there are clear benefits for innovation both from the Marshallian and Jacobian externalities for industry (CARLINO; CHATTERJEE; HUNT, 2007; DURANTON; PUGA, 2004; AUTANT-BERNARD; LESAGE, 2011). From the university point of view, it is expected that more agglomerated regions will take advantage of the best conditions to generate, accumulate and disseminate knowledge arising from Marshallian knowledge spillovers and Jacobian learning mechanisms (DURANTON; PUGA, 2004). However, it is also not possible to ignore the possible impact of the historical choices of the location of university activities that are closely associated with public policies (ROSENTHAL; STRANGE, 2004). So, it's necessary to evaluate this possible differences regarding the relationship between agglomeration and industrial and university innovation.

Another fact commonly verified by the empirical literature on regional innovation is path dependence. Its theoretical foundation is that there will be cumulative knowledge and skills from previous efforts in the local as pointed by Duranton and Puga (2004) and it is valid for both industrial and university innovation. However, its magnitude could be different.

Concerning the inter-regional dynamics for innovation, there is theoretical motivation for the occurrence of spillovers in both cases, but it is not clear whether the same inter-regional effect will occur and if they differ in intensity as found by Autant-Bernard and Lesage (2011) for the Marshallian and Jacobian spillovers.

Finally, networks of co-inventors are very relevant for the diffusion of knowledge and are fundamental elements for the cohesion of local innovation (STRUMSKY; THILL, 2013). Furthermore, Ejermo and Karlsson (2006) point out that invention networks are closely linked to university and private R&D structures in the region

and inter-regional collaborative networks create the conditions to overcome local limitations and allow more and better innovations, being especially relevant in complex knowledge. In this sense, inter-regional network connections of co-inventors allow more innovation in any environment (industrial or university). However, the incentives and norms of industrial and university environments imply different patterns of collaboration that will have effects on the role of networks as sources of generation of new knowledge. In particular, under the Merton (1973) paradigm, universities are expected to be more open to collaboration than industry.

In a sense, there are multiple theoretical motivations to assess how the regional innovation ecosystem affect differently industrial and university innovations. We seek to reassess these determinants using a RKPF model for Brazil with a longer and more recent panel (1998 − 2018). We estimate a model for industrial and university patents in order to explore differences in the impact of local R&D, agglomeration, network, path dependence and inter-regional spillovers. Furthermore, given the technological disparities in Brazil, we explored the heterogeneity in the North and South portions. Finally, we ensured the robustness of our results by estimating models with specific cuts such as utility models (YING, 2008), international patents (RODRÍGUEZ-POSE; WILKIE, 2019; YING, 2008) and co-inventors patents (HIGHAM; RASSENFOSSE; JAFFE, 2021).

Descriptive Analysis: Brazilian Background

Patenting activity has been growing in Brazil, not only in terms of the number of patents, but also in their quality and in the density of inventor networks. The annual number of patents filed by Brazilian inventors grew 118% between 1998 and 2018. At the same time, the patenting activity that was previously concentrated in the two larger metropolitan areas (São Paulo and Rio de Janeiro) went through a process of geographic deconcentration with the emergence of new medium-sized regions with relevant innovative activity.

University patents growth and became 30% of patents in Brazil in 2018 and it is a rich source of heterogeneity, specially account for its complementary technological profile to industrial innovation (LISSONI, 2012). There are also evidence that the quality of innovation in Brazil is increasing. As argued by Higham, Rassenfosse, and Jaffe (2021), international patents (PCT) can be considered as a proxy for higher level patents. Therefore, the continuous increase in PCT patents in Brazil – from 29 in 1998 to 151 in 2018, cf. Figure 1a – shows a significant expansion of qualified innovation in the country. In addition, it appears that innovations in the country also started to be more developed in collaborative environments, since the average number of inventors increased from 1.6 to 4.3 between 1998 and 2018.

Besides the growth of the patenting activity, it is interesting to note the geographic distribution in Figure 2 below. It indicates a strong concentration in the South-Southeast region of patents *per capita*. This technological inequality is well known, and it helps to illustrate the spatial dynamics of innovation and reinforces the need to deal with macro-regional spatial heterogeneity.

As seen in Figure 1a, there was an increase in the relevance of university in patenting. In 1998, these patents accounted for 3.4% of all patents filed in Brazil, which is very low by international standards (DE MORAES SILVA; FURTADO; VONORTAS, 2018). In 2018, this share rose to 30.1%, closer to countries with more developed university systems and in line with the increase in expenditure on training graduate students and on R&D at universities. Since the university system is better spatially distributed than the manufacturing activity,

(a) Share of university patents vs. share of patents in
North-Northeast region

(b) Average number of inventors vs. international patents
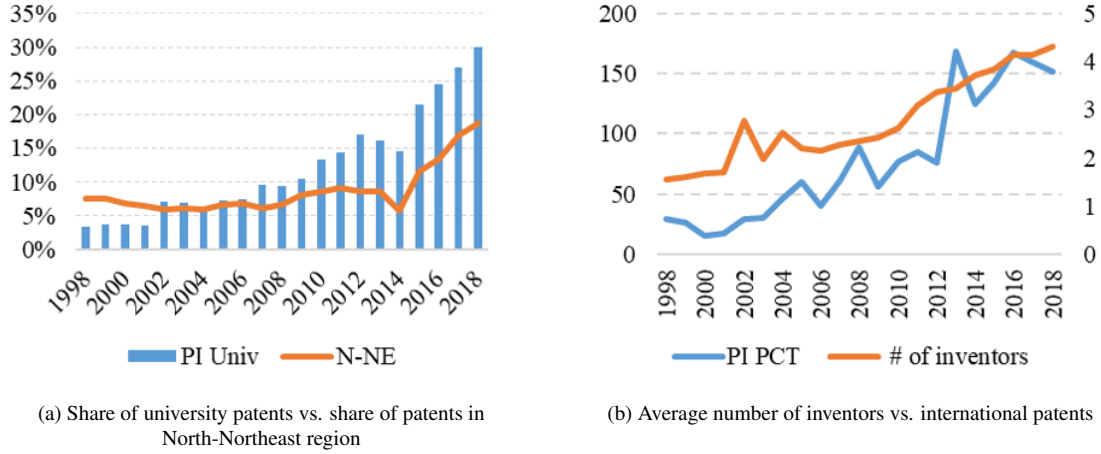
Figure 1: Growth in patenting activity (1998-2018)
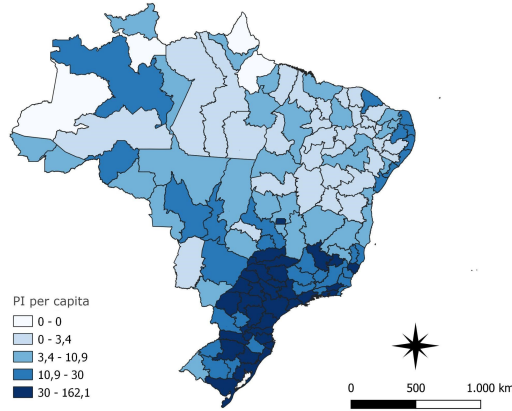Source: Own elaboration

Figure 2: Patents per 100,000 inhabit. by intermediate region (1998-2018)
Source: Own elaboration

this process seems to be associated with a change in the geography of patenting in Brazil. North-Northeast regions
that had a 7.5% share of patents filed in 1998 reached a share of 18.7% in 2018.

Model

According to the Literature, considering the inter-regional knowledge, heterogeneity is fundamental to
assess the regional innovation spatial dynamics. So, we estimate an RKPF using patents per capita as our de-
pendent variable and regional innovation effort and socioeconomic context as our independent variables. The
panel has 133 intermediate regions, and the periods are aggregated into moving average triennials. We estimate
an RKPF using the following Spatial Durbin Model in order to determine short-term and long-term direct effects,
and short-term and long-term indirect (spatial spillover) effects (ELHORST, 2014):

$$I_{r,t} = \tau I_{r,t-1} + \delta W I_{r,t} + \eta W I_{r,t-1} + \beta_1 X_{r,t-1} + \beta_2 W X_{r,t-1} + u_t$$

Where $I_{r,t}$ is the number of patents per capita in each region r, in period t. The $I_{r,t-1}$ is used to capture the

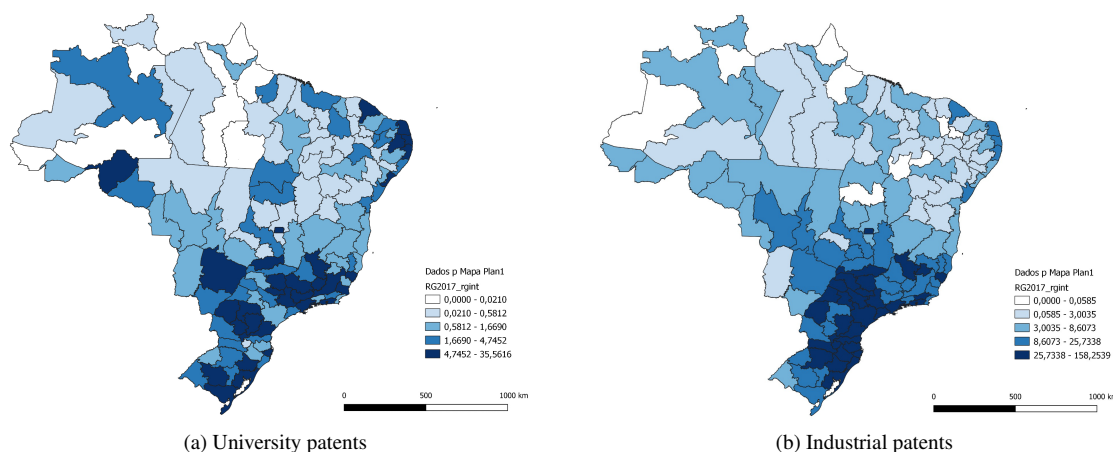(a) University patents   (b) Industrial patents

Figure 3: University and Industrial patents per 100,000 inhabit. by intermediate region (1998-2018)
Source: Own elaboration

path-dependence effects The $X_{r,t-1}$ vector indicates the local innovative effort, the socioeconomic and industrial characteristics and co-patent networks, in addition to controls. In this case, W is a normalized inverse distance spatial weight matrix with a 500 kilometers cutoff, which was selected by minimizing Akaike Information Criteria and Wald test (Appendix A1) following Zhang and Yu (2018). While u_t represents the random error. We also use an alternative formulation of the estimator which the panel effects follow the same spatial process as the errors (KAPOOR; KELEJIAN; PRUCHA, 2007).

Dependent variable: Patent per capita

We generate patent data per capita from the count of patents applied in Brazil. Patent application and granting data are aggregated in a database for statistical purposes by the National Patent Office (INPI - Statistical Database on Intellectual Property – BADEPI). It is created from administrative records on intellectual property that include the nature of the deposit (patents or utility model), data on the depositor, the inventor, adherence to the PCT system and technological field. For the present work, fractional patent counts were generated from the inventor's data, after a process of geolocation and fractional attribution to the patent co-inventors' network. The number of geolocalized patents along the period is $71,177$, which represents about 79% of the dataset. Patents have long been considered the best, though not perfect, output for innovation activity at the regional level possessing the advantage of being immediately available, measurable and comparable, both over time and across space (ASCANI et al., 2020; KANG; DALL'ERBA, 2016; MIGUELEZ; MORENO, 2018). In order to measure the differences between industry and university we split patents into two groups: those that are produced with university participation (or academic patents), and the rest (industrial patents).

Regional R&D efforts

There are no regional variables for the expenditure of R&D activities in Brazil, so we measure local R&D efforts using proxies for Industrial and University R&D, Industry R&D and University R&D, respectively. Industry R&D is calculated using 'technical and scientific personnel' (PoTec) in the region*. University R&D is

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*Our proxy for Industrial R&D (POTEC: technological employment) comes from the formal registers of employees so it does not include informal workers. Since the share of informality in this kind of occupations is very low (only 1.7% in PNAD-Continua sample for 2012 to

composed of the number of graduate students in STEM careers in the region divided by total population, since these researchers are more linked to research efforts associated with innovation (ARAUJO; CAVALCANTE; ALVEZ, 2009; GONÇALVES; OLIVEIRA; ALMEIDA, 2020; KANG; DALL'ERBA, 2016).

Industrial and socioeconomic context

To capture the socioeconomic and industrial context of the region we used human capital, agglomeration variables and industrial structure. For Human Capital (HK) we use the proportion of workers with a higher education degree in manufacturing. DensPop is the population data divided by the total area of the region and DensPop^2 is its quadratic term. HHI is the Hirschman–Herfindahl index that measures the sectorial diversification for the region (CHARLOT; CRESCENZI; MUSOLESI, 2015; GONÇALVES; OLIVEIRA; ALMEIDA, 2020; WANG; ZHOU, 2013)

Co-patent Networks

Finally, we use Closeness that is calculated by the centrality level of the inventor in the co-patenting network and Betweenness which accounts for the position of the inventor in the whole network as a broker. Broker inventors bridge otherwise unconnected parts of the network and can thus foster knowledge sharing (TÓTH; LENGYEL, 2021). For that purpose, following Ter Wal (2013), we generate data using a five-year moving window procedure. This implies that a network of a particular year contains all co-inventorship linkages of that year and the preceding four years. The assumption is that social links between inventors persist over time (AGRAWAL; COCKBURN; MCHALE, 2006). We also used only industrial or university patents for generating these co-inventors networks

These variables are summarized in tables below (Table 1 and 2).

Table 1: Variables description

Variable	Description	Source
$PI_{r,t-1}$	Number of fractional patents per 100,000 inhabitants of the region in log form	BADEPI
Industry R&D$_{r,t-1}$	Number of 'technical and scientific personnel' (PoTec) of the region in log form	RAIS
University R&D$_{r,t-1}$	Number of graduate scholarships in STEM per 100,000 inhabitants of the region in log form	CAPES
HK$_{r,t-1}$	Share of higher education personnel for the region employment	RAIS
DensPop$_{r,t-1}$	Population density for the region	IBGE
HHI$_{r,t-1}$	Hirschman–Herfindahl index for the region employment in manufacturing	RAIS
Closeness$_{r,t-1}$	Centrality level of the region in the co-patenting network	BADEPI
Betweenness$_{r,t-1}$	Position of the region in the whole network as a broker	BADEPI
Dummies UF	Dummies for Federal States	IBGE

Source: Own elaboration

2018), it does not impact our proxy.

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
$I_{r,t-1}$	2,527	0.522	0.528	0	2.330
Industry R&D$_{r,t-1}$	2,128	1.166	1.212	0	6.076
University R&D$_{r,t-1}$	2,128	1.336	1.691	0	6.114
DensPop$_{r,t-1}$	2,128	70.461	194.167	0.310	2009.103
HHI$_{r,t-1}$	2,128	0.250	0.151	0.063	0.971
Closeness$_{r,t-1}$	2,128	0.272	0.230	0	1
Betweenness$_{r,t-1}$	2,128	0.010	0.030	0	0.373

Source: Own elaboration

In addition, it is important to highlight other methodological aspects relating to the territorial division adopted. For the study of regional innovation, the use of geographic units designed from a hierarchical-functional structure is particularly suitable. In its 2017 version, REGIC is divided into two main levels: 510 immediate regions and 133 intermediate regions. The immediate level corresponds to the delineation of urban centers by means of daily population flows for their immediate needs (labor, public and private services, etc.). The intermediate level groups some immediate regions into a pole of higher hierarchy differentiated from private and public management flows and the existence of more complex urban functions (IBGE, 2017). In this work, we chose intermediate regions that present sufficient granularity to assess regional innovation that allows comparison with studies for other countries.

Results

Table 3 presents the result of the estimation with data covering the years 1998 to 2018 for the 133 intermediate Brazilian regions.

Table 3: Regression results. Patent per capita as dependent variable

Variables	(1) Total patents		(2) Industrial patents		(3) University patents	
		W		W		W
$I_{r,t-1}$	0.222***	0.117*	0.169***	0.0575	0.786***	-0.184
	(0.027)	(0.064)	(0.025)	(0.061)	(0.029)	(0.120)
Industry R&D$_{r,t-1}$	0.091***	-0.161***	0.068***	-0.100**	-0.001	-0.001
	(0.014)	(0.048)	(0.015)	(0.046)	(0.005)	(0.022)
University R&D$_{r,t-1}$	0.038***	0.038	-0.0002	0.006	0.031***	0.009
	(0.006)	(0.0309)	(0.005)	(0.025)	(0.003)	(0.016)
Population density$_{r,t-1}$	0.001**	0.003***	0.001***	0.003***	-0.0001	0.001
	(0.0002)	(0.001)	(0.0002)	(0.001)	(8.47e-05)	(0.0003)
Population density$^2_{r,t-1}$	-4.29e-07***	-2.00e-06***	-5.38e-07***	-1.86e-06***	-5.44e-09	-4.29e-07*

	(1.26e-07)	(6.18e-07)	(1.21e-07)	(5.77e-07)	(4.34e-08)	(2.26e-07)
$HHI_{r,t-1}$	-0.036	0.279	-0.074	0.144	0.009	-0.232**
	(0.052)	(0.258)	(0.048)	(0.248)	(0.025)	(0.101)
$Closeness_{r,t-1}$	-0.017	-0.195*	-0.005	0.063	0.001	-0.066
	(0.028)	(0.117)	(0.024)	(0.125)	(0.017)	(0.066)
$Betwenness_{r,t-1}$	0.976***	1.010	0.508*	-2.063	0.705***	0.259
	(0.278)	(1.260)	(0.277)	(1.296)	(0.129)	(0.555)
$I_{r,t}$		0.362***		0.373***		0.359***
		(0.048)		(0.049)		(0.048)
N		2,128		2,128		2,128
n		133		133		133
T		16		16		16
State FE		Yes		Yes		Yes
Time FE		Yes		Yes		Yes
AIC		-2136.80		-2567.46		-3929.93
Pseudo R2		0.8983		0.8819		0.7919

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Own elaboration

In terms of differences, the coefficients of the R&D variables have statistical significance only for the respective type of patents. In other words, local Industrial R&D explains only industrial patents and local University R&D only explains university patents. The result for industrial patents is noteworthy because there is no evidence of spillover from university research to innovation in industry. This can be related to a separation between the scientific and technological efforts of academia and industries in Brazilian regions.

For industrial patents, the variables DensPop and DensPop^2 have statistically significant, positive and negative coefficients, respectively. Corroborating the expectation of agglomerative advantages in industry innovation for other countries and for Brazil (GONÇALVES; OLIVEIRA; ALMEIDA, 2020). This agglomeration result does not occur for university patents. Furthermore, even though the presence of more qualified workers in the industry should not imply more university patents. This may be evidence of the separation between Academia and industry, and it is important to bear in mind that, in Brazil, as in other countries, the main university research centers are public and their location does not result from typical agglomeration sources, but they are the result of industrial and technological policy.

The existence of technological path-dependence of regions, importance of network connections and the occurrence of spatial heterogeneity, measured by the coefficient of the error term.

Variables	(1) Total patents	(2) Industrial patents	(3) University patents
$I_{r,t-1}$	0.428*** (0.066)	0.296*** (0.064)	0.887*** (0.120)
Industry R&D$_{r,t-1}$	-0.042 (0.053)	-0.011 (0.051)	-0.002 (0.024)
University R&D$_{r,t-1}$	0.091*** (0.033)	0.006 (0.027)	0.052*** (0.017)
Population density$_{r,t-1}$	0.004*** (0.001)	0.004*** (0.001)	0.0004 (0.0004)
Population density$^2_{r,t-1}$	-2.66e-06*** (6,81e-07)	-2.71e-06*** (6.42e-07)	-4.51e-07* (2.52e-07)
HHI$_{r,t-1}$	0.240 (0.285)	0.049 (0.273)	-0.227* (0.117)
Closeness$_{r,t-1}$	-0.225* (0.128)	-0.060* (0.133)	-0.067 (0.072)
Betwenness$_{r,t-1}$	2.390*** (1.373)	-1.466 (1.462)	1.234** (0.600)

Source: Own elaboration

As pointed out by Araujo and Garcia (2019) and Santos and Mendes (2021), there is a great industrial and technological disparity between the North and South regions of Brazil, with innovative and manufacturing activities being much more concentrated in the southern portion, from an industrial rather than a university point of view, in part due to public efforts to provide different regions of the country with centers of excellence in research. In this sense, we chose to estimate a regression multiplying our variables with a dummy for N-NE regions, and another for the North and Northeast regions (model 4).

Table 5: Total effects results for main model and dummy for N-NE regions

Variables	(1) Total patents	(4)	Dummy N-NE
$I_{r,t-1}$	0.428*** (0.066)	0.414*** (0.076)	-0.202 (0.345)
Industry R&D$_{r,t-1}$	-0.042 (0.053)	-0.053 (0.066)	-0.168 (0.156)
University R&D$_{r,t-1}$	0.091*** (0.033)	0.083** (0.036)	-0.037 (0.089)
Population density$_{r,t-1}$	0.004*** (0.001)	0.004** (0.001)	-0.015*** (0.004)
Population density$^2_{r,t-1}$	-2.66e-06*** (6,81e-07)	-2.94e-06*** (7.39e-07)	-0.00004*** (0.0001)
HHI$_{r,t-1}$	0.240 (0.285)	0.140 (0.391)	1.169** (0.472)
Closeness$_{r,t-1}$	-0.225* (0.128)	-0.282 (0.181)	-0.057 (0.246)
Betwenness$_{r,t-1}$	2.390*** (1.373)	1.503 (1.537)	6.394 (4.867)

Source: Own elaboration

First, the Industry R&D effect is smaller in N-NE, which points to greater innovative industrial efficiency in South of the country.The results for the university research show that its effect is greater for the North. This may be linked to the spatial dispersion of universities and their greater relevance for innovation in this part of the

country, as illustrated in Figure 3a.

In addition, the variable that measures the technological path-dependence is smaller in N-NE regions, which points to a lower historical dependence in the Northern part, in line with the fact that technology centers were established more recently in this part of the country.

Finally, the coefficient of the Betweenness variable is bigger in N-NE, which demonstrates that networks are very important for this region, especially considering that the South can count on the greatest endowment of factors to generate innovation locally, without relying on external connections. Spatial error terms are also significant, reinforcing the presence of spatial heterogeneity.

Conclusions

A set of studies in the economic geography literature examines the determinants of regional innovation. However, there is still a limited understanding the heterogeneities of university and industrial patents and regional regimes. Based on this gap, our main contribution is to present new empirical evidence for how university and industrial R&D effects of knowledge spillovers on regional innovation. In this way, our findings show that local Industrial R&D explains only industrial patents and local University R&D only explains university patents.

In addition, the Industry R&D coefficient is positive and significant for both regressions of regional heterogeneities. The university research effect is only positive for the North-Northeast, which may be related to the spatial dispersion of universities and their greater relevance for innovation in this part of the country. The presented results are highly relevant to other developing countries that, similar to Brazil, have regional spatial heterogeneity regarding to the distribution of the patenting activity and local endowment of R&D.

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Appendix

Table A1: Inverse of distance weight matrix results

	(5)	(6)	(4)	(7)
	SEM	SAR	SDM	SDEM
$PI_{r,t-1}$	0.246***	0.238***	0.222***	0.221***
	(0.0271)	(0.0255)	(0.0270)	(0.0272)
Industry R&D$_{r,t-1}$	0.0908***	0.0604***	0.0905***	0.0912***
	(0.0139)	(0.0130)	(0.0144)	(0.0147)
University R&D$_{r,t-1}$	0.0342***	0.0353***	0.0375***	0.0379***
	(0.00573)	(0.00567)	(0.00576)	(0.00589)
DensPop$_{r,t-1}$	0.000400	0.000682***	0.000613**	0.000613**
	(0.000255)	(0.000248)	(0.000253)	(0.000259)
DensPop$^2_{r,t-1}$	-3.07e-07**	-4.36e-07***	-4.29e-07***	-4.48e-07***
	(1.26e-07)	(1.23e-07)	(1.26e-07)	(1.29e-07)
HHI$_{r,t-1}$	-0.0680	-0.0842*	-0.0355	-0.0496
	(0.0513)	(0.0499)	(0.0518)	(0.0529)
Closeness$_{r,t-1}$	-0.00725	0.00660	-0.0167	-0.0169
	(0.0280)	(0.0276)	(0.0278)	(0.0281)
Betweenness$_{r,t-1}$	0.902***	0.977***	0.976***	1.050***
	(0.277)	(0.276)	(0.278)	(0.283)
W PI$_{r,t-1}$			0.117*	0.245***
			(0.0637)	(0.0782)
W Industry R&D$_{r,t-1}$			-0.161***	-0.101
			(0.0480)	(0.0629)
W University R&D$_{r,t-1}$			0.0380	0.0672*
			(0.0309)	(0.0364)
W DensPop$_{r,t-1}$			0.00283***	0.00306***
			(0.000989)	(0.00118)
W DensPop$^2_{r,t-1}$			-2.00e-06***	-2.41e-06***
			(6.18e-07)	(7.05e-07)
W HHI$_{r,t-1}$			0.279	0.222
			(0.258)	(0.297)
W Closeness$_{r,t-1}$			-0.195*	-0.176
			(0.117)	(0.144)
W Betweenness$_{r,t-1}$			1.010	2.459
			(1.260)	(1.575)
W u$_t$	0.477***		0.381***	
	(0.0552)			(0.0675)
W PI$_{r,t}$		0.367***	0.362***	

		(0.0384)	(0.0478)	
N	2,128	2,128	2,128	v
n	133	133	133	133
T	16	16	16	16
State FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
AIC	-2080.46	-2107.69	-2136.80	-2111.26

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Own elaboration