Foreign Direct Investment and Local Development: the Role of Knowledge Spillovers and the Geography of Innovation in Brazilian Regions

Renato Garcia (presenting author); rcgarcia@unicamp.br.
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 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 local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation. Previous studies increasingly recognize that host region absorptive capacity matters for knowledge spillovers and innovation, but there is few empirical evidence on how the 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 period of 2003–2014 and relate them to regional innovative performance measured by patents. Our results show the greater the local absorptive capacity, expressed by the local firms' capabilities, local academic efforts, and regional industrial structure, the greater are the benefits of inward FDI spillovers on regional innovation.

Keywords: geography of innovation, local absorptive capacity, foreign direct investment, knowledge spillovers, regional innovation.

JEL Code: R11; R12; O33; F21

An analysis of the relation between inward FDI spillovers and regional innovation: the role of local absorptive capacity

1. Introduction

Developing countries, and lagging-behind regions, usually suffer from the lack of technological capabilities, with harmful effects on local innovation. 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, what motivates the building 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 economic geography literature (Ascani et al., 2020; Crescenzi et al., 2015; Javorcik, 2004). However, the main conditioning factors of the impact of inward FDI spillover on innovation in host regions requires 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; Kim, 2015; Moralles & Moreno, 2020), and other studies focus on the effects on regional innovation (Ascani et al., 2020; Huang et al., 2012; 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 on the role of the local absorptive capacity as a moderating factor on the relation between inward FDI spillovers and 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 the local absorptive capacity, which involves the local set of skills and capabilities, can shape the effects of inward FDI spillovers on regional innovation. We assess the local absorptive capacity by measuring local firms' capabilities, local academic efforts, and regional industrial structure. There is a growing recognition in the literature that the host region absorptive capacity matters for knowledge spillovers and innovation (Ascani & Gagliardi, 2020; Fu, 2008; Jin et al., 2019; Rojec & Knell, 2018; Ubeda & Pérez-Hernández, 2017). However, there are few empirical evidence on how the local absorptive capacity can be a moderating factor for the relation between inward FDI and regional innovation.

The main contribution of our paper lies precisely at this point, as we present new empirical evidence of the role of the 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 capacity, can differently benefit from the external knowledge provided by inward FDI spillovers. Our main contribution is reinforced by the

context in which we apply this subject, an emerging country, as Brazil. As in several emerging countries, there is a lack of the technological and scientific knowledge and in resources to engage in cutting-edge R&D in Brazil. Multinational companies (MNCs) respond for an important share of the domestic manufacturing activity, and they are responsible for most of 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, that can be combined with the local knowledge base, fostering interactive learning and innovation. In addition, as in several developed and emerging countries, strong regional differences can be found in Brazil.

In our empirical modelling, we use data from two main sources to estimate a Regional Knowledge Production Function. The first source is the fDi Markets-Financial Times database for the period 2003–2014, which encompasses all greenfield investments announced by MNCs in Brazil. The second source of data is the Brazilian patents database from the Brazilian Intellectual Property Office. Our empirical findings show the role of the local absorptive capacity in shaping the relation between inward FDI spillovers and regional innovation. Our results allow us to show to identify three main moderating factors, related to the local absorptive capacity, for the impact of inward FDI on innovation, that are local firms' capabilities, local academic efforts, and regional industrial structure.

The paper is structured as follows. The next section presents the conceptual background regarding the main drivers of the inward FDI spillovers and its 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 the 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 economic geography literature (Ascani et al., 2020; Crescenzi et al., 2015; Rojec & Knell, 2018). In general, previous studies indicate that foreign investments represent a key source of external knowledge for host countries and regions. Inward FDI represents 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 trough both vertical and horizontal linkages and other forms of local knowledge spillovers (Antonietti & Cainelli, 2011; 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 (Crescenzi et al., 2015; Valacchi et al., 2021; 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.

However, the transfer of knowledge from MNCs to local firms cannot be taken for granted. Instead, it depends both on the ability of local firms to assimilate and apply new technologies and, more generally, on the ability of the economic environment to allow for the transmission of knowledge from foreign companies to local firms (Antonietti et al., 2015; Ascani et al., 2020). Previous studies recognize that the local absorptive capacity determines the ability to transform new knowledge from external sources on 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. In this way, local absorptive capacity is a requirement to understand and transform extra-regional inflows of knowledge into regional innovation. Local actors' absorptive capacity can reside not only on individuals and firms but also on 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; Crescenzi et al., 2015; Miguélez & Moreno, 2015). 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 are not able to absorb external knowledge from inward FDI (Cui & Xu, 2019; Ubeda & Pérez-Hernández, 2017).

There are several ways to assess the local absorptive capacity. Literature points out 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). Previous studies recognizes that the heterogeneity of local firms, and of the local innovation environment, are conditioning factors for inward FDI spillovers (Ascani & Gagliardi, 2020; Rojec & Knell, 2018). In this way, the greater and the broader local actors' capabilities are, the greater the ability of local actors 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. These capabilities may reside both in local private firms and in the local support institutions of the regional innovation system. Previous studies show that 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).

Taking first the local firms. Local firms are not equally able to learn from foreign companies. 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 it 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 are unable to absorb external knowledge from inward FDI spillovers (Cui & Xu, 2019; Fu, 2008; Moralles & Moreno, 2020; Tang & Zhang, 2016; Ubeda & Pérez-Hernández, 2017). Based on these assumptions, we expect that local firms' capabilities can provide to the region the capacity to absorb the inward FDI spillovers, which 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.

New knowledge from inward FDI does not exist in a "territorial vacuum" (Crescenzi & Iammarino, 2017), and the evolution of a region becomes increasingly dependent on its capacity to search for and absorb external knowledge. 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 as follows:

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

Finally, regional industrial structure is usually mentioned as a factor that moderates the effects of inward FDI spillovers on local innovation (Ascani & Gagliardi, 2020; Crespo & Fontoura, 2007; Gao, 2004; Ning et al., 2016; Wang et al., 2016). In general, previous literature has found that industrial diversity enhances inward FDI knowledge spillovers (Garcia et al., 2022; Wang et al., 2016). Diversified regions may have a broader knowledge base that can play an important role in absorbing knowledge spillovers from MNCs, since a diversified knowledge base may improve the ability to introduce new knowledge from multiple fields, leading to a cross-fertilization of the new knowledge brought to a region by inward FDI and its local knowledge base, with positive effects on innovation and learning. We expect the diversity of regional industrial structure are related to the capacity of local actors to benefit from inward FDI spillovers, with positive impacts on regional innovation. Based on these issues, we propose the following hypothesis:

H3: Regional industrial structure moderates 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 the 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 137 Brazilian mesoregions, which 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 use perform a Regional Knowledge Production Function. We use the fractional patent count per 1 million inhabitants in mesoregion r in period t ($Pat_{r,t}$) as our dependent variable. To exclude annual sporadic event effects, our measure of regional innovation is calculated over a 3-year time window, and this approach provides us with data covering four subsequent periods (2003–2005, 2006–2008, 2009–2011, and 2012–2014).

Our main independent variable of interest is inward FDI at the regional level, which allows us to examine how inward FDI affects regional innovation in Brazil. To measure the local firms' capabilities, we use the volume of industrial R&D researchers, by taking the number of R&D staff in manufacturing activities at private firms. Private firms R&D researchers is a proxy of industrial R&D expenditures at the regional level. Regarding the local academic efforts, our proxy for university R&D expenditures is the number of graduate scholarships at the regional level. Finally, we use the Hirschman-Herfindahl index (HHI) as a measure of the regional productive structure. HHI assumes values near 0 when employment is more equally distributed in local industries; and near 1 when employment is concentrated in some specific industries. Thus, the HHI is higher for specialized regions and lower for diversified ones. 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 empirical model is defined as follows:

$$\mathrm{Pat}_{r,t} = \beta_1 \mathrm{FDI}_{r,t-1} + \beta_2 \mathrm{HHI}_{r,t-1} + \beta_3 \mathrm{RDI}_{r,t-1} + \beta_4 \mathrm{RDU}_{r,t-1} + \beta_5 \mathrm{X}'_r + \mathrm{v}_{r,t}$$

where:

$$\mathrm{v}_{r,t} = \lambda \mathrm{W}\mathrm{u}_{r,t} + \varepsilon_{r,t}$$

where r denotes the mesoregion and t represents the time period. Our dependent variable is a proxy for regional innovation ($Pat_{r,t}$). As is typical in empirical models that intend to examine innovation, we add a one time period lag to independent variables, since innovative efforts go on for some years until the patent is complete. $FDI_{r,t-1}$ 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; the Hirschman-Herfindahl index of local manufacturing employment (HHI_{t-1}) encompasses the characteristics of the regional productive structure; and a vector X' for state dummies. Finally, $v_{r,t}$ is an error term.

4. Results and Discussion

4.1 Results of the Econometric Analysis

To examine the role of local absorptive capacity in moderating the relation between inward FDI spillovers and regional innovation, we initially estimate four models (Table 3). In model (1), we include all the variables of interest: inward FDI ($FDI_{r,t-1}$); the Hirschman-Herfindahl index (HHI_{t-1}); industrial R&D ($RDI_{r,t-1}$); and academic R&D ($RDU_{r,t-1}$). All the 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 ($RDU_{r,t-1}$). Finally, in model 4, we add the interaction term between inward FDI ($FDI_{r,t-1}$) and the Hirschman-Herfindahl index (HHI_{t-1}). We also test different spatial model specifications, such as SEM, SAR, SDEM, and SDM using an inverse distance spatial weight matrix. Results from spatial models suggest that we should use a spatial error model (SEM) (Table A1, Appendix).

TABLE 3 ABOUT HERE

Regarding the effects of inward FDI, results show that the effect of inward FDI spillovers on regional innovation is positive and significant only when we include the interaction term between inward FDI and the regional industrial structure (HHI) (model 4). In the other specifications, inward FDI spillovers have a nonsignificant effect on regional innovation. So, we can ensure that the contribution of inward FDI spillovers alone is very limited in fostering regional innovation.

The coefficient of industrial R&D ($RDI_{r,t-1}$) is in most of the specifications positive and significant, except in model 2. This result shows that local innovation is affected by industrial R&D expenditures at the regional level, showing the importance of the local firms' capabilities. In addition, the positive and significant coefficient of the interactive term between inward FDI and industrial R&D shows that the association between inward

FDI spillovers and local industrial R&D has positive effects on regional innovation (model 3). In this way, the higher the local industrial R&D is, the stronger is 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.

The coefficient of academic R&D ($RDU_{r,t-1}$) is also positive and significant in all the specifications, confirming that academic research impacts on regional innovation. In addition, the interaction between academic R&D with inward FDI spillovers shows that local academic efforts are another moderating factor in the relation between the 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 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 and thus confirms H2.

Regarding regional industrial structure, the coefficient the HHI ($HHI_{r,t-1}$) is negative and significant in all the specifications. This finding shows that the there is an association between diversification and innovation at local level. The negative coefficient shows that as a region becomes more diversified, its innovative performance improves, since HHI increases as a region becomes more specialized. We also confirm that regional industrial structure is a moderating factor in the relation between inward FDI spillovers and regional innovation. The coefficient of the interactive term between inward FDI and the HHI is also negative and significant (Model 2), suggesting that the higher is the diversity of the regional industrial structure, the stronger the effects of inward FDI spillovers on regional innovation, confirming H3.

In order to ensure that our results are not choice-sensitive, we estimate models with alternative specifications, as robustness check. Our dependent variable is filled patents in the Brazilian Intellectual Property Office, which encompasses high- and low-level innovation patents. In this way, to ensure innovation quality, we estimate new models with only high-level patents (Higham et al., 2021), by changing our dependent variable first for international patents (Pat PCT), and second for coinvented patents (Pat Coinv) (Models 5 to 10 in Table 4). Overall results remain the same. In addition, we also use an alternative spatial matrix specification using a Queen-contiguity matrix, and the results are quite similar (Table A.2 in Appendix).

TABLE 4 ABOUT HERE

4.2 Discussion

Our findings show the moderating role of local absorptive capacity in the relation between inward FDI spillovers and regional innovation. Empirical results allow us to assess how local firms' capabilities, local academic efforts, and regional industrial structure moderate the effects of inward FDI spillovers on regional innovation. The contribution of inward FDI alone to regional innovation is quite limited, since we cannot find a strong correlation between inward FDI and innovation at the regional level in our specifications. But this result is consistent with those from previous studies that show that there are mixed evidence on empirical studies regarding the effects of inward FDI spillovers on regional innovation (Rojec & Knell, 2018), even though several studies find positive effects of inward FDI spillovers both on productivity (Ascani & Gagliardi, 2020; Moralles &

Moreno, 2020) and on regional innovation (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 among local actors. In developed countries, previous studies show that the more favourable environment for interactive learning and innovation, usually associated with the existence of high local absorptive capacity, makes positive the effects of inward FDI spillovers on regional innovation (Ascani et al., 2020; Ascani & Gagliardi, 2020; Rojec & Knell, 2018; Valacchi et al., 2021). In these regions, the diversity and the complexity of local capabilities allow local actors to combine external knowledge provided by inward FDI and the 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 to absorb and incorporate new external knowledge provided by foreign investments (Ascani & Gagliardi, 2020; Garcia et al., 2022; Valacchi et al., 2021; 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.

Our research is applied an emerging country, as Brazil, and empirical results show that is very limited the contribution of inward FDI spillovers alone to foster regional innovation. The transfer of knowledge from foreign companies to local firms 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 can only be seen when we add the interaction term of the variable for inward FDI to other variables related to the local absorptive capacity, such as local firms' capabilities, local academic efforts, and regional industrial structure. Factors related to the 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. In this way, the strength of the positive effect of the 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 the local private R&D expenditures and the inward FDI positively affect regional innovation. Our study applied to an emerging country adds new empirical findings that allows us to assure that local firms with high absorptive capacities have the necessary capabilities to internalize the more complex knowledge provided by foreign companies. High 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 as local firms with existing knowledge capabilities are better able to learn from foreign companies, with positive effects on regional innovation. High skilled firms are more able to learn with the new knowledge provided by foreign companies and apply it into new products and processes. Our findings also show that the

heterogeneity of local firms is also another 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 ecosystem as another important moderating factor on the relation between inward FDI spillovers and regional innovation. Once more, we cannot find positive effects of inward FDI alone on innovation. However, when inward FDI is combined with higher academic R&D expenditures, they positively affect regional innovation. Previous studies have pointed out the importance of the regional innovation environment to foster the positive effects of the inward FDI spillovers (Fu, 2008; Li et al., 2018). Our findings add new empirical evidence that the institutions of the regional innovation ecosystem 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 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.

Regarding the regional industrial structure, our empirical results show that the combination of inward FDI spillovers and the diversity of the regional productive structure can exert strong effects on regional innovation. Confirming previous empirical results (Garcia et al., 2022; Ning et al., 2016; Wang et al., 2016), our findings show that inward FDI is an important source of new knowledge for regions with complex and diversified local capabilities. The combination of diverse local knowledge with new external knowledge introduced to a region through the foreign companies can create new knowledge combinations that foster innovation at regional level. Diversified regions feature better conditions for absorbing new knowledge because they cover a broader scope of technological fields and have denser vertical and horizontal linkages.

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 the 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, as Brazil, where the lack of technological capabilities among local actors hinders local firms to absorb and incorporate new external knowledge provided by foreign companies. In this way, the contributions of inward FDI alone to regional innovation are quite limited. Nevertheless, high local absorptive capacity, both among private firms, and on local supportive institutions, can leverage the positive effects of inward FDI spillovers on regional innovation. In this way, when inward FDI is combined 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 the local actors in such regions are more able to combine existing local knowledge bases with new knowledge brought by foreign companies. Therefore, our empirical findings allow us to conclude that the regional productive structure and the local absorptive capacity are moderating factor of 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 regional industrial structure and the local absorptive capacity moderate the effects of inward FDI spillovers on regional innovation. Thus, for regional innovation to benefit from inward FDI spillovers, it is necessary they have a complex set of local capabilities that could be able to absorb the new knowledge brought 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. However, the contributions of inward FDI alone to regional innovation are quite limited. 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 alone have limited 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, these policies should be combined with policies aimed at building and strengthening local absorptive capacity, in order to create 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, supporting local academic efforts, and foster the diversification of the regional industrial structure. These are the main factors that moderates the relation between inward FDI spillovers and regional innovation.

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Tables and Figures

Table 1 - Definition of the variables in mesoregions

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 1 million inhab. in log form	fDI Markets
RDI	Local firms' capabilities: Number of R&D researchers per 100 workers in manufacturing in log form	RAIS
RDU	Local academic efforts: Number of graduate scholarships per 1 million inhab. in log form	GEOCAPES and IBGE
HHI	Regional industrial structure: Hirschman-Herfindahl index of the meso-region employment (2 digit)	RAIS

Source: own elaboration.

Table 2 - Descriptive statistics of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Pat	548	1.072	0.874	0	3.355
FDI	548	1.217	2.172	0	8.043
RDI	548	0.498	0.306	0	1.935
RDU	548	172.775	355.581	0	2898.405
HHI	548	0.234	0.148	0.060	0.888

Table 3 – Regression Estimations Results (SEM). PAT as dependent variable

Variables	(1)	(2)	(3)	(4)
$FDI_{r,t-1}$	0.0118	-0.0140	-0.0176	0.0752***
	(0.00851)	(0.0165)	(0.0117)	(0.0178)
$RDI_{r,t-1}$	0.264**	0.180	0.256**	0.202*
	(0.106)	(0.115)	(0.103)	(0.104)
$RDU_{r,t-1}$	0.000397***	0.000393***	0.000375***	0.000392***
	(6.17e-05)	(6.16e-05)	(6.08e-05)	(6.09e-05)
$HHI_{r,t-1}$	-0.698***	-0.704***	-0.695***	-0.636***
	(0.204)	(0.204)	(0.198)	(0.200)
$FDI_{r,t-1} * RDI_{r,t-1}$		0.0449*		
		(0.0247)		
$FDI_{r,t-1} * RDU_{r,t-1}$			0.0104***	
			(0.00284)	
$FDI_{r,t-1} * HHI_{r,t-1}$				-0.319***
				(0.0790)
W u_t	0.824***	0.830***	0.831***	0.836***
	(0.0642)	(0.0624)	(0.0622)	(0.0607)
Constant	0.721***	0.758***	0.695***	0.715***
	(0.269)	(0.269)	(0.253)	(0.258)
Observations	548	548	548	548
Number of regions	137	137	137	137
State dummies	Yes	Yes	Yes	Yes
R^2	0.7445	0.7553	0.7650	0.7589
AIC	412.23	401.58	400.85	398.08

Table 4 – Regression Estimations Results (SEM)

Variables	(5) Pat PCT	(6) Pat PCT	(7) Pat PCT	(8) Pat Coinv	(9) Pat Coinv	(10) Pat Coinv
$FDI_{r,t-1}$	-0.0181***	0.000234	0.00879***	-0.0376**	-0.00730	0.0494***
	(0.00316)	(0.00108)	(0.00165)	(0.0181)	(0.00592)	(0.00914)
$RDI_{r,t-1}$	0.0361***	0.0514***	0.0479***	0.145***	0.172***	0.149***
	(0.00855)	(0.00845)	(0.00840)	(0.0504)	(0.0465)	(0.0475)
$RDU_{r,t-1}$	1.03e-05**	7.96e-06	1.05e-05**	0.000368***	0.000351***	0.000371***
	(5.07e-06)	(5.29e-06)	(5.15e-06)	(3.00e-05)	(2.94e-05)	(2.97e-05)
$HHI_{r,t-1}$	-0.00159	0.00259	0.00805	-0.152	-0.127	-0.102
	(0.0158)	(0.0163)	(0.0161)	(0.0934)	(0.0898)	(0.0910)
$FDI_{r,t-1} * RDI_{r,t-1}$	0.0192***			0.0458***		
	(0.00279)			(0.0160)		
$FDI_{r,t-1} * RDU_{r,t-1}$		0.000912***			0.00689***	
		(0.000250)			(0.00141)	
$FDI_{r,t-1} * HHI_{r,t-1}$			-0.0295***			-0.185***
			(0.00752)			(0.0408)
W u_t	0.546***	0.617***	0.619***	0.827***	0.834***	0.831***
	(0.160)	(0.136)	(0.137)	(0.0713)	(0.0690)	(0.0692)
Constant	-0.00293	-0.0140	-0.0129	0.0493	0.00850	0.0227
	(0.0182)	(0.0188)	(0.0181)	(0.112)	(0.105)	(0.106)
Observations	548	548	548	548	548	548
Number of regions	137	137	137	137	137	137
State dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5265	0.4921	0.5140	0.7000	0.7207	0.7188
AIC	-2284.86	-2252.52	-2254.71	-358.86	-374.10	-371.23

Apêndix

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

Variables	(A1) OLS	(1) SEM	(A2) SAR	(A3) SDEM	(A4) SDM
$FDI_{r,t-1}$	0.0172*	0.0118	0.00999	0.0140	0.0129
	(0.00939)	(0.00851)	(0.00854)	(0.00866)	(0.00860)
$RDI_{r,t-1}$	0.289***	0.264**	0.219**	0.267**	0.266**
	(0.111)	(0.106)	(0.106)	(0.106)	(0.105)
$RDU_{r,t-1}$	0.000466***	0.000397***	0.000348***	0.000388***	0.000391***
	(6.38e-05)	(6.17e-05)	(5.90e-05)	(6.07e-05)	(6.02e-05)
$HHI_{r,t-1}$	-0.848***	-0.698***	-0.635***	-0.652***	-0.736***
	(0.220)	(0.204)	(0.206)	(0.217)	(0.210)
W $FDI_{r,t-1}$				0.0185	-0.0502
				(0.103)	(0.0803)
W $RDI_{r,t-1}$				-1.770	-2.460**
				(1.355)	(1.058)
W $RDU_{r,t-1}$				0.000401	0.000507
				(0.000722)	(0.000469)
W $HHI_{r,t-1}$				1.443	-1.625
				(3.541)	(2.664)
W u_t		0.824***		0.830***	
		(0.0642)		(0.0702)	
W $Pat_{r,t}$			0.718***		0.730***
			(0.0686)		(0.0876)
Constant	0.747***	0.721***	0.392	1.337	1.468
	(0.278)	(0.269)	(0.275)	(1.124)	(1.149)
Observations	548	548	548	548	548
Number of regions	137	137	137	137	137
State dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.7544	0.7445	0.7394	0.7931	0.8048
AIC	–	412.23	416.07	425.68	431.41

Table A.2 – Queen Contiguity Matrix results. Pat as dependent variable

Variables	(18) SEM	(19) SAR	(20) SDEM	(21) SDM
$FDI_{r,t-1}$	0.0128	0.0140	0.0184**	0.0172*
	(0.00898)	(0.00916)	(0.00910)	(0.00905)
$RDI_{r,t-1}$	0.304***	0.296***	0.324***	0.348***
	(0.109)	(0.109)	(0.102)	(0.101)
$RDU_{r,t-1}$	0.000426***	0.000444***	0.000392***	0.000394***
	(6.26e-05)	(6.17e-05)	(5.92e-05)	(6.01e-05)
$HHI_{r,t-1}$	-0.812***	-0.804***	-0.861***	-0.860***
	(0.208)	(0.212)	(0.211)	(0.203)
W $FDI_{r,t-1}$			0.0379	0.0156
			(0.0262)	(0.0228)
W $RDI_{r,t-1}$			-0.324	-0.499*
			(0.301)	(0.263)
W $RDU_{r,t-1}$			0.000233	7.95e-05
			(0.000172)	(0.000156)
W $HHI_{r,t-1}$			-0.584	-0.178
			(0.713)	(0.609)
W u_t	0.429***		0.408***	
	(0.0683)		(0.0682)	
W $Pat_{r,t}$		0.247***		0.318***
		(0.0559)		(0.0661)
Constant	0.749***	0.691**	1.048***	1.019***
	(0.261)	(0.271)	(0.266)	(0.270)
Observations	548	548	548	548
Number of regions	137	137	137	137
State dummies	Yes	Yes	Yes	Yes
R^2	0.7509	0.7422	0.8114	0.8149
AIC	464.18	479.07	462.60	472.21