TEXTO PARA DISCUSSÃO

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The role of regional linkages in shaping technological branching in Brazil

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Abstract

This study explores the often-overlooked roles of regional linkages and the technological capacity of partners in facilitating technological branching, particularly in developing countries. By analysing 127 technology classes across 136 Brazilian regions from 1997 to 2020, we find that different types of regional linkages play distinct roles in shaping technological trajectories. While intraregional linkages decrease the likelihood of regions entering new technological specialisations, while interregional linkages significantly promote the entry of new technologies, highlighting their critical role in fostering technological branching. The relationship between interregional linkages and technological branching is moderated by the technological capacity of regional partners. Collaborations with specialised regions enhance technological branching, while connections with non-specialised regions constrain this potential, emphasising the importance of technological capacity in facilitating technological development. Technological persistence is also influenced by regional linkages. Both intraregional and interregional linkages positively affect technological persistence, reinforcing the stability of existing specialisations and enhancing the resilience of technological trajectories. Collaborations with specialised regions further strengthen these effects. However, connections with non-specialised regions are negatively correlated with persistence, suggesting that such linkages may hinder regions' ability to maintain their technological status. These findings highlights the dual role of regional linkages in technological branching: while both intraregional and interregional linkages, particularly with specialised regions, support persistence and foster new technological paths, connections with non-specialised regions can hinder technological stability. This emphasises the critical importance of technological capacity in driving successful technological branching.

Keywords: Regional linkages; Branching; New technological entry; Technological capacity, Regional Persistence
JEL Code: O19, O31, R11.

Resumo

O papel das ligações regionais na dinâmica da diversificação tecnológica no Brasil

Este estudo investiga os papéis frequentemente negligenciados das ligações regionais e da capacidade tecnológica dos parceiros na promoção do *branching* tecnológico, especialmente em países em desenvolvimento. Ao analisar 127 classes tecnológicas em 136 regiões brasileiras entre 1997 e 2020, identificamos que diferentes tipos de ligações regionais exercem papéis distintos na definição das trajetórias tecnológicas. As conexões intra-regionais reduzem a probabilidade de entrada das regiões em novas especializações tecnológicas, ao passo que as conexões inter-regionais promovem significativamente a incorporação de novas tecnologias, ressaltando seu papel crucial no fomento à diversificação tecnológica. A relação entre ligações inter-regionais e *branching* tecnológico é moderada pela capacidade tecnológica dos parceiros regionais. Colaborações com regiões especializadas favorecem a diversificação tecnológica, enquanto conexões com regiões não especializadas limitam esse potencial, evidenciando a importância da capacidade tecnológica no avanço do desenvolvimento tecnológico. A persistência tecnológica também é influenciada pelas ligações regionais. Tanto ligações intra quanto inter-

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regionais impactam positivamente a persistência tecnológica, reforçando a estabilidade das especializações existentes e fortalecendo a resiliência das trajetórias tecnológicas. Colaborações com regiões especializadas amplificam esses efeitos. No entanto, conexões com regiões não especializadas estão negativamente associadas à persistência, sugerindo que tais vínculos podem comprometer a capacidade das regiões de manter seu status tecnológico. Esses resultados destacam o papel dual das conexões regionais na diversificação tecnológica: enquanto conexões intra e inter-regionais, especialmente com regiões especializadas, sustentam a persistência e promovem novos caminhos tecnológicos, vínculos com regiões não especializadas podem enfraquecer a estabilidade tecnológica. Isso reforça a importância crítica da capacidade tecnológica para impulsionar trajetórias bem-sucedidas de *branching* tecnológico.

Palavras-chave: Ligações regionais; *Branching*; Entrada de novas especializações tecnológicas; Capacidade tecnológica; Persistência regional.

1 Introduction

The literature on innovation economics has increasingly focused on understanding the role of technological specialization and knowledge complexity (Balland; Boschma, 2021b; Krafft et al., 2014; Montresor; Quatraro, 2017; Petralia et al., 2017). These studies have demonstrated that local capabilities, a primary source of regional change, can be developed from a region's competitive advantage in new domains where relevant capabilities already exist. In this context, scholars argue that regional linkages can provide access to crucial knowledge essential for regional technological branching (Ascani et al., 2020; Balland; Boschma, 2021b; Tavassoli; Carbonara, 2014).

However, despite the importance of these linkages, our understanding of how intraregional and interregional connections affect regional branching and technological persistence remains limited. The mixed evidence from previous studies encompassing concepts such as productivity, efficiency, spillover effects, and agglomeration dynamics regarding their role in fostering innovation highlights this gap (Broekel et al., 2015; De Noni et al., 2017, 2018; Santoalha, 2019). This mixed evidence can be attributed to the distinct nature of intraregional and interregional linkages. While intraregional connections facilitate knowledge flow among local actors, interregional linkages grant access to resources and knowledge that may otherwise be unavailable, suggesting that interregional linkages are particularly valuable, helping regions overcome challenges related to technological lock-in and path dependence. Consequently, it becomes clear that relying solely on local production may not suffice to sustain innovation and diversification. Understanding the unique roles of both types of linkages is essential for fostering regional technological diversification, particularly as interregional linkages can provide complementary capacities that enhance technological branching, especially in peripheral regions (Balland; Boschma, 2021b; De Noni et al., 2017; De Noni; Ganzaroli, 2024; Santoalha, 2019).

Furthermore, the effectiveness of interregional linkages is likely contingent on the technological capacity of the partner regions involved. The complementarity of exchanged knowledge and resources is crucial for enabling regions to explore novel technological pathways. Previous studies indicate that regions are more likely to develop new activities when neighbouring regions possess specialised expertise (Boschma et al., 2017; Santoalha, 2019). For instance, De Noni et al. (2018) found that collaborative linkages with technology-intensive regions enhance innovation and competitiveness. Regions with high levels of technological knowledge production are more inclined to connect with one another, benefiting from knowledge spillovers. In contrast, less developed regions often rely on nonlocal linkages for innovation due to their limited local capacities, underscoring the significance of technological capacity and strategic partnerships in fostering regional branching (De Noni et al., 2018).

Despite these insights, scholarly attention has predominantly focused on developed countries and regions near the technological frontier, leaving a substantial gap regarding developing countries. Few studies have explored the intricate relationships between technological diversification and both intra- and interregional linkages, with most focusing on a limited number of developed economies (Balland; Boschma, 2021b; De Noni; Ganzaroli, 2024). Consequently, we lack a robust and comprehensive understanding of the nature of regional linkages and their influence on the entry of new technological capabilities in developing economies. This study aims to address this gap by examining the effects of regional linkages on technological specialization within these contexts. Using patent data from the Brazilian Patent Office (INPI – National Institute of Industrial Property) concerning 136 Brazilian regions from 1997 to 2020, we investigate how both intraregional and interregional linkages, alongside the technological capacity of regional partners, influence the likelihood of regions entering new technological specializations and technological persistence.

Thus, our contribution to the literature is threefold. First, while existing research highlights the importance of regional linkages for technological diversification, there is limited understanding of how intra- and interregional linkages affect the development of new activities, particularly in terms of how interregional linkages can compensate for weak or absent regional capabilities. Second, our focus on the technological capacity of regional partners emphasises the importance of complementarity in determining regional branching. Third, there is a substantial lack of literature addressing developing countries in this domain; our examination of Brazilian firms can provide valuable insights into regional branching within this context.

Our results indicate that intraregional linkages tend to decrease the likelihood of a region entering a new technological specialization, while interregional linkages contribute to the entry of new technologies in Brazilian regions. This suggests that local connections (intraregional linkages) can lead to a lock-in effect, thereby restricting technological branching. In contrast, connections with other Brazilian regions (interregional linkages) can expand and stimulate the flow of knowledge and ideas, fostering regional technological diversification.

Furthermore, when we focus on the capacity of regional partners, our results show that linkages with specialised regions facilitate the entry of new technologies. Conversely, connections to nonspecialised regions decrease the probability of new technology entering a region. These findings emphasise that it is not merely connections with other regions that foster technological branching. Instead, the technological capacity of partners plays a critical role in this process. Specifically, a new technology is more likely to enter a region when it is linked with other regions that possess expertise in that technology, as these connections facilitate the transfer of knowledge, skills, and innovative practices that promote technological branching.

Technological persistence is also influenced by regional linkages. Both intraregional and interregional linkages positively affect technological persistence, reinforcing the stability of existing specialisations and enhancing the resilience and longevity of technological trajectories. Collaborations with specialised regions further strengthen these effects, promoting sustained technological development. However, connections with non-specialised regions are negatively correlated with persistence, suggesting that such linkages may undermine regions' ability to maintain their technological status.

Furthermore, the regional heterogeneity within Brazil, characterized by disparities in technological capacities and economic development across its regions, plays a critical role in shaping these dynamics. Lagging regions are more likely to depend on interregional collaborations to access advanced knowledge and innovative practices. These linkages are crucial for fostering technological diversification and overcoming challenges related to limited local capabilities, enabling these regions to access complementary technological strengths and knowledge from more specialized areas. This regional variation is key to understanding the different effects of technological specialization and persistence across Brazilian regions

In light of these findings, we suggest that regions should adopt a strategic approach in their networking efforts. They should prioritise partnerships with specialised regions to enhance their technological capabilities. The implications of this are profound, as regions that neglect to foster such targeted linkages may find themselves at a competitive disadvantage and unable to leverage the full potential of technological advancements. Therefore, our findings not only emphasise the importance of the nature of regional linkages but also call for policymakers to support initiatives that promote linkages with specialised regions. Ultimately, this approach aims to enhance regional technological diversification and allow regions to better position themselves in an increasingly interconnected and technologically driven global landscape.

The paper proceeds as follows. The next section reviews the related literature and develops our main hypotheses. Section 3 describes the data and measures of regional linkages and new technology. Sections 4 and 5 present and discuss our findings on new entry specialization and persistence. In Section 6, we compare the effects of regional linkages in dominant and lagging behind areas. The final section offers a conclusion.

2 Literature review

It is broadly accepted that territories differ in terms of their ability to diversify and adapt to change (Rigby, 2015). This claim also applies to their ability to develop new technologies and technological advantages (Balland; Rigby, 2017). Several empirical studies related to the innovation economy indicate an unequal distribution of regional knowledge production (Audretsch; Belitski, 2020; Boschma et al., 2022; Crescenzi; Jaax, 2016; Mewes; Broekel, 2022) and emphasise the importance of local capabilities, particularly technological relatedness, as a driver of regional transformation (Balland; Boschma, 2021a; De Noni et al., 2018; Tavassoli; Carbonara, 2014).

The concept of technological relatedness is rooted in the understanding that knowledge has an architecture based on similarities in how different types of knowledge can be utilised. This occurs when subsets of knowledge are close substitutes for one another or require similar cognitive abilities and skills for their application within the knowledge space[5] (Balland; Rigby, 2017). The idea that technological relatedness favours regional diversification has been well-documented across various regions (Balland et al., 2018; Boschma et al., 2023; Colombelli, 2016; Montresor; Quatraro, 2017; Rigby, 2015; Zhong et al., 2024), as well as specific technologies in developed countries, including green technologies (Montresor; Quatraro, 2020; Santoalha; Boschma, 2021), biotechnologies (Boschma et al., 2014) and technologies related to Industry 4.0 (Balland; Boschma, 2021a).

Moreover, the literature suggests that regions are interconnected by shared goals and the need to promote innovative and inventive activity (Barzotto et al., 2019; Tóth et al., 2021; Wanzenböck;

(5) 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.

Piribauer, 2018). These studies confirmed the importance of technological relatedness in the process of technological change. Regions incur diversification costs, which diminish as they become more proximate to related technological fields. As such, regions are more likely to introduce new specialisations that are similar, though not identical, to their existing ones, given that these new specialisations share similar capabilities, such as knowledge, skills, and institution (Balland; Boschma, 2021b).

While the literature highlights the benefits of relatedness in fostering technological branching across different regions and countries, there is still much to learn about the effects of regional linkages on technological diversification and persistence. Moreover, there is limited research on how the technological capacity of regional partners affects these relationships, particularly in developing economies like Brazil. Balland and Boschma (2021) are among the few who have examined the extent to which interregional linkages influence the diversification process in European regions.

Empirical evidence supports the view that regional linkages foster innovation by facilitating the flow of knowledge and ideas across geographic boundaries. Such flows are particularly relevant for technological branching. However, it is crucial to distinguish between intra- and interregional linkages, as their significance may vary depending on the specific process involved (Broekel et al., 2015; De Noni et al., 2017; Santoalha, 2019).

While intraregional linkages are important for connecting local actors and providing new knowledge to the organisations involved, interregional linkages can also play a key role by introducing previously unavailable resources. Theoretical arguments concerning the specific mechanisms that underlie such processes range from arguments focused on productivity and efficiency to those oriented towards spillovers and agglomeration effects (De Noni et al., 2017; Santoalha, 2019). Interregional linkages provide access to external knowledge, enabling regions to overcome or circumvent technological lock-in and path dependence (Noni et al., 2018; Tavassoli; Carbonara, 2014). These linkages are particularly valuable for peripheral regions, as they offer complementary capacities that stimulate technological branching (Wanzenböck; Piribauer, 2018). A significant reason for this effect is that local inventive production is often insufficient to sustain innovation and diversification on its own.

Thus, while intraregional linkages support knowledge recombination and sharing within regions, they may also lead to technological lock-in, restricting technological branching. This occurs when regions become overly dependent on established linkages and familiar technologies, causing them to overlook new opportunities and innovations. By concentrating on existing capabilities, regions may resist adopting novel technologies or exploring alternative pathways, ultimately constraining their potential for technological diversification.

Beyond their role in diversification, regional linkages also affect technological persistence. Persistence refers to the sustained development and reinforcement of existing technological specialisations within a region. While persistence can strengthen regional capacities and provide stability, it may also contribute to technological lock-in if regions fail to pursue new avenues for growth. Interregional linkages, however, can counteract this by providing access to complementary and diverse knowledge, which enhances regional branching and mitigates the risks of stagnation. By fostering connections with other regions, especially those with advanced technological capabilities, regions can introduce fresh ideas and innovations, fostering adaptability and creativity.

The effectiveness of interregional connections depends on the complementarity of the exchanged knowledge and resources, which enables regions to explore new technological paths. Absorptive capacity and relatedness between regions are crucial in this process. A region's ability to absorb external knowledge and translate it into innovation hinges on its existing technological capabilities, which are strengthened by regional linkages. This synergy enhances the potential for successful integration of new ideas, promoting further regional branching. Moreover, interregional linkages, particularly with technologically advanced partners, can bolster persistence by introducing complementary knowledge and resources that sustain existing technological advantages (Balland; Boschma, 2021b; De Noni et al., 2018). Such collaborations allow regions to build on their strengths while accessing external knowledge that enhances their competitiveness. In contrast, linkages with non-specialised regions may lack the depth necessary to support persistence, potentially undermining regional capabilities.

Previous studies suggest that regions are better equipped to develop new activities in areas where neighbouring regions already specialise (Balland; Boschma, 2021b; Boschma et al., 2017; De Noni et al., 2018). For example, Noni et al. (2018) found that regions tend to be more innovative and competitive when they develop collaborative linkages with technology-intensive regions. Furthermore, regions with strong technological knowledge production are more likely to connect with each other and nearby areas (Balland; Boschma, 2021), as local capacities tend to encourage and benefit from knowledge spillover effects (Jaffe et al., 1993). In many cases, less developed regions depend on external linkages to innovate, as their own local capacities and networks tend to be weak and limited (Balland; Boschma, 2021b; Fitjar; Rodríguez-Pose, 2011; De Noni; Ganzaroli, 2024).

In fact, it is essential to understand that regions require technological capacity to effectively utilize external knowledge, thereby circumventing the tendency toward technological stagnation and lock-in. In this sense, it is important for regions to collaborate with other regions that possess technologies beyond their current scope. However, this does not imply that such technologies can exist outside the region's portfolio, as absorptive capacity is also necessary in this context.

3 Empirical model

3.1 Data sources and technological branching

This section explains the data we used, the variables constructed, and the method employed to analyse the effect of regional linkages and the technological capabilities of regional partners on technological branching in 135 mesoregions in Brazil for the period 1997-2020[6].

We employed patent data drawn from the Brazilian Patents Office (*INPI - National Institute of Industrial Propert – INPIy*), and following other studies (Balland; Boschma, 2021b; Montresor; Quatraro, 2017; Rigby, 2015), we estimate an entry model that assesses the probability of a region specializing in a new technology and persistence, providing insights into technological branching. We assigned patents to 127 technological classes[7] (International Patent Classification) *i* and to 135 Brazilian regions, *r* based on the addresses of the inventors.

(6) Two regions do not have patents at the INPI in the period, they are: Norte do Amapá (AP) and Centro-Sul Cearense (CE).

(7) Four technological classes do not have a patent at the INPI in the period, they are: C99; D99; E99 and E99, referring to subject matter not otherwise provided for in the section.

Our dependent variable is technological branching, measured by the entry (or not) of new technological specializations within a specific technology in a region. This approach aligns with the literature on the emergence of new activities in a regional context (Balland and Boschma, 2021b; Balland et al., 2018; Montresor and Quatraro, 2017). We define new technological specialization by examining the regional acquisition of a new technological specialization *i* at time *t*, which indicates a technological specialization that the region did not possess at the previous time (*t–1*). *NewEntry* is thus linked to the emergence of a revealed technological advantage (RTA). *NewEntry* is therefore linked to the emergence of a revealed technological advantage (RTA).

Additionally, we measure the persistence of regions by examining whether a region retains its technological specialisation status in *i* at time *t*, compared to the previous period (t-*1*). This includes cases where a region either continues to be specialised or remains non-specialised in i. *Persistence* is thus defined as the consistency of a region's technological specialisation status over time.

We denote the new technological specialization and persistence as follows:

$$NewEntry_{r,i} = \begin{cases} 1 \; if \; M_{r,i,t} = 1 \;\&\; M_{r,i,t-1} = 0 \\ 0 \; if \; M_{r,i,t} = 0 \;\&\; M_{r,i,t-1} = 0 \end{cases}$$

and

$$Persistence_{r,i} = \begin{cases} 1 \; if \; M_{r,i,t} = 1 \;\&\; M_{r,i,t-1} = 1 \\ 0 \; if \; M_{r,i,t} = 0 \;\&\; M_{r,i,t-1} = 0 \end{cases}$$

with

$$M_{r,i} = \begin{cases} 1 \quad if \quad RTA_{r,i} = \dfrac{Pat_{r,i} \big/ \sum_i Pat_{r,i}}{\sum_r Pat_{r,i} \big/ \sum_r \sum_i Pat_{r,i}} > 1 \\ 0 \; otherwise \end{cases}$$

The occurrence of entering a new technological specialization or persistence is assessed over five-year time windows. As we have patent data for the period 1997–2020, we calculate these for six subsequent periods *t:* 1997-2000; 2001-04; 2005-2008; 2009-2012; 2013-2016; and 2017-2020. All independent variables are measured in the period before the time window of four years.

3.2 Regional linkages and technological capabilities of regional partners

We construct two measures to assess the effect of regional linkages on the new entry of technological specialization: intraregional linkages (*IntraLinks*) and interregional linkages (*InterLinks*).

IntraLinks are based on coinventors residing in the same region. For each technology i, this measure counts the number of copatents between inventors located in the same region r. *InterLinks* are based on coinventors residing in different regions. For each technology i, this measure counts the number of linkages that inventors in region r have with inventors in other Brazilian regions. For example, suppose that a patent in technology *i* is copatented by six inventors: three in region A, two in region B, and one in region C. We compute nine *InterLinks* and six *IntraLinks* for region A, eight *InterLinks* and two *IntraLinks* for region B, and five *InterLinks* and zero *IntraLinks* for region C, all in technology i. Note that if the patent includes more than one technology, we account for the *InterLinks* for each technology.

To understand how regional capabilities influence the effect of interregional linkages on technological branching, we developed two new indicators based on regional technological specialization. The first indicator, referred to as *SpecLinks*, measures the number of specialised regions in technology i to which region r is linked. This indicates that region r has some activity in this technology but is not specialised, and it is linked with regions that are specialised in this technology *i*. The second indicator, referred to as *NoSpecLinks*, measures the number of linkages with nonspecialised regional partners in technology *i*. This means that interregional links are formed between regions that both have some activity in technology *i* but are not specialised in it. For example, considering the previous example, a patent in technology *i* is copatented by six inventors, three located in region A, two in region B, and one in region C. Region B is specialised in technology *i*. We computed 3 *NoSpecLinsk* and 6 *SpecLink*s for region A, 8 *NoSpecLink*s and 0 *SpecLinks* for region B, and 3 *NoSpecLink*s and 2 *SpecLinks* for region C in technology *i*. For example, considering the previous example, a patent in technology i is copatented by six inventors: three located in region A, two in region B, and one in region C. Region B specializes in this technology i. We computed 6 *SpecLinks* and 3 *NoSpecLinks* for region A, 0 *SpecLinks* and 8 *NoSpecLinks* for region B, and 2 *SpecLinks* and 3 *NoSpecLinks* for region C in technology i.

We also include four control variables. First, we include regional capabilities, proxied by relatedness density (RD). We expect that the greater the relatedness density (RD) is, the greater the probability of that region entering a new specialization. Second, we control for technology complexity (TCI) by ranking the diversity and sophistication of the technology know-how required to introduce the technology[8]. We expect that the greater a technology's complexity (TCI) is, the lower the probability of that region entering into a new technological specialization because it is more difficult for regions to enter into more complex technologies. Third, we include gross domestic product (GDP) per capita to account for the level of economic development within a region. We expect that the greater a region's GDP per capita is, the greater the probability of that region acquiring a new specialization. Fourth, we include the natural logarithm of population size to account for variations in population sizes across regions. Again, we expect a positive effect in this context. We also incorporate time fixed effects.

Furthermore, we also included interactions between our regional linkage variables and relatedness density in the specifications. By incorporating these interactions, we sought to capture the nuanced dynamics that emerge when regional linkages interact with the existing knowledge base within a region. Specifically, the aim was to investigate whether the effect of regional connections on technological diversification is moderated by the level of relatedness density, and whether these interactions might enhance or offset the effect of each individual factor on technological branching.

4 New technological specialization in Brazilian regions

Table 1 presents the findings of the new technological specialization model.

(8) Both RD and TCI were calculated using the EconGeo package in R, with the function's relatedness_density and TCI.

Table 1
New entry of technological specialization, RTA>1.0

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**-0.152***** **(0.040)**	**-0.185***** **(0.036)**	-0.056 (0.037)	**-0.120***** **(0.040)**	**-0.366***** **(0.097)**	**-0.351***** **(0.083)**	-0.121 (0.095)	**-0.273***** **(0.100)**
Number of interregional linkages (InterLinks) (ln)	**0.079*** **(0.045)**				**0.360***** **(0.103)**			
Number of specialised linkages (SpecLinks) (ln)		**0.223***** **(0.048)**		**0.268***** **(0.050)**		**0.589***** **(0.114)**		**0.634***** **(0.116)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			**-0.133**** **(0.055)**	**-0.201***** **(0.057)**			-0.046 (0.135)	-0.192 (0.138)
*Intra*RD*					**0.006***** **(0.002)**	**0.005**** **(0.002)**	0.002 (0.002)	**0.004*** **(0.002)**
*Inter*RD*					**-0.008***** **(0.003)**			
*SpecLinks * RD*						**-0.011***** **(0.003)**		**-0.011***** **(0.003)**
NoSpecLinks RD*							-0.003 (0.004)	-0.000 (0.004)
Relatedness density (RD)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)
Technological Complexity Index (TCI)	-0.666*** (0.087)	-0.675*** (0.086)	-0.749*** (0.088)	-0.744*** (0.088)	-0.648*** (0.088)	-0.671*** (0.086)	-0.746*** (0.088)	-0.739*** (0.089)
GDP per capita (ln)	0.337*** (0.045)	0.338*** (0.045)	0.342*** (0.045)	0.341*** (0.045)	0.339*** (0.045)	0.341*** (0.045)	0.343*** (0.045)	0.343*** (0.045)
Population (ln)	0.132*** (0.038)	0.125*** (0.038)	0.131*** (0.038)	0.120*** (0.038)	0.129*** (0.038)	0.124*** (0.038)	0.130*** (0.038)	0.119*** (0.038)
Constant	-4.785*** (0.525)	-4.682*** (0.526)	-4.788*** (0.525)	-4.615*** (0.526)	-4.757*** (0.525)	-4.671*** (0.525)	-4.775*** (0.525)	-4.602*** (0.525)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,544	42,544	42,544	42,544	42,544	42,544	42,544	42,544
Number of IDMI	13,446	13,446	13,446	13,446	13,446	13,446	13,446	13,446
ll_c	-17365	-17353	-17363	-17343	-17360	-17346	-17363	-17336
chi2	1493	1511	1493	1524	1500	1520	1494	1533

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

Initially, as expected, the coefficients of our control variables, relatedness density (RD), GDP per capita, and population, are positive and significant, suggesting that RD, size, and GDP per capita tend to increase the probability of new technology entry in regions. Additionally, the technological complexity (TCI) index is negative and significant, indicating that the more complex the technologies are, the more difficult it is to enter new technological specializations.

Regarding intraregional linkages (*IntraLinks*), our analysis reveals a negative and significant effect on the entry of new technological specializations in all specifications. This result suggests that more connections within a region tend to decrease the likelihood of entering new technologies. This aligns with the idea presented in the literature that intraregional linkages often facilitate the reinforcement of existing capabilities and knowledge bases, potentially leading to a lock-in effect (Balland and Boschma, 2021b; De Noni et al., 2017). Such an effect occurs when regions become overly reliant on familiar technologies, thus hindering innovative processes and the exploration of new technological pathways. This negative coefficient underscores the potential challenges that regions with pronounced intraregional connections might face in diversifying their technological portfolios. This result suggests a need to reassess the role of local networks, indicating that while intraregional linkages promote collaboration and knowledge sharing within a region, they may simultaneously limit the potential for technological branching. This, in turn, could impede regional competitiveness in a dynamic global economy.

On the other hand, we find a positive and significant effect of interregional linkages on new technological specialization. This result emphasises the critical role of connections between regions in fostering innovation and technological diversification. Interregional linkages provide access to diverse knowledge, skills, and resources not available within a single region, thereby facilitating the entry of new technologies. This means that external links can help regions overcome the limitations of their existing knowledge bases and stimulate the development of new capabilities. This is because interregional linkages are particularly valuable because they grant regions access to external knowledge, which can help combat or circumvent the tendency towards technological lock-in and path dependence (De Noni et al., 2018). By offering access to complementary and additional capacities, these linkages significantly increase technological branching in regions, especially in peripheral regions. In this context, our results suggest that local inventive production alone may not suffice to sustain innovation and technological diversification. Thus, strategic interregional collaboration can be pivotal in driving regional technological branching.

Regarding the role of the technological capacity of regional partners in new technological specialization, our results indicate that being connected to specialised regions (*SpecLinks*) has a positive relationship with technological diversification. This suggests that linkages with specialised regions tend to contribute to the entry of new technologies in Brazilian regions. Conversely, connections to nonspecialised regions (*NoSpecLinks*) decrease the probability of new technology entering a region, suggesting that adding connections with other regions that are not technologically specialised comes at a price, tending to impede the entry of new technologies in Brazilian regions. These findings emphasise that it is not merely connections with other regions that foster technological branching. Instead, the technological capacity of regional partners plays a critical role in this process. Specifically, a new technology is more likely to enter a region when it is linked with other regions that possess expertise in that technology. These connections facilitate the transfer of knowledge, skills, and innovative practices, thereby promoting technological branching. Therefore, the effect of regional linkages on technological diversification is contingent upon the technological capacity of the partner regions. Hence, interregional linkages tend to positively affect technological branching only if the partner region is technologically specialised.

Regarding the interactions between regional linkage variables and relatedness density, our results reveal that the interaction between intraregional linkages and relatedness density *(Intra*RD*) is positive and significant. This suggests that in regions with higher RD, the combination of existing regional knowledge with emerging technological pathways can support diversification, rather than reinforcing a lock-in effect. Thus, while *IntraLinks* generally have a negative effect, this effect is moderated by regional relatedness density, implying that high RD may enable more productive intraregional linkages. Additionally, the coefficients of the interactions between relatedness density and interregional linkages (*Inter*RD*) and specialized regional linkages (*SpecLinks*RD*) are negative and significant. This implies a substitutive relationship between relatedness density and these linkages, meaning that one can compensate for the other. Specifically, in regions with high RD, the positive effect of interregional or specialized regional linkages may be less pronounced, as the regional knowledge base already provides sufficient support for technological diversification.

As a robustness check, we also ran the same estimations, defining regional entry as a new specialization, based on RTA > 1.5 and RTA > 2. In these same estimations, we also used this new threshold of RTA > 1.5 and RTA > 2 in the construction of other variables RD, TCI, *SpecLink* and *NoSpecLink*. The findings for our key variables remained the same, and the results are presented in Appendix A.

5 Persistence in Brazilian regions

Table 2 presents the findings of the persistence model.

At first, except for coefficient of the population, which is not significant, the coefficients of our control variable, relatedness density (RD), GDP per capita, and technological complexity (TCI), are positive and significant. This suggests that higher RD, GDP per capita, and more complex technologies tend to increase the probability of persistence in Brazilian regions.

Regarding regional linkages, both intraregional (*IntraLinks*) and interregional (*InterLinks*) linkages exhibit consistently positive and significant effects on technological persistence. These results reveal that linkages per se play a crucial role in sustaining technological activity over time. By fostering opportunities for knowledge spillovers and learning, these linkages facilitate the exchange of tacit knowledge and the diffusion of innovative practices. This interplay between regional and interregional linkages may not only sustain current technological strengths but also lay the groundwork for the emergence of new capabilities, reinforcing the dynamic nature of regional technological ecosystems.

In addition, the coefficients for linkages with specialised regions (*SpecLinks*) are positive and significant, indicating that these connections further enhance technological persistence by facilitating the transfer of advanced knowledge and innovative practices. These findings support the notion that linkages with regions possessing established technological expertise can help other regions overcome local limitations and create a robust environment for innovation and technological progress.

On the other hand, non-specialised linkages (*NoSpecLinks*) show a contrasting effect, with negative and significant coefficients. This indicates that connections with regions lacking technological specialisation may dilute the benefits of knowledge spillovers and hinder persistence, as these regions may not contribute meaningfully to local technological progress.

The interactions between linkages and relatedness density (RD) provide further insights into the dynamics of technological persistence. While intraregional linkages show no significant interaction with RD, the positive effects of interregional linkages are weakened in regions with higher RD, as reflected by the negative and significant interaction coefficient. This suggests that while interregional linkages are beneficial overall, their role diminishes when technological relatedness within the region is already high, potentially due to diminishing marginal returns to external knowledge flows. Similarly, the interactions between specialised linkages and RD reveal a negative and significant effect, indicating that the benefits of specialised connections may be attenuated in highly related technological environments. Meanwhile, the interaction term for non-specialised linkages with RD is weaker and only partially significant, suggesting a less pronounced influence.

In summary, the results underscore the critical role of both regional and interregional linkages, particularly specialised linkages, in driving technological persistence. While intraregional connections provide a strong local foundation, interregional and specialised linkages create pathways for advanced knowledge diffusion, helping regions overcome local constraints. The findings also highlight the moderating role of relatedness density, revealing that its interactions with external linkages introduce nuances to the persistence dynamics. Collectively, these results reinforce the importance of fostering well-connected and specialised regional technological ecosystems to sustain and enhance technological capabilities over time.

As a robustness check, we also ran the same estimations, defining technological persistence based on RTA > 1.5 and RTA > 2. In these same estimations, we also used this new threshold of RTA > 1.5 and RTA > 2 in the construction of other variables RD, TCI, *SpecLink* and *NoSpecLink*. The findings for our key variables remained the same, and the results are presented in Appendix B.

Table 2
Persistence, RTA>1.0

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**1.701***** **(0.064)**	**1.668***** **(0.063)**	**2.067***** **(0.067)**	**1.894***** **(0.068)**	**1.566***** **(0.139)**	**1.653***** **(0.129)**	**2.217***** **(0.141)**	**1.861***** **(0.148)**
Number of interregional linkages (InterLinks) (ln)	**0.484***** **(0.079)**				**1.237***** **(0.189)**			
Number of specialised linkages (SpecLinks) (ln)		**0.836***** **(0.089)**		**1.051***** **(0.095)**		**1.670***** **(0.217)**		**1.951***** **(0.233)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			**-0.823***** **(0.107)**	**-1.168***** **(0.125)**			-0.419 (0.258)	**-1.048***** **(0.303)**
*Intra*RD*					0.004 (0.003)	0.001 (0.003)	-0.004 (0.003)	0.001 (0.003)
*Inter*RD*					**-0.021***** **(0.004)**			
*SpecLinks * RD*						**-0.023***** **(0.005)**		**-0.025***** **(0.005)**
NoSpecLinks RD*							**-0.011*** **(0.006)**	-0.004 (0.007)
Relatedness density (RD)	0.085*** (0.003)	0.085*** (0.003)	0.083*** (0.003)	0.084*** (0.003)	0.087*** (0.003)	0.088*** (0.003)	0.086*** (0.003)	0.087*** (0.003)
Technological Complexity Index (TCI)	1.368*** (0.244)	1.297*** (0.246)	0.717*** (0.231)	0.847*** (0.243)	1.443*** (0.249)	1.330*** (0.251)	0.745*** (0.232)	0.869*** (0.247)
GDP per capita (ln)	1.302*** (0.131)	1.304*** (0.131)	1.268*** (0.127)	1.274*** (0.129)	1.286*** (0.131)	1.295*** (0.132)	1.248*** (0.128)	1.259*** (0.129)
Population (ln)	0.122 (0.113)	0.084 (0.114)	0.095 (0.109)	0.024 (0.112)	0.129 (0.114)	0.094 (0.114)	0.095 (0.109)	0.025 (0.112)
Constant	-9.721*** (1.581)	-9.167*** (1.588)	-9.219*** (1.539)	-8.202*** (1.568)	-9.883*** (1.589)	-9.348*** (1.591)	-9.241*** (1.543)	-8.268*** (1.571)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	43,754	43,754	43,754	43,754	43,754	43,754	43,754	43,754
Number of IDMI	13,744	13,744	13,744	13,744	13,744	13,744	13,744	13,744
ll_c	-13442	-13395	-13078	-12942	-13425	-13377	-13056	-12906
chi2	2330	2316	2459	2360	2343	2333	2490	2387

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

6 Comparing regional linkages' effects in dominant and lagging behind areas

To capture regional heterogeneity and provide a clearer understanding of how regional linkages influence the entry of new technological specializations across regions with varying levels of development, we divide our analysis into two groups. The South macroarea focuses on regions in the Southern and Southeastern parts of Brazil, which include the wealthiest regions of the country, while the North macroarea examines regions in the Northern, Northeastern, and Midwestern parts, where most of Brazil's less developed regions are located. The results of this analysis are presented in Table 3.

The relationship between the number of intraregional linkages (*IntraLinks*) and the entry into new specializations follows a consistent pattern across regions in both macroareas: the coefficients are negative and significant. This indicates that, regardless of the level of regional development, a higher number of intraregional linkages tends to constrain the entry into new specializations, thereby limiting regional branching. This phenomenon could be attributed to the potential redundancy in knowledge flows within highly closed networks, which may suppress the emergence of innovations and lead to lock-in effects. Similarly, specialized linkages (*SpecLinks*) exhibit a positive and significant effect on the entry into new specializations in both economically dominant and lagging regions. This suggests that greater connectivity with specialized regions fosters the emergence of new specializations, irrespective of the level of regional development.

On the other hand, differences arise when interregional linkages (*InterLinks*) are considered. In economically dominant regions, the coefficients associated with these linkages are not statistically significant, suggesting that the South and Southeast regions, with their robust and well-established internal resources, are less dependent on external networks to foster diversification. Conversely, in lagging regions, the coefficients for interregional linkages are positive and significant. This underscores the critical role of external connections in overcoming structural constraints and compensating for local limitations by providing access to external knowledge and resources that drive technological diversification.

Furthermore, non-specialised linkages (*NoSpecLinks*) exhibit a negative effect in both macro-regions, with the effect being more pronounced in economically dominant regions. This finding suggests that connections with technologically dissimilar regions tend to be less effective in fostering entry into new specialisations, possibly due to challenges in adapting or integrating knowledge from markedly different technological bases

Finally, relatedness density (RD) emerges as a universally significant factor, exhibiting a positive and significant effect across all models and regions. This finding reaffirms the central role of related knowledge as a key driver of regional diversification. However, the interactions between RD and different regional linkages reveal important nuances. For instance, while interregional linkages are particularly beneficial for lagging regions, their effectiveness tends to diminish as relatedness density increases. This suggests that in contexts of high technological proximity, the importance of interregional linkages may become substitutable.

Table 3
New entry of technological specialization in dominant and lagging behind regions, RTA>1.0

				South Macroarea				
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**-0.111****	**-0.138*****	-0.035	**-0.090****	**-0.252****	**-0.277*****	-0.090	-0.177
	(0.044)	**(0.040)**	(0.041)	**(0.045)**	**(0.112)**	**(0.095)**	(0.108)	(0.116)
Number of interregional linkages (InterLinks) (ln)	0.069				0.128			
	(0.051)				(0.127)			
Number of specialised linkages (SpecLinks) (ln)		**0.188*****		**0.217*****		**0.292****		**0.339****
		(0.054)		**(0.055)**		**(0.139)**		**(0.141)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			-0.099	**-0.149****			-0.183	-0.249
			(0.063)	**(0.065)**			(0.164)	(0.170)
*Intra*RD*					0.004	0.004	0.001	0.002
					(0.003)	(0.002)	(0.003)	(0.003)
*Inter*RD*					-0.002			
					(0.003)			
*SpecLinks * RD*						-0.003		-0.003
						(0.004)		(0.004)
NoSpecLinks RD*							0.003	0.003
							(0.004)	(0.004)
Relatedness density (RD)	0.026***	0.026***	0.026***	0.026***	0.025***	0.025***	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Technological Complexity Index (TCI)	0.146	0.135	0.075	0.080	0.146	0.131	0.068	0.073
	(0.116)	(0.114)	(0.116)	(0.117)	(0.117)	(0.115)	(0.117)	(0.118)
GDP per capita (ln)	0.297***	0.297***	0.302***	0.299***	0.300***	0.300***	0.305***	0.302***
	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)
Population (ln)	0.084*	0.078*	0.084*	0.073*	0.085*	0.078*	0.086*	0.075*
	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Constant	-3.548***	-3.455***	-3.545***	-3.397***	-3.547***	-3.456***	-3.563***	-3.412***
	(0.610)	(0.610)	(0.610)	(0.611)	(0.611)	(0.611)	(0.611)	(0.611)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,959	22,959	22,959	22,959	22,959	22,959	22,959	22,959
Number of IDMI	6,461	6,461	6,461	6,461	6,461	6,461	6,461	6,461
ll_c	-10463	-10456	-10462	-10452	-10462	-10455	-10461	-10451
chi2	712.6	722.6	713.0	728.2	712.8	723.0	712.8	728.0

continuation

				Nouth Macroarea				
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	-0.124	**-0.158****	0.031	-0.057	**-0.323***	-0.227	-0.002	-0.200
	(0.089)	**(0.078)**	(0.079)	(0.085)	**(0.180)**	(0.156)	(0.180)	(0.181)
Number of interregional linkages (InterLinks) (ln)	0.140				**0.734*****			
	(0.095)				**(0.169)**			
Number of specialised linkages (SpecLinks) (ln)		**0.341*****		**0.447*****		**1.043*****		**1.060*****
		(0.104)		**(0.111)**		**(0.182)**		**(0.193)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			**-0.191***	**-0.343*****			0.262	-0.092
			(0.114)	**(0.123)**			(0.251)	(0.255)
*Intra*RD*					**0.009***	0.004	0.002	0.006
					(0.005)	(0.004)	(0.005)	(0.005)
*Inter*RD*					**-0.022*****			
					(0.005)			
*SpecLinks * RD*						**-0.025*****		**-0.022*****
						(0.006)		**(0.006)**
NoSpecLinks RD*							**-0.016****	-0.008
							(0.007)	(0.008)
Relatedness density (RD)	0.018***	0.017***	0.018***	0.017***	0.019***	0.018***	0.018***	0.018***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Technological Complexity Index (TCI)	-1.767***	-1.770***	-1.882***	-1.863***	-1.742***	-1.747***	-1.856***	-1.824***
	(0.144)	(0.141)	(0.144)	(0.143)	(0.146)	(0.142)	(0.145)	(0.143)
GDP per capita (ln)	0.368***	0.370***	0.371***	0.373***	0.362***	0.367***	0.364***	0.368***
	(0.072)	(0.072)	(0.072)	(0.072)	(0.072)	(0.072)	(0.072)	(0.072)
Population (ln)	0.384***	0.385***	0.387***	0.386***	0.383***	0.387***	0.382***	0.387***
	(0.083)	(0.083)	(0.083)	(0.083)	(0.083)	(0.083)	(0.083)	(0.083)
Constant	-8.118***	-8.117***	-8.160***	-8.129***	-8.105***	-8.138***	-8.097***	-8.142***
	(1.124)	(1.122)	(1.124)	(1.120)	(1.123)	(1.121)	(1.125)	(1.120)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,585	19,585	19,585	19,585	19,585	19,585	19,585	19,585
Number of IDMI	6,985	6,985	6,985	6,985	6,985	6,985	6,985	6,985
ll_c	-6826	-6820	-6826	-6814	-6812	-6805	-6822	-6799
chi2	642.8	649.7	657.3	669.8	645.7	666.6	656.6	684.2

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

Conclusions

While numerous studies emphasise the significance of regional linkages, particularly interregional ones, in accessing external sources of innovation and avoiding technological lock-in, limited attention has been paid to the technological capacity of regional partners in shaping regional diversification and persistence. Most research assumes that regions establish linkages to acquire knowledge unavailable within their local systems but often overlooks the reality that partner regions may not always possess the desired knowledge. Consequently, there is a lack of substantial empirical evidence regarding the influence of regional partners' technological capacity on diversification and persistence, particularly in developing economies. Furthermore, existing literature on this subject has primarily focused on European regions (Balland; Boschma, 2021; De Noni, 2024), leaving a gap in understanding the dynamics of intra- and interregional linkages in contexts like Brazil.

This study addresses this research gap by examining how intraregional and interregional linkages influence the development of new technological specializations and technological persistence in Brazilian regions, with particular attention to the role of partner regions' technological capacity. Our findings reveal distinct patterns. While intraregional linkages tend to reinforce existing technological capabilities, thereby reducing the probability of introducing new specialisations, they are also associated with technological persistence. This suggests that intraregional connections consolidate existing strengths, which may support stability but simultaneously risk leading to technological lock-in. In contrast, interregional linkages not only promote technological diversification but also play a key role in supporting technological persistence. By enabling access to diverse knowledge and resources, interregional collaborations foster innovation, sustain current technological capabilities, and provide the foundation for future growth.

Importantly, the technological capacity of regional partners significantly shapes these outcomes. Collaborations with technologically specialised regions amplify the positive effects, enhancing both the persistence of existing capabilities and the likelihood of introducing new technologies. Such partnerships facilitate the transfer of advanced knowledge and innovative practices, which are critical for maintaining technological competitiveness and fostering diversification. Conversely, linkages with non-specialised regions exhibit a negative effect, as these regions may lack the knowledge base necessary to contribute meaningfully to technological progress, thereby hindering both persistence and diversification.

Regarding regional heterogeneity, our analysis, divided into two groups, reveals that while some key relationships, such as the effects of intraregional and specialized linkages, remain consistent across macroareas, significant structural differences between economically dominant and lagging regions shape the dynamics of interregional linkages and their reliance on external resources.

These findings have critical policy implications for fostering technological persistence and diversification in Brazil. Policymakers should prioritise strategic interregional collaborations, particularly with technologically specialised regions, to ensure access to advanced knowledge and innovative practices that sustain existing capabilities and promote new technological opportunities. To mitigate the risks of technological lock-in associated with intraregional linkages, policies should encourage diversification strategies within regions by fostering the exploration of emerging technologies and knowledge areas. Targeted incentives and frameworks should also support partnerships between regions with complementary technological strengths.

By aligning interregional collaborations with regional development goals, policymakers can enhance Brazil's technological persistence while creating conditions for diversification. Moreover, our findings underscore the need for region-specific policies that address disparities, highlighting the importance of strengthening external networks in lagging regions to foster diversification and regional development.

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Appendix A

Table A1
New entry of technological specialization using RTA>1.5

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**-0.164*** (0.035)**	**-0.180*** (0.031)**	**-0.101*** (0.034)**	**-0.142*** (0.035)**	**-0.287*** (0.081)**	**-0.254*** (0.071)**	-0.101 (0.078)	**-0.214** (0.083)**
Number of interregional linkages (InterLinks) (ln)	**0.078* (0.043)**				**0.334*** (0.092)**			
Number of specialised linkages (SpecLinks) (ln)		**0.216*** (0.051)**		**0.241*** (0.052)**		**0.533*** (0.113)**		**0.554*** (0.117)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			-0.051 (0.049)	**-0.104** (0.051)**			0.033 (0.116)	-0.078 (0.121)
*Intra*RD*					**0.005* (0.003)**	0.003 (0.002)	0.000 (0.002)	0.003 (0.003)
*Inter*RD*					**-0.010*** (0.003)**			
*SpecLinks * RD*						**-0.013*** (0.004)**		**-0.012*** (0.004)**
NoSpecLinks RD*							-0.004 (0.004)	-0.001 (0.004)
Relatedness density (RD)	0.026*** (0.001)	0.026*** (0.001)	0.026*** (0.001)	0.026*** (0.001)	0.027*** (0.001)	0.027*** (0.001)	0.026*** (0.001)	0.027*** (0.001)
Technological Complexity Index (TCI)	0.016 (0.089)	0.013 (0.088)	-0.027 (0.090)	-0.017 (0.090)	0.032 (0.089)	0.017 (0.089)	-0.021 (0.090)	-0.011 (0.091)
GDP per capita (ln)	0.283*** (0.045)	0.282*** (0.045)	0.287*** (0.045)	0.284*** (0.045)	0.282*** (0.045)	0.282*** (0.045)	0.285*** (0.045)	0.283*** (0.045)
Population (ln)	0.065* (0.037)	0.059 (0.037)	0.065* (0.037)	0.056 (0.037)	0.062* (0.037)	0.058 (0.037)	0.064* (0.037)	0.055 (0.037)
Constant	-3.927*** (0.526)	-3.840*** (0.526)	-3.934*** (0.525)	-3.806*** (0.526)	-3.898*** (0.526)	-3.831*** (0.526)	-3.923*** (0.525)	-3.792*** (0.526)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	44,470	44,470	44,470	44,470	44,470	44,470	44,470	44,470
Number of IDMI	13,666	13,666	13,666	13,666	13,666	13,666	13,666	13,666
ll_c	-16702	-16691	-16703	-16688	-16695	-16685	-16702	-16681
chi2	1119	1133	1114	1136	1133	1144	1117	1148

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

Table A2
New entry of technological specialization using RTA>2.0

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**-0.184*** (0.035)**	**-0.231*** (0.031)**	**-0.110*** (0.033)**	**-0.160*** (0.035)**	**-0.246*** (0.070)**	**-0.274*** (0.060)**	**-0.136** (0.068)**	**-0.206*** (0.071)**
Number of interregional linkages (InterLinks) (ln)	0.038 (0.043)				0.145 (0.088)			
Number of specialised linkages (SpecLinks) (ln)		**0.303*** (0.054)**		**0.354*** (0.056)**		**0.418*** (0.110)**		**0.452*** (0.114)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			**-0.129*** (0.050)**	**-0.196*** (0.050)**			-0.019 (0.108)	-0.103 (0.112)
*Intra*RD*					0.003 (0.003)	0.002 (0.002)	0.001 (0.003)	0.002 (0.003)
*Inter*RD*					-0.006 (0.004)			
*SpecLinks * RD*						-0.006 (0.005)		-0.005 (0.005)
NoSpecLinks RD*							-0.006 (0.005)	-0.005 (0.005)
Relatedness density (RD)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)	0.030*** (0.001)
Technological Complexity Index (TCI)	0.342** (0.148)	0.344** (0.151)	0.289* (0.152)	0.287* (0.157)	0.356** (0.148)	0.342** (0.151)	0.308** (0.152)	0.303* (0.157)
GDP per capita (ln)	0.221*** (0.046)	0.218*** (0.046)	0.226*** (0.046)	0.222*** (0.046)	0.221*** (0.046)	0.218*** (0.046)	0.225*** (0.046)	0.222*** (0.046)
Population (ln)	0.034 (0.038)	0.025 (0.038)	0.031 (0.038)	0.020 (0.038)	0.033 (0.038)	0.025 (0.038)	0.031 (0.038)	0.019 (0.038)
Constant	-3.566*** (0.529)	-3.441*** (0.530)	-3.535*** (0.529)	-3.369*** (0.529)	-3.558*** (0.529)	-3.434*** (0.530)	-3.530*** (0.529)	-3.362*** (0.529)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45,920	45,920	45,920	45,920	45,920	45,920	45,920	45,920
Number of IDMI	13,834	13,834	13,834	13,834	13,834	13,834	13,834	13,834
ll_c	-15852	-15834	-15847	-15823	-15850	-15832	-15846	-15821
chi2	992.6	1018	991.3	1024	1001	1020	1000	1036

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

Appendix B

Table B1
Persistence using RTA>1.5

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	1.451***	1.376***	1.721***	1.604***	1.171***	1.189***	1.566***	1.395***
	(0.058)	(0.054)	(0.060)	(0.060)	(0.119)	(0.102)	(0.115)	(0.120)
Number of interregional linkages (InterLinks) (ln)	0.148**				0.502***			
	(0.073)				(0.169)			
Number of specialised linkages (SpecLinks) (ln)		0.633***		0.803***		0.888***		0.994***
		(0.082)		(0.086)		(0.180)		(0.188)
Number of nonspecialised linkages (NoSpecLinks) (ln)			-0.772***	-0.960***			-0.353*	-0.559**
			(0.093)	(0.100)			(0.208)	(0.228)
*Intra*RD*					0.009***	0.006**	0.005	0.007**
					(0.003)	(0.003)	(0.003)	(0.004)
*Inter*RD*					-0.012**			
					(0.005)			
*SpecLinks * RD*						-0.009		-0.007
						(0.006)		(0.006)
NoSpecLinks RD*							-0.016**	-0.015**
							(0.007)	(0.007)
Relatedness density (RD)	0.090***	0.090***	0.088***	0.089***	0.089***	0.088***	0.088***	0.088***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Technological Complexity Index (TCI)	1.068***	1.179***	0.613***	0.758***	1.062***	1.165***	0.614***	0.767***
	(0.203)	(0.205)	(0.205)	(0.209)	(0.204)	(0.209)	(0.203)	(0.209)
GDP per capita (ln)	0.976***	0.983***	0.956***	0.956***	0.983***	0.989***	0.957***	0.959***
	(0.128)	(0.128)	(0.127)	(0.127)	(0.128)	(0.128)	(0.127)	(0.127)
Population (ln)	-0.061	-0.107	-0.089	-0.148	-0.067	-0.111	-0.096	-0.156
	(0.104)	(0.105)	(0.103)	(0.104)	(0.104)	(0.105)	(0.103)	(0.104)
Constant	-7.170***	-6.513***	-6.674***	-5.787***	-7.088***	-6.446***	-6.567***	-5.680***
	(1.589)	(1.593)	(1.553)	(1.557)	(1.591)	(1.592)	(1.554)	(1.557)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	44,391	44,391	44,391	44,391	44,391	44,391	44,391	44,391
Number of IDMI	13,770	13,770	13,770	13,770	13,770	13,770	13,770	13,770
ll_c	-12137	-12127	-11817	-11704	-12123	-12105	-11799	-11686
chi2	2167	2133	2207	2144	2164	2138	2205	2155

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

Table B2
Persistence using RTA>2.0

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of intraregional linkages (IntraLinks) (ln)	**1.375*** (0.055)**	**1.250*** (0.049)**	**1.644*** (0.057)**	**1.534*** (0.057)**	**1.072*** (0.106)**	**0.917*** (0.086)**	**1.412*** (0.100)**	**1.268*** (0.105)**
Number of interregional linkages (InterLinks) (ln)	-0.012 (0.072)				0.049 (0.154)			
Number of specialised linkages (SpecLinks) (ln)		**0.645*** (0.083)**		**0.837*** (0.089)**		**0.718*** (0.169)**		**0.912*** (0.181)**
Number of nonspecialised linkages (NoSpecLinks) (ln)			**-0.877*** (0.086)**	**-1.041*** (0.093)**			**-0.706*** (0.175)**	**-0.900*** (0.196)**
*Intra*RD*					**0.013*** (0.004)**	**0.015*** (0.003)**	**0.010*** (0.004)**	**0.012*** (0.004)**
*Inter*RD*					-0.001 (0.006)			
*SpecLinks * RD*						-0.002 (0.007)		-0.002 (0.007)
NoSpecLinks RD*							-0.007 (0.007)	-0.006 (0.008)
Relatedness density (RD)	0.094*** (0.003)	0.094*** (0.003)	0.092*** (0.003)	0.093*** (0.003)	0.088*** (0.004)	0.089*** (0.004)	0.089*** (0.004)	0.089*** (0.004)
Technological Complexity Index (TCI)	0.667* (0.349)	0.712** (0.342)	0.069 (0.322)	-0.017 (0.318)	0.543 (0.351)	0.539 (0.342)	0.020 (0.324)	-0.087 (0.332)
GDP per capita (ln)	0.892*** (0.132)	0.908*** (0.132)	0.868*** (0.130)	0.880*** (0.130)	0.900*** (0.131)	0.916*** (0.131)	0.876*** (0.130)	0.895*** (0.132)
Population (ln)	-0.243** (0.105)	-0.292*** (0.106)	-0.276*** (0.103)	-0.340*** (0.104)	-0.253** (0.105)	-0.304*** (0.106)	-0.282*** (0.103)	-0.339*** (0.106)
Constant	-4.675*** (1.632)	-3.991** (1.641)	-4.107*** (1.574)	-3.181** (1.576)	-4.455*** (1.617)	-3.722** (1.626)	-3.976** (1.568)	-3.266** (1.617)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	44,997	44,997	44,997	44,997	44,997	44,997	44,997	44,997
Number of IDMI	13,785	13,785	13,785	13,785	13,785	13,785	13,785	13,785
ll_c	-10690	-10710	-10389	-10283	-10662	-10653	-10376	-10268
chi2	1981	1941	2024	1974	1971	1929	2010	1898

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

Appendix C

Correlation Matrix

	NewEntry	Persistence	IntraLinks	InterLinks	SpecLinks	NoSpecLinks	RD	TCI	GDPper	POP
NewEntry	1.000	-	0.059	0.067	0.070	0.037	0.297	-0.022	0.229	0.185
Persistence	-	1.000	0.486	0.317	0.342	0.136	0.544	-0.018	0.362	0.327
IntraLinks	0.059	0.486	1.000	0.746	0.610	0.706	0.199	-0.243	0.233	0.280
InterLinks	0.067	0.317	0.746	1.000	0.840	0.884	0.176	-0.274	0.214	0.235
SpecLinks	0.070	0.342	0.610	0.840	1.000	0.555	0.149	-0.175	0.177	0.208
NoSpecLinks	0.037	0.136	0.706	0.884	0.555	1.000	0.140	-0.278	0.176	0.190
RD	0.297	0.544	0.199	0.176	0.149	0.140	1.000	0.013	0.621	0.501
TCI	-0.022	-0.018	-0.243	-0.274	-0.175	-0.278	0.013	1.000	-0.008	-0.012
GDPper	0.229	0.362	0.233	0.214	0.177	0.176	0.621	-0.008	1.000	0.441
POP	0.185	0.327	0.280	0.235	0.208	0.190	0.501	-0.012	0.441	1.000