Foreign Direct Investment Spillovers and the Geography of Innovation in Brazilian Regions

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Abstract

Literature has showed that inward Foreign Direct Investment (FDI) can generate important knowledge spillovers on the local economies, fostering regional innovation. In this way, we aim to analyze the main effects of the inward FDI in the innovative performance of Brazilian regions. We use data from investments by Multinational Companies (MNC) in Brazil for the period 2003 to 2014, distributed by regions, and we correlate them to the innovative performance of Brazilian regions, measured by patents. Our results shows that inward FDI positively affect innovation ate regional level, since Brazilian regions that received inward FDI presented better innovative performance. In addition, the positive effects of the inward FDI on local innovation is reinforced by the diversification of the local productive structure. In this way, diversified regions that receive inward FDI are able to better leverage the benefits of local spillovers from the inward FDI.

Keywords: Foreign Direct Investment (FDI); Knowledge spillovers; Regional innovation; Diversification

JEL: O33; F21; O19; R11; R12

Resumo

A literatura tem mostrado que o ingresso de Investimento Direto Externo (IED) pode gerar importantes spillovers de conhecimento nas economias locais, fomentando a inovação regional. Dessa forma, o objetivo deste artigo é analisar os principais efeitos da entrada de IED no desempenho inovador das regiões brasileiras. Para isso, nós utilizamos dados de investimentos de Empresas Multinacionais (EMN) no Brasil para o período de 2003 a 2014, distribuídos por regiões, e os correlacionamos ao desempenho inovador das

regiões brasileiras, medido por patentes. Nossos resultados mostram que o IED afetou positivamente a inovação em nível regional, uma vez que as regiões brasileiras que receberam IED apresentaram melhor desempenho inovador. Além disso, os efeitos positivos do IED sobre a inovação local são reforçados pela diversificação da estrutura produtiva local. Dessa forma, as regiões diversificadas que recebem o IED interno são capazes de aproveitar melhor os benefícios das repercussões locais do IED.

Palavras-chave: Investimento Direto Externo (IED); Spillovers de conhecimentos; Inovação regional; Diversificação

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1. Introduction

In the last decades, the world has seen a rapid change in the innovation landscape. Some emerging countries have displayed rapid catch-up trajectories, with the incorporation of new and important capabilities (Lee & Malerba, 2017). However, most developing countries, and their regions, continue to suffer from the lack of domestic technological capabilities and rely mainly on technology transferred from advanced countries (Fagerberg et al., 2010) (Fagerberg et al, 2010). Main learning channels traditionally available to domestic firms in emergent countries include technology licensing, reverse engineering, labor mobility, exchange of information and knowledge with suppliers and buyers, learning from trade exchange, and spillovers from Foreign Direct Investment (FDI) (Amendolagine et al., 2019).

As for the sources of knowledge creation, literature has focused on discussing the role of the Foreign Direct Investment, as an engine of regional growth and technological catch-up and innovation. Knowledge spillover effects have been studied both at the firm and regional levels, besides studies at the national level. Literature in this line of research also pointed out the conditions that enable major knowledge spillovers from FDI in the recipient regions (Crescenzi & Iammarino, 2017; Wang et al., 2016). For example, studies on the absorption capacity of host regions show that it can be a determining factor that affects the magnitude and importance of FDI spillovers. Also, other factors such as an effective link between foreign and domestic companies upstream or downstream of the value chain, and the local stock of local human capital and mobility are important as drivers of the effect of the inward FDI on innovation.

Based on these assumptions, we aim to analyze the main effects of the inward FDI in the innovative performance of Brazilian regions. We also consider the role of local factors such as the role of the industrial structure (specialization and diversification) and qualified human capital. We use data from the the fDi Markets-Financial Times database for the period 2003 to 2014, which comprises all announced investments by Multinational Companies (MNC) in Brazil during the period.

The contribution of this paper is twofold. First, we present is the presentation of a great picture of the FDI in Brazilian regions, showing the regions that received greater investments and the profile of these investments, in terms of the volume of resources and the sectoral industry. Second, we related the FDI investments in Brazilian regions with the innovative performance of the regions, controlling the characteristics of the regions, regarding their industrial structure and their main technological and scientific capabilities. Based on this association, we can present new empirical evidence on the role of the inward FDI in providing innovative spillovers to the Brazilian regions. Our results show that Brazilian regions that received inward FDI present better innovative performance, which allows us to conclude that FDI represents important flows of new knowledge to local agents.

The paper is structured as follows. The next section presents the main conceptual background regarding the relation between inward FDI and innovative performance of regions. The third section provides a brief description of the data and the main

methodological issues, including our measures for inward FDI. The fourth section presents the exploratory analysis and some descriptive results from the regional distribution of inward FDI in Brazilian regions. in this section we also present the overall results and discusses the main findings regarding the effect of the inward FDI on innovation in Brazilian regions. The final section presents final remarks, limitations, and policy implications.

2. Literature Review – Inward FDI and Regional Innovation

There is a wide recognition in the literature that inward FDI has positive effects on the technological and organizational knowledge of host countries (Amendolagine et al., 2019; Reddy, 2011). This knowledge is embedded as tacit or codified knowledge in technology products or processes of foreign firms, and it represents new knowledge to the host country or region. In this sense, inward FDI is an important external knowledge source that can contribute to regional innovation by generating FDI technological spillovers to local firms. FDI spillovers can take form through imitation of foreign firms' products and technologies; through labor market mobility of skilled workers; through 'demonstration effects' in which new products and technologies developed in other markets are carried out by local producers; even through the simply copy strategies of local firms at the host regions (Fu, 2008; Wang et al., 2016). Therefore, there are several types of linkages and interactions between foreign companies and local firms that can generate local knowledge spillovers, and improve regional knowledge and capabilities environment.

In world landscape, we can observe a huge growth of the FDI worldwide in the last three decades. FDI stocks as a percentage of world's gross domestic product went from around 10% in 1990 to around 35% in 2016. Estimates indicate that Multinational Companies were more than 100,000 in 2012, and that the number of their affiliates was close to 1 million. We can also observe a strong growth of small and medium enterprises, either born-global, or growing as MNC (all data are from UNCTAD presented by Iammarino, 2018). There were also a widening of the geography of world FDI recipients and investors, since the share of developing countries on global FDI flows has gone steadily up, in 2014 accounting for more than a half (55%) of world total inflows (though down to 41% in 2016), and around 40% of total outflows (down to under 30% in 2016) (Iammarino, 2018). In the literature, we can observe a growing concern on how the increase of FDI can affect innovative performance of regional economies (Crescenzi & Iammarino, 2017; Iammarino, 2018; Völlmecke et al., 2016; Wang et al., 2016). There is a recognition that regional economic and local innovation trajectories do not depend exclusively on local knowledge assets, but in the capacity of local agents to combine local capabilities to external sources of knowledge (Crescenzi & Iammarino, 2017; Hassink, 2005). In this sense, the evolutionary trajectory of a region is increasingly dependent on its capacity to search and absorb external knowledge, which circulates in the global circuits of production and generation of knowledge.

The international circuit of generation of knowledge has a strong participation of MNC, as major "flagships" in Global Production Networks (Ernst & Kim, 2002). The presence of MNC in the Global Production Networks takes place in different forms, such as vertical disintegration, international outsourcing, and offshoring. These modes have emerged as predominant types of control and coordination of MNC's activities, giving rise to what has been called the 'concentrated dispersion' of geographical production networks.

Moreover, Global Production Networks have increasingly integrated more functions such as engineering, product development, design and research within inter-firm networks situated worldwide, forming what is labelled as Global Innovation Networks – GIN (Crescenzi & Iammarino, 2017; Ernst, 2010). Global Networks of Innovation are not spatially bounded, and linkages are stablished by overseas, with strong participation of Multinational Companies.

Global Innovation Networks brought about important changes in the regional connectivity and interdependence around the world (Crescenzi & Iammarino, 2017; Miguelez et al., 2019). MNC networks significantly affected regions, contributing to the uneven development of capabilities of regions in different parts of the world. In fact, the inward FDI into a region can represent an important source of new knowledge for local producers, influencing the innovative capabilities of firms and other actors from the Regional Innovation System. In fact, inward FDI can play the role of a global technological "gatekeeper", since MNC can be active players in the search for new sources of knowledge. New knowledge is internalized in the local system, through interactions with local capabilities, and disseminated among local actors.

In this way, inward FDI can affect the regional economic development trajectories, which could to be analyzed in terms of the degree of local connectivity through global investment flows (Crescenzi & Iammarino, 2017). Regional connectivity means that new knowledge from the inward FDI does not run in a "territorial vacuum". Inward FDI operate as a part of a set of geographical, economic, and socio-institutional local characteristics that shape regional innovation. We can highlight two of these main characteristics of the region. The first is geographical diffusion of knowledge spillovers and the region's industrial specialization. The second is the set of local capabilities and supportive socio-institutional environments, which can be able to absorb the new knowledge from the inward FDI, and transform it into new combinations of knowledge. The interaction between inward FDI and local actors determines the evolutionary trajectories of regions by: (1) shaping the capability of local actors to establish relations based on both spatial and non-spatial forms of interaction and defining the connectivity of each region and its position in global networks; and (2) influencing how global knowledge and resources made available by regional connectivity are translated and put into productive use in the regional economy, as well as how local resources and results of local innovative efforts are 'channeled' into global markets (Crescenzi, 2014)

Despite the growing literature on inward FDI knowledge spillovers, most empirical studies have focused on the effects of inward FDI on productivity growth, as a result of FDI-led technology transfer (Crespo & Fontoura, 2007; Moralles & Moreno, 2020; Wang et al., 2016). In general, previous literature found and produced mixed results, which suggests that FDI spillovers are conditional on some factors. Regarding to investments in new technologies, there are some aspects that affect the capacity of technological investments to significantly impact the performance of local producers, by increasing local productivity, transferring technology or increasing capabilities. Among these factors, we can point out the nature of the investment and also the receptivity of the region in relation to the innovation capabilities, the technological gap and the knowledge structure of the innovators in the host region (Crespo & Fontoura, 2007; Wang et al., 2016; Wang & Zhou, 2013). Whether FDI has positive or negative effects on local innovation and economic performance depends on exogenous and endogenous aspects, not only the amount of FDI itself. Previous studies on China show that the absorptive capacity of local agents and the presence of complementary assets in the regional

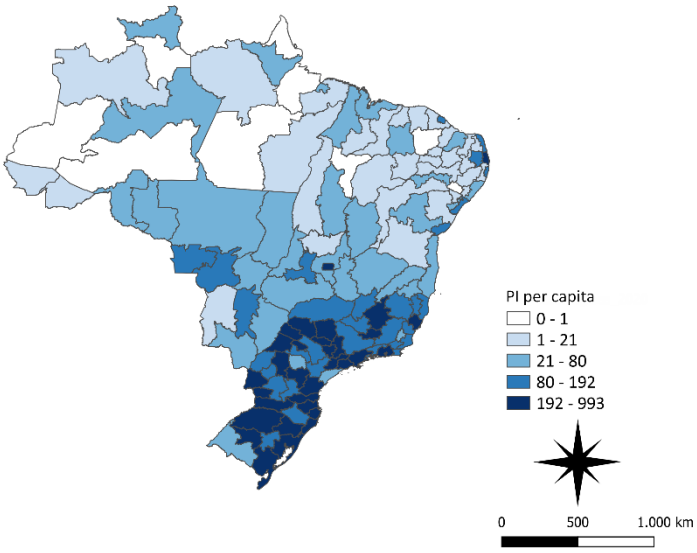
innovation system are factors that affect the ability of local agents to fully appropriate the benefits from the inward FDI.

3. Data and methodology

3.1 The assembly of the database

We use two main datasets to assembly our data. The first dataset is about patents from the Brazilian Intellectual Property Office (BADEPI/INPI, in Portuguese acronym), and comprises patent applications from the period of 2006 to 2017. To the data on patents, we attribute patent geolocation in a fractional count of inventors' addresses. The second dataset is the fDi Markets-Financial Times database for the period 2003 to 2014, which comprises all announced investments by Multinational Companies (MNC) in Brazil. We divided the whole period in three years periods to avoid sporadic effects. We aggregate the data are aggregated on the 137 Brazilian mesoregions, which is equivalent to European NUTS-2. The geographical distribution patents in Brazil is showed in Figure 1.

Map 1 – Patents per 1 million inhab. by meso-region (2006-2017)

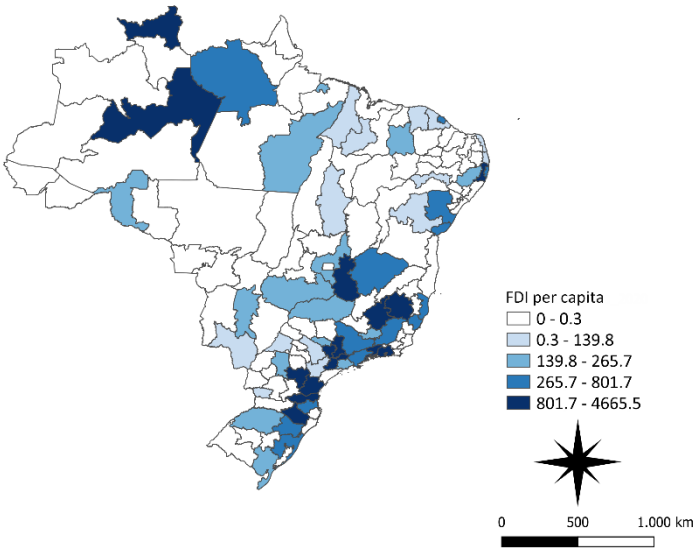


Source: own elaboration based on BADEPI/INPI data.

The distribution of patents per capita in Brazilian regions is concentrated in Southern part of Brazil. On the other regions, patents are concentrated in the bigger cities, mainly in the state capitals. Geographical concentration of innovation is not only common but it's also a well-known stylized fact for Brazil (Araújo & Garcia, 2019; Gonçalves et al., 2019; Montenegro et al., 2011).

During this period, inward FDI in Brazil grow from around 63 billion USD in 2003-2005 to 74 billion USD in 2012-2014, reaching a maximum in 2009-2011 with 120 billion USD. In this period, Brazilian economy faces years of great growth which attracted strong FDI, even after the international crisis (Figure 2).

Figure 2 – FDI (USD million) per 1 million inhab. by meso-region (2003-2014)



Source: own elaboration based on fDi Markets-Financial Times database.

Even with strong inward FDI, we can also see a great regional concentration, since only 59 or 137 meso-regions received FDI inflows. Inward FDI was concentrated in South-Southeast Brazilian regions and, in general, close to the major cities, which reveals a strong market oriented inward FDI. In addition, even among regions that received inward FDI, the amount of capital varies a lot. Average inward FDI among regions are 1.37 billion USD, in the period analyzed (2003-2014), but only 16 regions are above this level. To illustrate the concentration, we list the top 10 meso-regions FDI inflows (Table 1).

Table 1 – Top 10 meso-regions on inward FDI (USD million) – Brazil, 2003-2014

	Meso-region	FDI (MM USD)
1	Rio de Janeiro Metro Region	19.651
2	Belo Horizonte Metro Region	6.914
3	South Rio de Janeiro State	4.910
4	Curitiba Metro Region	4.598
5	Macro Sao Paulo – Sorocaba and Jundiai	4.318
6	Manaus	4.274
7	Sao Paulo Metro Region	4.017
8	Campinas Metro Region	3.464
9	Litoral Pernambuco	2.815
10	Piracicaba Region	2.208

Source: fDi Markets-Financial Times database.

The case of Rio de Janeiro, for example, the inward FDI are mainly related to Oil, Energy and Chemical complex located in the Petrobras Science Park. Petrobras is the Brazilian Oil & Gas State Owned Enterprise (SOE) and is the firm that holds the largest number of patents in Brazil. In addition, the sectoral distribution of the inward FDI reveals that there

is not a huge concentration in a specific sector. The main sectors are ICT and Electronics and Transport Equipment, sectors that have a strong participation of MNC in Brazil (Table 2).

Table 2 – Sectoral distribution of inward FDI (USD million) – Brazil, 2003-2014

Industries Cluster	**FDI** (MM USD)
ICT & Electronics	58.311
Transport Equipment	55.639
Physical Sciences	41.256
Financial Services	33.220
Industrial	29.872
Environmental Technology	22.936
Energy	19.219
Food, Beverages & Tobacco	18.913
Construction	8.919
Wood, Apparel & Related Products	8.022
Transportation, Warehousing & Storage	6.259
Consumer Goods	4.917
Tourism	4.279
Life sciences	3.664
Professional Services	1.454
Other	885

Source: fDi Markets-Financial Times database.

3.2 Empirical Strategy

Our dependent variable is the fractional patent counts per 1 million inhabitants in the meso-region ($PI_{r,t}$). The use of patent data as a proxy on innovation output is traditional on innovation studies literature (Araújo & Garcia, 2019; Corsatea & Jayet, 2014; Gonçalves et al., 2019; Kang & Dall'erba, 2016; Mascarini et al., 2020; Miguelez & Moreno, 2018; Paci et al., 2014). We included temporal-lagged patents per capita region ($PI_{r,t-1}$) in all models, since regional innovation tends to be stable over time presenting a temporal dynamic.

The main variable of interest is the regional inward FDI. In this way, we aim to examine how the inward FDI affect the regional innovation in Brasil. In addition to FDI of each meso-region, we selected some independent variables associated with the local innovation ecosystem such as Industrial R&D, University R&D, Local Industrial Diversification (HHI) and regional dummies. As usual in empirical models that aims to examine innovation, we use the independent variables with a one time period lag, since the innovative efforts demands some years until the final patent is filled. Hence, we have a 4-time period panel with 548 observations. Table 3 presents the description of the variables and Table 4 the descriptive statistics.

Table 3- Description of the variables

	Description	Source
PI	Fractional patents count per 1 million inhab. In the meso-region	BADEPI and IBGE
FDI	Announced FDI per 1 million inhab. In the meso-region	fDI Markets
RDI	Number of R&D researchers per 100 workers in the meso-region	RAIS
RDU	Number of graduate scholarships per 1 million inhab. in the meso-region	GEOCAPES and IBGE
HHI	Hirschman-Herfindahl index of the meso-region employment (2 digit)	RAIS
Region	Dummy for five Brazilian macro-regions	IBGE

Source: own elaboration.

Table 4 - Descriptive statistics of the variables

Variables	N	Mean	SD	Min	Max
PI	685	34,0	47,2	0,0	277,8
FDI	548	63,9	227,8	0,0	3111,4
RDI	685	2,1	0,9	0,2	6,3
RDU	548	172,8	355,6	0,0	2898,4
HHI	685	0,2	0,1	0,1	0,9

Source: own elaboration.

3.3 The Econometric Model

The empirical model is defined as follows:

$$\mathrm{PI}_{\mathrm{r,t}} = \beta_1 \mathrm{PI}_{\mathrm{r,t-1}} + \beta_2 \mathrm{FDI}_{\mathrm{r,t-1}} + \beta' \mathrm{X}'_{\mathrm{r,t-1}} + v_{r,t}$$

Where r denotes the meso-region and t the time period. Our proxy for regional innovation is $PI_{r,t}$ which consists in the average number of patents filled over a three-year period per 1 million inhabitants in meso-region *r* and time period *t*. The variable ($PI_{r,t-1}$) correspond to the patents the three-year prior to *t* in the same region *r*. $FDI_{r,t-1}$ indicates the inward FDI in millions USD divided by the population in the region *r* in the for the period t - 1. $X'_{r,t-1}$ is a vector which resumes the characteristics of the Regional Innovation System composed of four variables that reflect a region's overall level of development at time *t-1*, such as: industrial R&D ($RDI_{r,t}$); university R&D ($RDU_{r,t}$); Hirschman-Herfindahl index (HHI) of the local manufacturing employment and regional dummies. Finally, $v_{r,t}$ is the error term.

Since we do not have data on Industrial or university R&D expenditures in a regional level in Brazil, we use some traditional proxies (Table 3). As the proxy for Industrial R&D expenditures, we use as the number of R&D researchers divided by 100 workers in the region (Gonçalves et al., 2019; Kang & Dall'erba, 2016). For University R&D, we used the number of scholarships granted for graduate students per 1 million inhabitants in the region. This proxy is related to the fact that University R&D is heavily linked to graduate programs (Araújo & Garcia, 2019). Regarding local diversification, we used the Hirschman-Herfindahl index (HHI) calculated using the number of workers in 2-digit industrial classification. Finally, we added dummies for the five Brazilian Macro-regions to control the heterogeneity of the technological profiles among locations.

4. Preliminary Results and Discussion

The results of the empirical model are presented in Table 5. The first model (1) is the simple dynamic model ($PI_{r,t}$ and $PI_{r,t-1}$) with the FDI of the previous period ($FDI_{r,t-1}$) and regional dummies. Second model (2) includes all the control variables. Third model (3) includes an interaction term of the FDI and the HHI, in order to examine how the FDI effects are modified by the local industrial diversification.

Table 5 - Regression Results

	(1) PI_PC	(2) PI_PC	(3) PI_PC
L.PI_PC	0.910***	0.844***	0.831***
	(0.0233)	(0.0327)	(0.0313)
L.ln_FDI_PC	0.752**	0.586*	1.788***
	(0.311)	(0.321)	(0.648)
L.RDU_E		0.0176***	0.0180***
		(0.00264)	(0.00267)
L.RDI_CBO_ET		1.396**	1.121**
		(0.554)	(0.558)
L.HHI		-5.902**	-3.999
		(2.836)	(2.837)
L.i_ln_FDI_PC_HHI			-7.007***
			(2.700)
Constant	1.093*	-0.515	-0.584
	(0.590)	(1.552)	(1.527)
Macroregional dummies	Yes	Yes	Yes
Observations	548	548	548
r2_o	0.874	0.892	0.893

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: own elaboration.

Findings from the model (1) points that the coefficient of the temporal dynamic term ($PI_{r,t-1}$) is positive, statistically significant, and below the unit. This result attest the path-dependence of innovation on regions. Also, as expected, inward FDI presents positive effect on local innovation.

The dynamic path-dependence of the regional innovation is the other models, even after the inclusion of the control variables in Model (2). The coefficients of the time-legged innovation ($PI_{r,t-1}$) and inward FDI ($FDI_{r,t-1}$) are positive and significant. Coefficients for Industrial R&D ($RDI_{r,t}$) and university R&D ($RDU_{r,t}$) are also positive and significant, which means that patents at the local level grow when industrial and university R&D expenditures increase. Previous empirical studies that use similar specifications found that both local industrial and academic R&D are local determinants of innovation (Fritsch & Slavtchev, 2010; Kang & Dall'erba, 2016).

Regarding the local industrial structure, the HHI coefficient is negative and significant. It is worthy to remember that HHI takes higher values when the region is more specialized.

In this way, as regions become more diversified, their innovative performance improves. This evidence shows the importance of local benefits of diversification for local innovation, in line with previous studies (Corsatea & Jayet, 2014; Fritsch & Slavtchev, 2007).

It is relevant to consider in detail the cases in which FDI occur in diversified regions, which can be accomplished by including a simple interaction term between these variables (Model 3). In Model (3) estimations, all the previous results are maintained except HHI coefficient that became not significant. Otherwise, the interaction term is negative and significant and the coefficient of FDI increases. The interpretation of these results is not straightforward. The FDI effect on innovation depends on the sum of the coefficients of FDI with the interaction term multiplied by the specific HHI level. The FDI coefficient increases from 0.586 in Model (2) to 1.788 in Model (3) and the coefficient of the interaction term in this new model is -3.999. Therefore, we apply the new coefficients using 0.185 as the average value of HHI on regions that receive inward FDI. The total effect is this case is 0.495 which is positive and similar to Model (2) results (0.586).

However, the interaction term varies the FDI effect on diversified regions. Increasing the specialization by HHI 1 s.d. (+0.112) we obtain a negative coefficient (-0.289). On the other way, increasing the diversification (reducing 1 s.d.) we obtain a 1.279 coefficient. So, we can state that the Model (3) results points that the FDI has positive effects on innovation for diversified regions, but it can have no effect (or even negative ones) in very specialized regions.

5. Final Remarks and Policy

The aim of this paper is to analyze the main effects of the inward FDI in the innovative performance of Brazilian regions. In this way, we aim to examine the role of the local knowledge spillovers generated by the inward FDI at the regional innovation. Previous literature shows that inward FDI can represent an important source of new knowledge for regional innovation systems. This new knowledge can be recombined with the local knowledge base and thus stimulate local innovation.

Our main findings confirm theoretical expectations. Inward FDI positively affect innovation ate regional level, since Brazilian regions that received inward FDI presented better innovative performance. In addition, the positive effects of the inward FDI on local innovation is reinforced by the diversification of the local productive structure. In this way, diversified regions that receive inward FDI are able to better leverage the benefits of local spillovers from the inward FDI.

These results can have some policy implications. FDI attraction policies are widely used by local governments to stimulate regional economic growth and local income generation. However, these policies must consider that the benefits of local spillovers are better exploited if they are associated with the existence of a diversified local industrial structure and with a set of diversified and complex capabilities. Therefore, FDI attraction policies must be associated with policies for the formation, consolidation and structuring of local capacities, in order to be able to absorb the new knowledge brought by the inward FDI,

recombining them with the set of local knowledge and transforming them into new knowledge and innovation.

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Appendix

Table A1 - Correlation Matrix (N=548)

	PIr,t+1	PIr,t	FDIr,t	RDUr,t	RDIr,t	HHIr,t
PIr,t+1	1.000					
PIr,t	0.9327	1.000				
FDIr,t	0.1421	0.1333	1.000			
RDUr,t	0.5012	0.4107	0.0178	1.000		
RDIr,t	0.3758	0.3361	0.1665	0.4043	1.000	
HHIr,t	-0.4035	-0.3879	-0.1309	-0.2531	-0.4023	1.000

Source: own elaboration.