Local absorptive capacity, inward FDI knowledge spillovers and regional innovation: an assessment to Brazilian regions

Renato Garcia
Institute of Economics at University of Campinas, Brazil
Veneziano Araujo
Federal University of São Paulo, Brazil
Suelene Mascarini
Institute of Economics at University of Campinas, Brazil
Emerson Gomes dos Santos
Federal University of São Paulo, Brazil
Ariana Ribeiro Costa
Getulio Vargas Foundation, Brazil
Sarah Cristina Ribeiro Ferreira
Institute of Economics at University of Campinas, Brazil

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Abstract

There is a strong recognition that inward FDI spillovers can be an important channel for the introduction of new technological knowledge in host regions, with positive effects on regional innovation. In this paper, we aim to examine the role of the local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation. Previous studies increasingly recognize that the host region absorptive capacity matters for knowledge spillovers and innovation, but there is little empirical evidence on how local absorptive capacity can be a moderating factor for the relation between inward FDI and regional innovation. We use data on investments of multinational companies (MNCs) in Brazilian regions in the 2003-2014 period and relate them to regional innovative performance measured by patents. Our results show that the greater the local absorptive capacity, expressed by the local firms' capabilities and by the local academic efforts, the greater the benefits of inward FDI spillovers on regional innovation.

Keywords: Geography of Innovation; Foreign Direct Investment (FDI); Knowledge spillovers; Regional innovation; Local Absorptive Capacity

JEL Code: R11; R12; O33; F21

Resumo

Há um crescente reconhecimento de que os transbordamentos de IDE podem ser um importante canal para a introdução de novos conhecimentos nas regiões anfitriãs, com efeitos positivos sobre a inovação regional. Neste artigo, nós examinamos o papel da capacidade de absorção local como um fator moderador da relação entre os transbordamentos de IDE e a inovação regional. Estudos prévios reconhecem que a capacidade de absorção da região anfitriã é um fator importante para o transbordamento de conhecimento e inovação, porém há poucas evidências empíricas sobre como a capacidade de absorção local pode ser um fator moderador para a relação entre IDE e inovação regional. Para avaliar essa relação, nós utilizados dados sobre investimentos de empresas multinacionais (EMNs) em regiões brasileiras no período de 2003-2014 e os relacionamos com o desempenho inovador das regiões, medido por patentes. Nossos resultados mostram que quanto maior a capacidade de absorção local, expressa pelas capacidades das empresas locais, pelos esforços acadêmicos locais e pela estrutura industrial regional, maiores são os benefícios dos transbordamentos de IDE na inovação regional.

Palavras-chave: Geografia da inovação, capacidade de absorção local, investimento direto externo, transbordamento de conhecimentos, inovação regional.

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1. Introduction

Developing countries and lagging-behind regions usually suffer from a lack of technological capabilities. Due to the lack of indigenous capabilities and competences in emerging economies, local actors are encouraged to search for external sources of knowledge. In general, emerging countries are largely dependent on technology transferred from advanced countries. The knowledge spillovers provided by inward FDI are among the most prominent beneficial channels of new and advanced knowledge for local firms, motivating the creation of FDI attraction policies to foster regional innovation. The importance of inward FDI as a vehicle for introducing new knowledge and technology into host regions and its potential beneficial repercussions for local firms are already well established in the regional science literature (Capello & Lenzi, 2014, 2019; Javorcik, 2004; Ning et al., 2023). However, the main conditioning factors of the impact of inward FDI spillover on innovation in host regions require further investigation. There is an ongoing debate revolving around whether host regions, and by extension local firms, benefit from inward FDI. Research has just begun to dig deeper into the distinct effects of inward FDI in different regions, suggesting that inward FDI might not be equally beneficial to all regions.

A growing body of literature analyses the role of inward FDI knowledge spillovers. Nevertheless, most studies have focused on the effects of FDI spillovers on the productivity growth of firms in recipient regions (Ascani & Gagliardi, 2020; Crespo & Fontoura, 2007; Huynh et al., 2021; Jones, 2017; Kim, 2015; Moralles & Moreno, 2020), and other studies focus on the effects on regional innovation (Ascani et al., 2020; Garcia et al., 2022; Huang et al., 2012; Jiang et al., 2022; Ning et al., 2016; Valacchi et al., 2021; Wang et al., 2016). Despite the growing literature on inward FDI spillovers, we still have a limited understanding of how local absorptive capacity can affect the ability of regions to benefit from inward FDI spillovers, with positive effects on regional innovation.

Based on this debate, the aim of our paper is to examine the role of local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation. We investigate how local absorptive capacity, expressed by the local set of skills and capabilities, can shape the effects of inward FDI spillovers on regional innovation. We assess local absorptive capacity by dividing it into two main components: local firms' capabilities and local academic efforts. Previous literature has recognized that the host region absorptive capacity matters for knowledge spillovers and innovation (Ascani & Gagliardi, 2020; Fu, 2008; Jin et al., 2019; Rojec & Knell, 2018; Smith & Thomas, 2017; Ubeda & Pérez-Hernández, 2017). However, there is little empirical evidence on how the local absorptive capacity can moderate the relation between inward FDI and regional innovation.

The contribution of our paper is to present new empirical evidence of the role of local absorptive capacity as a moderating factor for the relation between inward FDI and regional innovation. Our assumption is that different regions with different absorptive capacities can benefit differently from the external knowledge provided by inward FDI spillovers. Our contribution is reinforced by the context in which we apply this subject, an emerging country such as Brazil. As in several emerging countries, there is a lack of technological and scientific knowledge and resources to engage in cutting-edge R&D (Moralles & Moreno, 2020; Vujanović et al., 2022; Wang et al., 2016). In Brazil, multinational companies (MNCs) represent an important share of domestic manufacturing activity, and they are responsible for most domestic private R&D expenditures (Suzigan et al., 2020). In this way, MNCs are an important source of technological knowledge for local firms since investments of foreign companies can provide new external sources of knowledge. New knowledge provided by MNCs can be combined with the local knowledge base, fostering interactive learning and innovation.

In our empirical modelling, we estimate a Regional Knowledge Production Function for Brazilian regions. We use data from the fDi Markets-Financial Times database for the period 2003–2014, encompassing all greenfield investments announced by MNCs in Brazil. As a proxy for regional innovation, we use data from the Brazilian Intellectual Property Office. Our empirical findings show the role of local absorptive capacity in shaping the relation between inward FDI spillovers and regional innovation. Our results allow us to identify that the local absorptive capacity, expressed by local firms' capabilities and local academic efforts, are moderating factors for the impact of inward FDI spillovers on regional innovation.

The paper is structured as follows. The next section presents the conceptual background regarding the main drivers of inward FDI spillovers and their effects on regional innovation. The third section provides a brief description of the data and the main methodological issues, including our measures for regional innovation, inward FDI, and local absorptive capacity. The fourth section presents the overall results and discusses the main findings regarding the moderating factors of the relation between inward FDI spillovers and regional innovation. The final section presents final remarks, limitations, and policy implications.

2. Literature Review: Drivers of Inward FDI and Regional Innovation

The effect of FDI spillovers on host countries has been the subject of several empirical investigations in the regional science literature (Ascani et al., 2020; Rojec & Knell, 2018). In general, previous research indicates that foreign investments represent a key source of external knowledge for host countries and regions. Inward FDI is an important channel for technology transfer since MNCs tend to be more productive and more innovative than domestic firms, and they usually invest more in R&D. The entry of MNCs into a country or a region can benefit local firms due to the transmission of knowledge through both vertical and horizontal linkages and other forms of local knowledge spillovers (García et al., 2013; Javorcik, 2004).

Recent research has recognized that inward FDI spillovers can have fairly different effects across developed and emerging countries (Valacchi et al., 2021). One of the reasons usually pointed out for these differences is the strong disparities between the productive and knowledge bases of developed and emerging countries (Rojec & Knell, 2018). In emerging economies, knowledge spillovers from MNCs are among the most important channels of benefits for domestic firms (Vujanović et al., 2022). The lack of domestic capabilities among local actors, both at firms and at supportive institutions, makes searches for external sources of knowledge one of the main sources of novelty. In this way, for emerging countries and lagging-behind regions, inward FDI spillovers can be an important source of new technical and technological knowledge, and they can contribute to the improvement of local skills.

There are various mechanisms through which MNCs have a beneficial effect on host regions on innovation and productivity, especially when carrying out knowledge-intensive and innovative activities (Javorcik et al., 2018). Largely, the benefits of MNCs in host regions involve both positive vertical and horizontal spillovers mechanisms. Vertical externalities are manifested through interindustry interactions following the supply chain due to the strong incentives for MNCs to support knowledge and technological insights to their suppliers (Cortinovis et al., 2020; Havranek & Irsova, 2011; Lu et al., 2017). Horizontal intraindustry spillovers are usually associated with the agglomeration of firms in the same industry. However, there is much less evidence of horizontal spillovers (Belderbos & Somers, 2015; Cortinovis et al., 2020; Javorcik et al., 2018) since MNCs try to protect their expertise to minimize knowledge outflows that can favor local firms.

The transfer of knowledge from MNCs to local firms cannot be taken for granted. It depends on the ability of local firms to assimilate and apply new technologies and, more generally, on the ability of the economic environment to enable the transmission of knowledge from foreign companies to local firms (Antonietti et al., 2015; Ascani et al., 2020). Scholars recognize that local absorptive capacity determines the ability of regions to transform new knowledge from external sources into local innovation (Caragliu & Nijkamp, 2012; Lau & Lo, 2015; Miguélez & Moreno, 2015). Since innovation is a cumulative and evolutionary process, it depends on the ability of local actors to identify, assimilate, and develop useful external knowledge, combining it with the existing knowledge. Local absorptive capacity is a requirement to understand and transform extraregional inflows of knowledge into regional innovation. Local actors must be able to combine local skills with external sources of knowledge to generate new knowledge and new capabilities that they can then apply to regional production and innovation. Regions with narrow capabilities and weak knowledge bases face greater difficulties in absorbing external knowledge from inward FDI (Cui & Xu, 2019; Ubeda & Pérez-Hernández, 2017).

There are several ways to assess the local absorptive capacity. The absorptive capacity of regions can reside not only in individuals and firms but also in organizations and institutions, such as universities, public research institutes and technological centres, that interact and engage across geographical space and within networks (Ascani & Gagliardi, 2020; Miguélez & Moreno, 2015). The greater and broader local actors' capabilities are, the greater their ability to benefit from inward FDI spillovers. Highly skilled local firms and institutions are more able to create new knowledge combinations that involve the new external knowledge provided by inward FDI and the local knowledge base. The strength of the positive effects of inward FDI spillovers depends on the absorptive capacity of local firms and the existence of complementary assets in the region (Fu, 2008).

Previous studies show that the local firms' absorptive capacity can shape the effects of inward FDI spillovers on regional innovation (Ascani & Gagliardi, 2020; Jin et al., 2019; Ubeda & Pérez-Hernández, 2017). The heterogeneity of local firms and of the local innovation environment are conditioning factors for inward FDI spillovers since local firms are not equally able to learn from foreign companies (Ascani & Gagliardi, 2020; Rojec & Knell, 2018). Firms with greater existing technological capabilities are likely to be in a better position to innovate in response to MNC entry (Jin et al., 2019; Rojec &

Knell, 2018; Valacchi et al., 2021). They can also better leverage their technological capabilities to learn from foreign entrants by transforming knowledge acquired from inward FDI into local innovation. On the other hand, local firms that lack technological capabilities are likely to be more vulnerable to foreign entry. Therefore, knowledge transfer from MNCs requires absorptive capacity and depends on the learning efforts of local firms (Ubeda & Pérez-Hernández, 2017). Local firms that are relatively close to the knowledge frontier have greater potential to benefit from inward FDI spillovers than those that are lagging technologically, and local firms with higher absorptive capacity benefit most from internal FDI. Regions with limited capabilities and poor knowledge bases among local firms are unable to absorb external knowledge from inward FDI spillovers (Cui & Xu, 2019; Fu, 2008; Tang & Zhang, 2016; Ubeda & Pérez-Hernández, 2017). Hence, we expect that local firms' capabilities can provide the region with the capacity to absorb inward FDI spillovers, with positive impacts on regional innovation. Based on these assumptions, we propose the following hypothesis:

H1: Local firms' capabilities moderate the effects of inward FDI spillovers on regional innovation.

In addition, new knowledge from inward FDI does not exist in a "territorial vacuum" (Crescenzi & Iammarino, 2017), and the local absorptive capacity can reside not only in private firms but also in the local institutions of the regional innovation system. Previous studies also show that the presence of technology and training institutions can affect the way new technology is incorporated by local agents (Fu, 2008). In this way, opportunities to realize the benefits of inward FDI spillovers can also depend on the technological capacity of local supportive institutions, such as universities, public research institutes and technological centres (Ascani & Gagliardi, 2020; Fu, 2008; Rojec & Knell, 2018). Therefore, we assume that the higher the academic efforts in a region are, the stronger the impact of inward FDI spillovers on regional innovation. Based on this assumption, we outline our second hypothesis:

H2: Local academic efforts moderate the effects of inward FDI spillovers on regional innovation.

3. Data and Methodology

3.1 Database

We use two main sources of data to assemble our database. The first source is the Brazilian Institute of Intellectual Property (BADEPI/INPI), which covers patent applications for the period 2006-2017. We use the geolocation of inventors' addresses to obtain a fractional count of patents. Data were gathered from the Brazilian patent office because a significant share of innovation in Brazil is related to the exploration of the domestic market, which motivates firms to drive their patenting activities to the Brazilian office. The second database is the fDi Markets-Financial Times database for 2003 to 2014, which includes all announced greenfield investments made by multinationals in Brazil. We assigned data to 133 intermediate regions, and these are similar to EU NUTS-2 regions.

It is important to reinforce that MNCs play an important role in the domestic productive structures of emerging countries. These companies exhibit a high level of participation in the domestic manufacturing industry, especially in high-tech sectors. In Brazil, they account for a high share of domestic R&D expenditure (Suzigan et al., 2020). The importance of MNCs in emerging countries is reinforced by the fact that several countries and regions have established aggressive policies to attract FDI (Crescenzi and Iammarino 2017).

3.2 Empirical strategy

We aim to examine the role of local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation. To do that, we perform a Regional Knowledge Production Function. Our dependent variable is the fractional patent count per 1 million inhabitants in mesoregion r in period t ($Pat_{r,t}$). Our measure of regional innovation is calculated over a 3-year moving average time window to exclude annual sporadic events. This approach provides us with data covering 15 periods.

Our independent variable of interest is inward FDI at the regional level since we aim to examine how inward FDI affects regional innovation in Brazil. Other independent variables are local firms' capabilities and local academic efforts. To measure local firms' capabilities, we use the number of industrial R&D researchers by taking the total R&D staff at private firms, which is a proxy for industrial R&D expenditures at the regional level. Regarding local academic efforts, our proxy for university R&D expenditures is the number of graduate scholarships at the regional level. We also add controls for agglomeration, human capital, regional international trade and technological fields of regional patents. Table 1 presents descriptions of the variables, and Table 2 shows the descriptive statistics.

TABLE 1 ABOUT HERE

TABLE 2 ABOUT HERE

3.3 The Econometric Model

The theoretical model is defined as follows:

$$\mathrm{Pat}_{\,\mathrm{r,t}} = \beta_1 \mathrm{FDI}_{\mathrm{r,t-1}} + + \beta_2 \mathrm{RDI}_{\mathrm{r,t-1}} + \beta_3 \mathrm{RDU}_{\mathrm{r,t-1}} + \beta_4 \mathrm{X}'_{\mathrm{r}} + \phi_r + \mathrm{v}_{\mathrm{r,t}}$$

where r denotes the region and t represents the time period. Our dependent variable is a proxy for regional innovation ($Pat_{r,t}$). We add a one time period lag to independent variables, since innovative efforts go on for some years to generate innovation outcomes. $FDI_{r,t-1}$ indicates the inward FDI for period t – 1; industrial R&D ($RDI_{r,t-1}$) represents the local firms' capabilities; university R&D ($RDU_{r,t-1}$) represents the local academic efforts. We also add a vector X' for controls and use region fixed effect specification (ϕ_r); $v_{r,t}$ is an error term. Finally, we estimate additional specifications with interaction terms to examine how local absorptive capacity, measured by local industrial and university R&D efforts, moderates the relation between inward FDI and regional innovation.

We use a spatial model specification because we are dealing with a spatial phenomenon. Following Kubara & Kopczewska (2023), we use an Inverse Distance spatial weight matrix. We test different spatial model specifications (Table A.1, Appendix), and the results of minimizing the Akaike Information Criteria (AIC) show that the best specification is the Spatial Durbin Model (SDM).

4. Results and Discussion

4.1 Results of the Econometric Analysis

Our aim is to examine the role of local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation. Therefore, we initially estimate three models (Table 3). In model (1), we include our variables of interest: inward FDI ($FDI_{r,t-1}$); industrial R&D ($RDI_{r,t-1}$); and academic R&D ($RDU_{r,t-1}$). All the independent variables are lagged by one period. In model (2), we add the interaction term between inward FDI ($FDI_{r,t-1}$) and industrial R&D ($RDI_{r,t-1}$). Model (3) includes the interaction term between inward FDI ($FDI_{r,t-1}$) and academic R&D ($RDU_{r,t-1}$). We also present the total effects of the estimation (Table A.2, Appendix).

TABLE 3 ABOUT HERE

Regarding inward FDI, the overall results show that the effect of inward FDI spillovers on regional innovation is positive and significant (model 1). We can indicate that the contribution of inward FDI spillovers is overall positive in fostering regional innovation.

The coefficient of industrial R&D ($RDI_{r,t-1}$) is not significant in most of the specifications. However, the coefficient of the interactive term between inward FDI and industrial R&D is positive and significant (model 2), which allows us to indicate that the association between inward FDI spillovers and local industrial R&D has positive effects on regional innovation. In this way, the higher the local industrial R&D is, the stronger the impact of inward FDI on regional innovation. Therefore, our results show that local industrial R&D tends to strengthen the effect of inward FDI spillovers on innovation in Brazilian regions, confirming H1. This result can also be seen in the specification with the total effects (Table A.2 in Appendix), in which the interactive term between inward FDI and industrial R&D is also positive and significant.

The coefficient of academic R&D ($RDU_{r,t-1}$) is also positive and significant in all specifications, confirming that academic research positively impacts regional innovation. In addition, the interaction between academic R&D and inward FDI spillovers shows that local academic efforts are another moderating factor in the relation between inward FDI spillovers and regional innovation, as we can see from the positive and significant coefficient of the interaction term between inward FDI and academic R&D (model 3). The higher the academic R&D expenditures at the local level are, the stronger the effects of inward FDI spillovers on regional innovation. This result allows us to assume that academic R&D impacts the effect of inward FDI, confirming H2.

4.2 Robustness Check

To ensure that our results are not choice-sensitive, we estimate models with alternative specifications as robustness checks (Table 4). First, one can argue that our results could be led by outliers. Therefore, we estimate the same regressions removing regions with over 1% more FDI inflows from our sample, and the results remain the same. The results of this specification show that the removal of outliers improves the regression results, confirming the main associations among the variables of interest. In addition, we add a control for MNC patenting in the region before foreign investment to ensure that our findings are not biased by MNC patents. Again, the main results remain. Third, our dependent variable is filled patents in the Brazilian Intellectual Property Office, encompassing high- and low-level innovation patents. In this way, we estimate new models with only high-level patents (Higham et al., 2021) to ensure innovation quality by changing our dependent variable for coinvented patents (*Pat Coinv*). The overall results remain the same. Finally, we also use an alternative spatial matrix specification using an inverse distance weight matrix with a 500-kilometer cut-off, and the results are quite similar (Table A.3 in Appendix).

TABLE 4 ABOUT HERE

4.3 Discussion

Our main findings show the moderating role of local absorptive capacity on the relation between inward FDI spillovers and regional innovation. The empirical results allow us to assess how local firms' capabilities and local academic efforts moderate the effects of inward FDI spillovers on innovation at the regional level.

Overall, the results regarding the impacts of inward FDI spillovers show that inward FDI has important effects on regional innovation, since we found a positive association between these two variables. Previous literature shows that there is mixed evidence from empirical studies regarding the impact of inward FDI spillovers on regional innovation (Rojec & Knell, 2018). However, our results are in line with other studies that find positive effects of inward FDI spillovers on innovation at the regional level (Ascani et al., 2020; Fu, 2008; García et al., 2013; Garcia et al., 2022).

Mixed evidence in the empirical literature reveals that the transfer of technological knowledge from MNCs to local firms cannot be taken for granted. The positive effects of inward FDI spillovers on regional innovation occur when the new knowledge provided by inward FDI can be associated with the existing capabilities of local actors. In developed countries, previous studies show that a more favourable environment for interactive learning and innovation, usually associated with the existence of high local absorptive capacity, positively affects the main impacts of inward FDI spillovers on regional innovation (Ascani et al., 2020; Ascani & Gagliardi, 2020; Rojec & Knell, 2018). In these regions, the diversity and complexity of local capabilities allow local actors to combine external knowledge provided by inward FDI and existing local capabilities, with positive effects on regional innovation. On the other hand, in emerging countries and in lagging-behind regions, the lack of technological and scientific knowledge among local actors hinders local firms from absorbing and incorporating new external knowledge provided by foreign investments (Garcia et al., 2022; Vujanović et al., 2022). In this way, the positive effects of inward FDI spillovers are only perceived when the new knowledge provided by MNCs can be combined with the existing capabilities of local actors. Local capabilities can reside both in the skills of local firms, usually expressed by the qualification of the industrial workforce, and in the institutions of the regional innovation system, such as local universities and research institutes.

Our research is applied to an emerging country, such as Brazil, and the empirical results show that inward FDI spillovers can provide important contributions in fostering regional innovation. Our findings show that the transfer of knowledge from foreign companies to local firms highly depends on the ability of local firms to assimilate and apply new technologies and on the main characteristics of the local economic and innovation environment. In this way, our research adds new empirical evidence that shows that the association between inward FDI and regional innovation occurs when we add the interaction term of the variable for inward FDI to other variables related to local absorptive capacity, such as local firms' capabilities and local academic efforts. Factors related to local absorptive capacity are the main moderating factors of the relation between inward FDI spillovers and regional innovation, both among local firms and throughout the regional innovation environment. Therefore, the strength of the positive effect of inward FDI spillovers depends on the existence of local absorptive capacity and on the presence of innovative complementary assets in the host region.

Local firms' capabilities are an important moderating factor for the relation between inward FDI spillovers and regional innovation. Confirming theoretical expectations and previous empirical studies (Ascani & Gagliardi, 2020; Jin et al., 2019; Tang & Zhang, 2016; Ubeda & Pérez-Hernández, 2017), our findings show that the interaction term between local private R&D expenditures and inward FDI positively affects regional innovation. Our study applied to an emerging country adds new empirical findings that allow us to assure that local firms with high absorptive capacities have the necessary capabilities to internalize the more complex knowledge provided by foreign companies. Highly skilled local firms can better benefit from positive inward FDI spillovers. The moderating role of local firms' capabilities on the relationship between inward FDI and local firm innovation can be seen by the existing internal skills of local firms. Highly skilled firms have further ability to learn with the new knowledge provided by foreign companies and apply it to new products and processes, with positive effects on regional innovation. Our findings show that the heterogeneity of local firms is a factor that matters for the incorporation of external knowledge provided by inward FDI.

Local academic efforts show the role of the capabilities of the local institutions of the regional innovation system as another important moderating factor in the relation between inward FDI spillovers and regional innovation. When inward FDI is combined with higher academic R&D expenditures, it positively affects regional innovation. Previous studies have noted the importance of the regional innovation environment to foster the positive effects of inward FDI spillovers (Fu, 2008; Li et al., 2018). Our findings add new empirical evidence that the institutions of the regional innovation system can facilitate the access of local firms to the new knowledge provided by foreign companies. Local universities can play an important role both in the formation of high-skilled labour for local firms and through joint applied research projects with local firms and foreign companies. Local research efforts can foster new combinations of knowledge between the local knowledge base and the new knowledge provided by inward FDI, with positive effects on interactive learning and innovation.

5. Final remarks and policy implications

In this study, we examine the role of the moderating factors of the relation between inward FDI spillovers and regional innovation. Previous literature shows that inward FDI spillovers usually have a positive influence on regional innovation (Ascani & Gagliardi, 2020; García et al., 2013), even though different studies present mixed evidence on this subject (Rojec & Knell, 2018). In general, the positive effects of inward FDI spillovers are related to the existing capabilities of local actors, which can be combined with the new knowledge provided by foreign companies. Therefore, regions with high local absorptive capacity are more able to benefit from inward FDI spillovers.

Our results add new contributions to this subject. Our research is applied to an emerging country, such as Brazil, where the lack of technological capabilities among local actors hinders local firms from absorbing and incorporating new external knowledge provided by foreign companies. High local absorptive capacity, both among private firms and in local supportive institutions, can leverage the positive effects of inward FDI spillovers on regional innovation. In this way, when inward FDI is combined with high local absorptive capacity, it produces positive impacts on regional innovation. Regions with higher industrial and academic capabilities are more able to benefit from inward FDI spillovers since local actors in such regions are more able to combine the existing local knowledge base with new knowledge brought by foreign companies. Therefore, our empirical findings allow us to conclude that local absorptive capacity is a moderating factor for the relation between inward FDI spillovers and regional innovation.

Our empirical analysis is applied to the Brazilian context. However, we believe that our findings are general enough to be applied to other contexts, especially those of other emerging countries and lagging-behind regions. Many of these countries and regions receive large volumes of inward FDI, even though these inflows are often regionally skewed and uneven. Our findings show that local absorptive capacity moderates the effects of inward FDI spillovers on regional innovation. Thus, for regional innovation to benefit from inward FDI spillovers, it is necessary that it has a complex and diversified set of local capabilities that can absorb the new knowledge provided by inward FDI. Local actors must be able to combine the local knowledge base with the new knowledge brought by inward FDI, generating new combinations of knowledge that can foster regional innovation.

Finally, our results have policy implications. Several countries and regions have aggressive policies to attract inward FDI. For the new knowledge provided by foreign companies to have positive effects on innovation, a region must already have a set of local capabilities. Inward FDI spillovers have minor effects on innovation in regions with few and limited local capabilities. Therefore, policies to attract FDI will not affect regional innovation, and they will not be able to foster regional innovation-based economic development. In this way, policies to attract inward FDI should be combined with policies aimed at building and strengthening local absorptive capacity. These policies should have the goal of creating mechanisms for the new knowledge provided by inward FDI to be absorbed by local actors, exerting positive effects on innovation. Thus, policies should be directed towards strengthening local firms' capabilities, and supporting local institutions of the regional innovation system. These factors moderate the relation between inward FDI spillovers and regional innovation, and they will be able to leverage the benefits of inward FDI spillovers over host regions.

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Tables

Table 1 - Definition of the variables in meso-region

Variable	Description	Source
Pat	Fractional patents count per 1 million inhab. in log form	BADEPAT and IBGE
FDI	Inward FDI as Announced inward FDI in millions USD per million inhab. in log form	fDI Markets
RDI	Local firms' capabilities: Number workers in research related jobs in the region per million inhab in log form	RAIS
RDU	Local academic efforts: Number of graduate students in STEM related fields per million inhab in log form	GeoCapes and IBGE
Agglomeration	Density of employment of the region in linear and quadratic form	IBGE
Import	Imports in FOB dollars by the GDP of the region	ComexStat and IBGE
Human Capital	Percentual of workers with higher education in manufacturing	RAIS

Source: own elaboration.

Table 2 - Descriptive statistics of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Pat	1,995	0.621	0.553	0.000	2.364
FDI	1,995	3.334	13.981	0.000	283.435
RDI	1,995	2.656	3.467	0.000	30.318
RDU	1,995	1.046	2.089	0.000	24.364
Agglomeration	1,995	17.750	61.649	0.004	714.641
Import	1,995	1.041	2.507	0.000	35.287
Human Capital	1,995	4.212	3.324	0.000	38.063

Table 3 – Regression Estimations Results (SDM). Patents as dependent variable

VARIABLES	(1)	(2)	(3)
$FDI_{r,t-1}$	0.00103***	0.000561	0.000819***
	(0.000311)	(0.000402)	(0.000316)
$RDI_{r,t-1}$	-0.00365	-0.00397	-0.00488*
	(0.00296)	(0.00296)	(0.00296)
$RDU_{r,t-1}$	0.00191***	0.00192***	0.00165***
	(0.000304)	(0.000304)	(0.000312)
W $FDI_{r,t-1}$	-0.00401	-0.00970**	-0.00553*
	(0.00293)	(0.00415)	(0.00297)
W $RDI_{r,t-1}$	-0.0147	-0.0198	-0.0470
	(0.0301)	(0.0303)	(0.0312)
W $RDU_{r,t-1}$	0.000799	0.00226	0.000510
	(0.00204)	(0.00216)	(0.00205)
$FDI_{r,t-1}$ * $RDI_{r,t-1}$		0.00797*	
		(0.00469)	
$FDI_{r,t-1}$ * $RDU_{r,t-1}$			0.0118***
			(0.00356)
W $FDI_{r,t-1}$ * $RDI_{r,t-1}$		0.0523*	
		(0.0291)	
W $FDI_{r,t-1}$ * $RDU_{r,t-1}$			0.0336**
			(0.0145)
W Pat_t	0.702***	0.691***	0.615***
	(0.0580)	(0.0592)	(0.0714)
Constant	-	-	-
Controls	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes
Observations	1,995	1,995	1,995
Number of regions	133	133	133
R-squared	0.4728	0.4771	0.4731
AIC	-1537.86	-1538.76	-1405.9

Table 4 – Robustness Checks: Regression Estimations Results (SDM). Patents as dependent variable

VARIABLES	Excluding outliers			Controlling for MNCs			Coinvented Patents		
	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FDI_{r,t-1}$	0.00106**	-0.000612	0.000686	0.00104***	0.000533	0.000828***	0.000682**	0.000116	0.000448
	(0.000453)	(0.000675)	(0.000464)	(0.000309)	(0.000400)	(0.000315)	(0.000283)	(0.000365)	(0.000288)
$RDI_{r,t-1}$	-0.00260	-0.00316	-0.00389	-0.00415	-0.00450	-0.00533*	-0.00432	-0.00469*	-0.00555**
	(0.00297)	(0.00296)	(0.00297)	(0.00294)	(0.00294)	(0.00295)	(0.00269)	(0.00269)	(0.00270)
$RDU_{r,t-1}$	0.00192***	0.00195***	0.00164***	0.00186***	0.00187***	0.00161***	0.00271***	0.00273***	0.00243***
	(0.000301)	(0.000301)	(0.000310)	(0.000302)	(0.000302)	(0.000311)	(0.000277)	(0.000276)	(0.000284)
$MNC_{r,t-1}$ (Dummy)				0.0601***	0.0618***	0.0587***			
				(0.0133)	(0.0133)	(0.0133)			
W $FDI_{r,t-1}$	-0.00317	-0.0168**	-0.00474	-0.00438	-0.0106**	-0.00585**	-0.00245	-0.0106***	-0.00312
	(0.00404)	(0.00779)	(0.00404)	(0.00292)	(0.00413)	(0.00295)	(0.00267)	(0.00378)	(0.00269)
W $RDI_{r,t-1}$	-0.0174	-0.0342	-0.0464	-0.0149	-0.0205	-0.0463	-0.0226	-0.0309	-0.0430
	(0.0295)	(0.0306)	(0.0303)	(0.0299)	(0.0301)	(0.0310)	(0.0274)	(0.0276)	(0.0284)
W $RDU_{r,t-1}$	0.000485	0.00210	-8.03e-05	0.00128	0.00288	0.000989	0.00191	0.00405**	0.00194
	(0.00195)	(0.00207)	(0.00197)	(0.00203)	(0.00215)	(0.00204)	(0.00186)	(0.00197)	(0.00187)
$FDI_{r,t-1}$ * $RDI_{r,t-1}$		0.0185***			0.00850*			0.00940**	
		(0.00572)			(0.00466)			(0.00427)	
$FDI_{r,t-1}$ * $RDU_{r,t-1}$			0.0126***			0.0115***			0.0129***
			(0.00359)			(0.00354)			(0.00323)
W $FDI_{r,t-1}$ * $RDI_{r,t-1}$		0.0821*			0.0570**			0.0765***	
		(0.0443)			(0.0290)			(0.0267)	
W $FDI_{r,t-1}$ * $RDU_{r,t-1}$			0.0338**			0.0326**			0.00964
			(0.0154)			(0.0144)			(0.0124)
W Pat_t	0.719***	0.709***	0.640***	0.708***	0.697***	0.625***	0.778***	0.753***	0.753***
	(0.0555)	(0.0565)	(0.0682)	(0.0572)	(0.0585)	(0.0703)	(0.0496)	(0.0537)	(0.0544)
Constant	-	-	-	-	-	-	-	-	-
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,995	1,995	1,995	1,995	1,995	1,995	1,995	1,995	1,995
Number of regions	133	133	133	133	133	133	133	133	133
R-squared	0.4725	0.4828	0.4713	0.5030	0.5045	0.5022	0.4494	0.4368	0.4485
AIC	-1544.74	-1553.47	-1541.01	-1551.07	-1552.52	-1547.67	-1884.15	-1891.05	-1882.08

Appendix

Table A.1 – Regression Estimations Results. Patents as dependent variable

VARIABLES	(A1) OLS	(A2) SEM	(A3) SAR	(A4) SDM	(A5) SDEM
$FDI_{r,t-1}$	0.000315 (0.000341)	0.000955*** (0.000309)	0.000844*** (0.000309)	0.00103*** (0.000311)	0.000989*** (0.000317)
$RDI_{r,t-1}$	-0.000858 (0.00314)	-0.00563* (0.00290)	-0.00585** (0.00284)	-0.00365 (0.00296)	-0.00401 (0.00300)
$RDU_{r,t-1}$	0.00338*** (0.000316)	0.00189*** (0.000302)	0.00206*** (0.000290)	0.00191*** (0.000304)	0.00201*** (0.000312)
W $FDI_{r,t-1}$				-0.00401 (0.00293)	-0.00481 (0.00416)
W $RDI_{r,t-1}$				-0.0147 (0.0301)	-0.0629 (0.0410)
W $RDU_{r,t-1}$				0.000799 (0.00204)	0.00578* (0.00338)
W u_t		0.867*** (0.0267)			0.723*** (0.0590)
W $Pat_{r,t}$			0.820*** (0.0338)	0.702*** (0.0580)	
Constant	0.534*** (0.0167)				
Controls	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,995	1,995	1,995	1,995	1,995
Number of regions	133	133	133	133	133
R-squared	0.1433	0.3664	0.3488	0.4728	0.4981
AIC		-1508.07	-1494.99	-1537.86	-1524.99

Table A.2 – Total effects Results. Patents as dependent variable

VARIABLES	(1)	(2)	(3)
$FDI_{r,t-1}$	-0.009 (0.009)	-0.027* (0.013)	-0.011 (0.007)
$RDI_{r,t-1}$	-0.057 (0.095)	-0.071 (0.093)	-0.126 (0.077)
$RDU_{r,t-1}$	-0.009 (0.006)	0.013* (0.007)	0.005 (0.005)
$FDI_{r,t-1}$ * $RDI_{r,t-1}$		0.182** (0.092)	
$FDI_{r,t-1}$ * $RDU_{r,t-1}$			0.111*** (0.032)

Table A.3 – Robustness Check: Different Spatial Weight Matrix. Patents as dependent variable

VARIABLES	(A6) Queen Contiguity	(A7) Inverse Distance 500 km cutoff	(A8) Inverse Distance 250 km cutoff
$FDI_{r,t-1}$	0.000854***	0.00100***	0.000855***
	(0.000321)	(0.000315)	(0.000319)
$RDI_{r,t-1}$	-0.00409	-0.00252	-0.00218
	(0.00305)	(0.00299)	(0.00305)
$RDU_{r,t-1}$	0.00249***	0.00218***	0.00241***
	(0.000300)	(0.000307)	(0.000315)
W $FDI_{r,t-1}$	-0.000930	-0.00333**	-0.00204*
	(0.000958)	(0.00163)	(0.00113)
W $RDI_{r,t-1}$	0.0227***	-0.0463***	-0.0192
	(0.00863)	(0.0169)	(0.0118)
W $RDU_{r,t-1}$	0.00223***	0.00122	0.00104
	(0.000822)	(0.00134)	(0.000937)
W Pat_t	0.342***	0.556***	0.539***
	(0.0381)	(0.0438)	(0.0381)
Constant	-	-	-
Controls	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes
Observations	1,995	1,995	1,995
Number of regions	133	133	133
R-squared	0.4067	0.4809	0.4423
AIC	-1343.48	-1492.68	-1427.33