Regional linkages and branching: An empirical study of Brazilian regions

Suelene Mascarini
Postdoctoral Researcher and Collaborative Professor at the Institute of Economics of University of Campinas, Brazil

Renato Garcia
University of Campinas, Brazil

Mabel Diz Marques
University of Bahia, Brazil

Francesco Quatraro
University of Turin

Abstract
A large body of literature demonstrates that regions build on the foundation existing capabilities to develop new activities or reinforce existing activities. Researchers argue that this process requires regions to identify and create links to different regions that can provide them with access to external knowledge as a means of addressing the tendency of regions towards lock-in. In this context, few empirical studies investigate the role played by regional links in regional branching or specialization. Analysing 127 classes of technologies across 135 Brazilian mesoregions during the period 1997-2019, this work attempts to address this research gap. We find strong evidence that both intra- and interregional linkages contribute to regional branching. In addition, linkages that are outside the region's technological portfolio are likely to impede regional branching, while linkages that are inside the region's technological portfolio are likely to promote regional branching. Therefore, the local absorptive capacity of regions is crucial to the diversification process for Brazilian mesoregions. In addition, regional linkages per se tend to impede the entry of new technologies to Brazilian regions, while technological linkages both inside and outside the region's technological portfolio tend to increase the probability of regional specialization. Therefore, a new technology has a higher probability of being introduced to a region when this region is connected to other regions that offer different technological capabilities in a manner that is independent of absorptive capacity.

Keywords: Regional linkages. Branching. Regional Specialization.

Area 11. Empreendedorismo, redes, arranjos produtivos e inovação

JEL classification: O30; O31; O33

INTRODUCTION

In recent decades, in the context of the innovation economics literature, increased efforts have been made to understand the role played by technological specialization and knowledge complexity (P. A. Balland & Boschma, 2021; Krafft et al., 2014; Montresor & Quatraro, 2017; Petralia et al., 2017; Rigby, 2015). These studies have shown that local capabilities, which are a primary source of regional change, can be developed from regions' competitive advantage in new domains in which those regions possess capabilities.

In this line of research, scholars have argued that the regional linkages can provide regions with access to crucial knowledge that essential to regional technological branching. (Ascani et al., 2020; P. A. Balland & Boschma, 2021; Tavassoli & Carbonara, 2014). Despite these claims in the literature, our understanding of how regional branching is affected by different regional linkages remains limited. In addition, scholarly attention has focused mainly on developed countries and regions close to the technological frontier, and much less is known regarding regions in developing countries. In fact, very few studies have explored technological diversification and regional linkages, and the few studies that exist and have often been restricted to the analysis of a handful of developed economies (P. A. Balland & Boschma, 2021). As a result, we lack a robust and comprehensive set of evidence concerning the basic character of the types of regional linkages are related to probability to introduce new technological capabilities in developing economies.

In Brazil, over the last decade, studies pertaining to the territorial dynamics of innovation and the existence of spatial concentration have emerged (Araújo & Garcia, 2019; Mascarini et al., 2019). Regarding the dynamics of innovation, particular attention has been given to the speed of the process of technological accumulation that each company adopts to progress through different levels of technological capacity (Mascarini et al., 2021; Miranda & Figueiredo, 2010). We continue to have no understanding of the impact of regional links on regional branching or specialization in this context.

This study contributes to addressing this gap. In this way, using patent data taken from the Brazilian Patent Office (INPI - National Institute of Industrial Property) concerning 137 Brazilian mesoregions during the period 1997-2019, this paper has two aims. The first objective is to investigate the impact of different regional ties (i.e., both intraregional and interregional) on regional branching. We expect both intra- and interregional linkages to have a positive impact on the ability of regions to diversify. Indeed, we do find strong evidence that regional branching likely promotes both intra- and interregional linkages. However, the positive effect of interregional linkages is related to pre-existing technologies in the region. Connecting to specialized regions in a technology that is missing in the region could decrease the probability of diversification for regions in Brazil. On the other hand, the addition of ties with other specialized regions in a technology that is pre-existing in the region might promote regional branching. That is, the region's technological portfolio or absorptive capacity of regions is mediator the relationship between regional linkages and branching. These results allow us to say that the absorptive capacity of regions is more significant than the partners to which those regions are connected.

The second objective of this paper is to examine the effect of regional linkages (both intraregional and interregional) on the probability of regions developing new technological specializations. Our findings suggest that regional linkages per se tend to impede regional specialization, while linkages with other regions that are specialized in a given technology, whether that technology is inside or outside of the initial region's technological portfolio, tend to increase the probability of the region developing new technological specializations. That is, in the context of the specialization process, the partners with which a region is connected are a noteworthy factor. The remainder of the paper is structured as follows.

This paper adds to the literature in two aspects. First, while the literature points out the importance of regional linkages on technological diversification, there is scarce understanding of how here little understanding of how intra- and inter-regional linkages is may affect the development of new activities in regions, especially, if found important, to what extent interregional linkages can compensate for weak or missing capabilities in a region. Second, there is a substantial lack of literature in this domain focusing on developing countries. Our focus on Brazilian firms can help shedding new light on regional branching and specialization in these contexts.

The following section provides a short literature review. We then describe the data set and variables used in this study. Subsequently, we present and discuss our findings concerning the impact of regional ties on regional branching and specialization in Brazilian mesoregions. The final section offers a conclusion.

THEORETICAL BACKGROUND

It is broadly accepted that territories differ in terms of their ability to diversify and adapt to change (Rigby, 2015). This claim also holds true of the ability of these territories to develop both new technologies in general and new technological advantages (P. A. Balland & Rigby, 2017). Several empirical studies related to the innovation economy indicate an unequal distribution of regional knowledge production (Crescenzi & Jaax, 2016; Crescenzi & Rodríguez-Pose, 2017; Mewes & Broekel, 2020) and emphasize the importance of local capabilities, in particular technological relatedness, as a source of regional change (P. A. Balland & Boschma, 2021; Noni et al., 2018; Tavassoli & Carbonara, 2014). The concept of technological relatedness is based on the view that knowledge has an architecture that is constructed on the foundation of similarities in the ways that different types of knowledge can be used. This situation occurs when knowledge subsets that are close substitutes for one another or require similar sets of cognitive abilities and skills to be used (P. A. Balland et al., 2018) are simultaneously present in the knowledge space[1] (P. A. Balland & Rigby, 2017).

The idea that technological relatedness favours regional diversification has been documented for a number of regions (R. Boschma et al., 2015; Rigby, 2015) and specific technologies in developed countries, including green technologies (Montresor & Quatraro, 2019; Santoalha & Boschma, 2021), biotechnologies (Ron Boschma et al., 2014) and technologies related to Industry 4.0 (P.-A. Balland & Boschma, 2021). Without exception, these studies have confirmed the importance of technological relatedness in the process of technological change. That is, regions face diversification costs that decrease as the level of proximity to related technological areas increases, and therefore, such regions should be more likely to introduce new specializations that are similar and/or related to those they already possess because these specializations feature similar (but not identical) capabilities, such as knowledge, skills, and institutions (P. A. Balland & Boschma, 2021).

Although this body of literature has emphasized the benefits and effectiveness of technological relatedness in the process of technological change in various countries and regions, we still have much to learn regarding the effect of regional linkage intensity on technological change, especially in the contexts of regions with developing economies. In the literature pertaining to regional diversification, some evidence has been found to suggest that (distinct) regions are connected via common goals and the need to expand and promote

[1] Inspired by the concept of "product space" (HIDALGO et al., 2007), the notion of the knowledge space is determined via an analysis of co-occurrences in technological areas.

innovative-inventive activity (Barzotto et al., 2019; Tóth et al., 2021; Wanzenböck & Piribauer, 2018).

Empirical evidence supports the claim that those regional linkages can promote innovation, i.e., that stimulating the flow of knowledge and ideas in different geographic regions is likely to be relevant for technological branching in regions. However, it is important to distinguish between intra- and interregional linkages because the significance of these types of linkage for these processes can differ (Broekel et al., 2015; De Noni et al., 2017; Santoalha, 2019).

While intraregional linkages can be important for connecting different regional actors and providing new knowledge to the organizations involved, interregional linkages can also facilitate this process by introducing resources that were previously unavailable to such regions. Theoretical arguments concerning the specific mechanisms that underlie such processes range from arguments focused on productivity and efficiency to those oriented towards spillover and agglomeration effects (De Noni et al., 2017; Santoalha, 2019). Interregional linkages are viewed as providing regions with access to external knowledge that can allow them to combat or circumvent the tendency of regions towards technological lock-in and path dependence (Noni et al., 2018; Tavassoli & Carbonara, 2014). Therefore, interregional linkages provide access to complementary and additional capacities, thus increasing technological branching in regions, especially peripheral regions (Wanzenböck & Piribauer, 2018). A reason for this effect is that inventive local production may not be sufficient to sustain innovation and technological diversification.

Thus, it seems possible for both forms of cooperation to have a positive impact on regional diversification. In this way, we formulate two initial hypotheses:

H1: The more intraregional linkages are, the greater (lower) the level of regional branching (specialization)

H2: The more the interregional linkages are, the greater (lower) the level of regional branching (specialization)

In the context of interregional linkages, one important aspect to consider is the role played by absorptive capacity. The impact of the absorption of external knowledge from other regions on innovation may also depend on a region's existing absorptive capacity derived from technological linkages. Previous studies have shown that regions are more capable of developing new activities in which their neighbouring regions are already specialized (Ron Boschma et al., 2017; De Noni et al., 2017; Santoalha, 2019). Noni et al. (2018) found that regions tend to be more innovative and therefore more competitive when they develop collaborative linkages with technology-intensive regions. On the one hand, regions that exhibit a high level of technological knowledge production are more likely to connect with one another and/or with nearby regions, (P. A. Balland & Boschma, 2021), as local capacities tend to encourage and benefit from knowledge spillover effects (Araújo & Garcia, 2019; Gonçalves & Fajardo, 2011; Jaffe et al., 1993). On the other hand, underdeveloped regions in particular rely on nonlocal linkages to innovate because their own local capacities and networks tend to be weak and limited (P.-A. Balland & Boschma, 2021; Fitjar & Rodríguez-Pose, 2011).

In fact, it is necessary to understand that regions require absorptive capacity to employ external knowledge, thereby circumventing the tendency of regions towards technological stagnation and lock-in. In this sense, it is important for regions to collaborate with other regions that possess technologies outside the scope of the regions, but this fact does not mean that such technologies can be outside the portfolio of the region because absorptive capacity is also necessary in this context. Based on these insights, we formulate our final two hypotheses.

H3: Regions that establish more interlinkages that are outside their technological portfolio are less capable of regional branching.

H4: Regions that establish more interlinkages that are inside their technological portfolio are more capable of regional branching.

DATA, VARIABLES, AND METHODS

To analyse the impact of regional linkages on technological branching and specialization in Brazil during the period 1997-2019, we developed a diversification/entry model to assess the probability that a region will specialize in a new technology, following the suggestions of other papers concerning regional branching (P. A. Balland & Boschma, 2021; Montresor & Quatraro, 2017; Rigby, 2015). We employed patent data drawn from the Brazilian Patents Office (INPI - National Institute of Industrial Property).

In the study, we assigned patents to 127 technological classes (International Patent Classification) and 135 Brazilian mesoregions based on the addresses of inventors. In line with the previous literature concerning the emergence of new activities in regional contexts (P. A. Balland et al., 2018; P. A. Balland & Boschma, 2021; Montresor & Quatraro, 2017), we employed two dependent variables.

The first dependent variable was built by looking at region acquisition of a new technological specialization *j* at time *t*, that is, a technological specialization (*RTA*) that the region did not have at previous time (t–1), named *NewEntry*.

$$NewEntry_{r,i,\Delta t} = M_{r,i,t} - M_{r,i,t-1}$$

$$\text{such that } M_{r,i,t} = 1 \; if RTA_{r,i,t} = \frac{Pat_{r,i,t} / \sum_i Pat_{r,i,t}}{\sum_r Pat_{r,i,t} / \sum_r \sum_i Pat_{r,i,t}} > 1.5$$

NewEntry is thus linked to the emergence of a revealed technological advantage, but it should be interpreted differently from $RTA_{r,j,t}$. In particular, a nil value for it may denote both the absence of specialization in technology *i*, as for $RTA_{r,j,t}$, and a technological specialization in *i* that the region keeps from the previous period: although different, both situations fall outside the acquisition of a new technological specialization. In addition, a -1 value denote a loss of specialization, since there is technological specialization in *t-1* and the absence of specialization in technology in *t*. In other words, acquisition of new specialization is only may denoted by a 1 value, that it is there is absence of specialization in *t-1* and specialization *t*.

The second dependent variable was built by looking at regional branching (new technological diversification, ***Branch)***, that is, the sum of new technological specialization in the mesoregion. Whereas it is possible occur loss of technological specialization, a negative value of the ***Branch*** demonstrates loss technological diversification, while a positive value represents a regional branching. $Branch_{r,\Delta t} = \sum_i NewEntry_{r,i,\Delta t}$

As we have patent data for the period 1997–2019, we calculate both for five subsequent periods (1997–99, 2000–04, 2005–09, 2010–14 and 2015–19).

All independent variables are measured in the period before the time window of five years. Our first main variable of interest is the intraregional linkages. This indicator is based on co-inventors residing in the same mesoregion. Intraregional linkages are measured by the number of linkages (***IntraLink***) between inventors in one region with inventors in the same mesoregion.

The second independent variable was interregional linkages. This indicator was based on the number of co-inventors residing in different regions, measured by the number of linkages (***InterLink***) between inventors in one region with one or multiple inventors in one or more different mesoregions.

The final main variable of interest pertained to pre-existing technological capabilities in the context of interregional linkages. This indicator was based on the number of co-inventors residing in different regions that exhibited different technological capacities. As discussed previously, we expected that local capabilities would shape the impact of interregional linkages on regional diversification. We constructed two new variables termed interregional linkages outside the local region's technological portfolio (*OuTech*) and interregional linkages inside the local region's technological portfolio (*InTech*). The first variable was measured in terms of the number of connections between one region and other specialized regions in a technology for which the region did not exhibit any activity, that is, a technology that was outside the region's technological portfolio.

The second variable was measured by the number of connections between one region and other specialized regions in a technology for which the region exhibits some activity but is not specialized in, i.e., a technology that is inside the local region's technological portfolio. Thus, the primary difference between the two measures is the region's previous knowledge of the technology in question, which was completely absent in the context of ***OuTech***, while in the context of ***InTech***, such previous knowledge exists.

We also included two control variables. First, we included gross domestic product (GDP) per capita to account for the level of economic development within a region. We expected that the higher a region's GDP per capita was, the higher the probability of that region diversifying or acquiring a new specialization. Second, we controlled for the level of population (log) within a region to account for regions with different population sizes. Again, we expected a positive effect in this context.

TECHNOLOGICAL BRANCHING IN BRAZILIAN REGIONS

Table 2 presents the findings concerning the regional branching model. Initially, the most notable finding from Model 1 is that the coefficients of our control variables are positive and significant: population size and GDP per capita tend to increase regional branching.

In Model 2, we find a positive impact from the number of intraregional linkages (*Intralink*), thus suggesting that a new technology has a higher probability of being introduced to a region when this region has certain inside connections. Thus, this result indicates that intraregional ties support the recombination and sharing of knowledge that is important for regional branching, thereby confirming H1.

In Model 3, we test our variable for interregional linkages (*InterLink*) independently from the effects of technological differences across regions. As expected, we find a positive and significant relationship. Being connected to other regions is positive related to technological diversification. Therefore, our findings suggest that interregional linkages tend to contribute to the introduction of new technologies to Brazilian regions that promote regional branching, thereby confirming H2.

In Model 4, we add an interaction variable between intraregional and interregional linkages (*IntraLink*InterLink*) to determine whether the two variables are substitutes or complements to one another. Our findings show that the interaction effect is positive and significant: the higher the level of internal linkage within a region is, the stronger the possible impact of external connections. Therefore, intraregional linkages tend to reinforce the effect of interregional linkages on technological diversification in regions in Brazil.

In Models 5-10, we test our variables related to pre-existing technological capabilities in the context of interregional linkages. We find a negative and significant coefficient for interregional linkages that are outside the region's technological portfolio (*OuTech*, Model 5).

This result suggests that more interregional linkages that are outside the region's technological portfolio decrease regional branching. That is, adding links with specialized regions in a particular technology in which the region has no competence impedes regional branching. Therefore, an additional connection with regions that are specialized in a technology for which the region does not have sufficient absorptive capacity comes at the cost of diversifying this region, confirming *H3*.

Regarding the number of interregional linkages that are inside local region's technological portfolio we find a positive impact on regional branching (*InTech,* Model 8), thus suggesting that a new technology has a higher probability of being introduced to a region when that region has connections to other specialized regions in the technologies that region has some degree of absorptive capacity, thereby confirming *H4*. Additionally, it is important to note that the positive effect of interregional linkages per se become non statically significant in this context (Models 9 and 10). Thus, reinforcing the results obtained previously and confirming the claim that the region's absorptive capacity shapes the relation between regional linkages and branching. In this sense, it is important for regions to collaborate with other regions that offer technologies outside the scope of the region, but this fact does not entail that these technologies can be outside the portfolio of the region because absorptive capacity is also necessary in this context. Therefore, our findings suggest that technological branching in Brazilian regions is less closely related to the partner to with which a region is connected and more closely related to the absorptive capacity of the regions in question.

TECHNOLOGICAL SPECIALIZATION IN BRAZILIAN REGIONS

Table 1 presents the findings of the regional entry model. As in the previous model, the coefficients of our control variables are positive and, in most cases, significant: population size and GDP per capita tend to increase the probability of new technologies being introduced into regions.

In Models 2 and 3, in contrast to the results concerning regional branching, we find negative impacts from the number of intraregional (*IntraLink*) and interregional (*InterLink*) connections. In this way, being connected to other regions is negatively related to technological specialization. Therefore, our findings suggest that both types of linkages, intraregional and interregional, tend to impede the introduction of new technologies to Brazilian mesoregions, thus confirming *H1* and *H2*. In Model 4, we added an interaction variable between intraregional and interregional linkages (*Intra*Inter*) to determine whether the two types of linkage are substitutes or complements for one another. Our findings show that this interaction is not significant.

Regarding pre-existing technological capabilities, we find a positive and significant coefficient for interregional linkages both outside and inside the region's technological portfolios (*OuTech* and *InTech, Models 5-10,* Table 1), thus suggesting that a region has a higher probability of specializing in a new technology when it has connections to other specialized regions in a manner that is independent of its absorptive capacity.

It is important to note that in all the models, the coefficients for intra- and inter-linkages are negative and significant even when we control for *OuTech* and *InTech*, thus suggesting that regional linkages per se come at a cost. Adding connections to other regions that do not have a strong technological structure is costly and can impede the introduction of a new technology specialization to a region. Therefore, our findings indicate that the partners with which a region is connected are a noteworthy factor in this context

Table 1: Branching model (diversification)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intraregional linkages		0.193***		0.148**		0.082	0.073		0.139*	0.130*
(IntraLink) (log)		(0.072)		(0.074)		(0.075)	(0.075)		(0.074)	(0.074)
Interregional linkages			0.241***	0.162*		0.100	0.071		0.035	0.005
(InterLink) (log)			(0.086)	(0.089)		(0.089)	(0.089)		(0.089)	(0.090)
IntraLink*InterLink				0.000***			0.000***			0.000***
				(0.000)			(0.000)			(0.000)
Interregional linkages outside the local region's technological portfolio (OuTech)					-0.584***	-0.563***	-0.566***			
					(0.059)	(0.060)	(0.060)			
Interregional linkages outside the local region's technological portfolio (InTech)								0.745***	0.729***	0.733***
								(0.076)	(0.077)	(0.077)
Population (log)	7.603***	7.604***	7.609***	7.616***	7.492***	7.499***	7.507***	7.574***	7.576***	7.584***
	(0.374)	(0.374)	(0.374)	(0.374)	(0.373)	(0.373)	(0.373)	(0.373)	(0.373)	(0.373)
GDP per capita (log)	2.570***	2.613***	2.616***	2.646***	2.513***	2.553***	2.558***	2.792***	2.825***	2.831***
	(0.145)	(0.146)	(0.145)	(0.146)	(0.145)	(0.146)	(0.146)	(0.146)	(0.147)	(0.147)
2.T	-3.516***	-3.556***	-3.555***	-3.582***	-3.407***	-3.444***	-3.446***	-3.723***	-3.753***	-3.757***
	(0.119)	(0.119)	(0.119)	(0.119)	(0.119)	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)
3.T	-7.333***	-7.405***	-7.408***	-7.456***	-7.164***	-7.232***	-7.237***	-7.690***	-7.745***	-7.753***
	(0.196)	(0.197)	(0.196)	(0.197)	(0.196)	(0.198)	(0.198)	(0.197)	(0.198)	(0.198)
4.T	-5.162***	-5.253***	-5.264***	-5.326***	-4.912***	-5.003***	-5.011***	-5.617***	-5.688***	-5.701***
	(0.276)	(0.278)	(0.277)	(0.278)	(0.277)	(0.280)	(0.280)	(0.278)	(0.280)	(0.280)
Constant	-104.430***	-104.517***	-104.579***	-104.736***	-102.796***	-102.955***	-103.070***	-104.386***	-104.471***	-104.596***
	(5.161)	(5.164)	(5.163)	(5.164)	(5.144)	(5.151)	(5.151)	(5.148)	(5.151)	(5.150)
Observation	68,580	68,580	68,580	68,580	68,580	68,580	68,580	68,580	68,580	68,580
R-squared	0.133	0.133	0.133	0.133	0.134	0.135	0.135	0.135	0.135	0.135
F	1582	1333	1337	1013	1328	1011	902.0	1371	1041	928.1
ll_0	-196417	-196417	-196417	-196417	-196417	-196417	-196417	-196417	-196417	-196417
ll	-191543	-191536	-191537	-191525	-191467	-191464	-191456	-191451	-191447	-191439
r2_a	0.132	0.133	0.133	0.133	0.134	0.134	0.135	0.135	0.135	0.135

Table 2: New entry (regional specialization)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intraregional linkages (IntraLink) (log)		-0.191***		-0.177***		-0.147***	-0.147***		-0.182***	-0.182***
		(0.008)		(0.008)		(0.008)	(0.008)		(0.007)	(0.007)
Interregional linkages (InterLink) (log)			-0.131***	-0.077***		-0.038***	-0.039***		-0.142***	-0.144***
			(0.010)	(0.010)		(0.010)	(0.010)		(0.009)	(0.009)
IntraLink*InterLink				0.000			0.000			0.000*
				(0.000)			(0.000)			(0.000)
Interregional linkages outside the local region's technological portfolio (OuTech)					0.243***	0.217***	0.217***			
					(0.006)	(0.006)	(0.006)			
Interregional linkages outside the local region's technological portfolio (InTech)								0.301***	0.332***	0.332***
								(0.007)	(0.007)	(0.007)
Population (log)	0.062	0.091**	0.076*	0.098**	0.074*	0.100**	0.100**	-0.018	0.018	0.019
	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.041)	(0.041)
GDP per capita (log)	0.029	-0.022	-0.001	0.035*	0.037*	-0.012	-0.012	0.139***	0.069***	0.070***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
2.T	-0.038***	0.008	-0.014	0.018	-0.080***	-0.032**	-0.033**	-0.139***	-0.079***	-0.079***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.013)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
3.T	-0.077***	0.006	-0.030	0.027	-0.135***	-0.051**	-0.051**	-0.249***	-0.137***	-0.138***
	(0.023)	(0.023)	(0.024)	(0.024)	(0.023)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
4.T	-0.059*	0.044	0.003	0.072**	-0.139***	-0.032	-0.033	-0.274***	-0.130***	-0.131***
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.033)	(0.032)	(0.032)
Constant	-0.862	-1.176**	-1.018*	-1.250**	-1.070*	-1.334**	-1.339**	0.044	-0.331	-0.342
	(0.573)	(0.572)	(0.573)	(0.572)	(0.574)	(0.574)	(0.575)	(0.573)	(0.567)	(0.567)
Observation	56,316	56,316	56,316	56,316	56,316	56,316	56,316	56,316	56,316	56,316
R-squared	0.001	0.026	0.008	0.028	0.046	0.062	0.062	0.054	0.090	0.090
F	11.71	106.8	39.93	87.32	310.1	280.3	249.3	305.8	378.9	337.6
ll_0	-27493	-27493	-27493	-27493	-27493	-27493	-27493	-27493	-27493	-27493
ll	-27454	-26759	-27262	-26696	-26161	-25691	-25690	-25922	-24833	-24827
r2_a	0.00141	0.0257	0.00819	0.0279	0.0462	0.0620	0.0620	0.0543	0.0902	0.0903

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

CONCLUSIONS

Despite previous studies regarding regional linkages and branching/specialization, our understanding of the ways in which regional linkages can provide access to relevant capabilities that can allow a region to diversify, the ways in which such linkages might affect the development of new activities in regions and the extent to which these relations are shaped by the existence or absence of relevant capabilities in regions, especially in the context of developing countries, remains limited. To address this gap in the scientific literature, this paper estimated the possible effects of intraregional and interregional linkages on the capability of Brazilian regions to diversify into new technologies or to specialize. We developed two indicators for pre-existing technological capabilities in interregional linkages to account for the fact that regions require absorptive capacity to exploit and benefit from the introduction of external knowledge via interregional linkages. These indicators highlight whether the impact of coinventor linkages with other regions that can provide access to relevant capabilities on diversification and specialization is moderated by pre-existing technological capabilities within the region.

The main findings of this study indicate a positive relationship between intra- and interregional linkages and the probability of regions diversifying. Furthermore, these ties are mutually reinforcing. In other words, our results showed that connections, whether intra- or interregional, can provide access to important knowledge and capabilities that promote regional branching. However, the relation between interregional linkages and diversification is shaped by the absorptive capacity of regions. Adding links to specialized regions in a technology in which the region has no competence impedes regional branching. In contrast, adding links to regions that are specialized in a technology in which the region has competence can increase the region's ability to diversify into a new technology. Therefore, absorptive capacity is relevant to the regional branching process.

Regarding the process of regional specialization, our main findings show that regional linkages per se, whether intra- or interregional, can decrease the ability of a region to specialize in a new technology. On the other hand, connections to other regions that are specialized in a technology provide additional capabilities to regions that can increase the probability of regional specialization regardless of the absorptive capacity of the region. In this way, the significant factor is not having connections per se but rather the requirement for regions to be linked to other regions that provide additional access to knowledge and capabilities that favour specialization; if this requirement is not met, such connections hamper specialization.

Thus, this work permits us to conclude that while the relation between linkages and regional branching is shaped by the absorptive capacity of regions, the relation between linkages and regional specialization is moderated by the partners with which such regions are connected.

Our findings imply that public policy intervention aimed at developing new technological specializations must consider that inter-and intra-regional connections may not favor the construction of new regional technological advantages in Brazil. For the most part, the large extension of Brazilian regions has few innovative clusters, weak organizational support structures, unfavorable institutional configurations, or even more, weak regional innovation systems that do not favor linkages. Finally, we assess those connections are recognized as potentially relevant for diversification. These questions are fundamental to broadening the understanding of the role of policy and political support in developing new regional technological specializations and diversifications in Brazil.

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