ARTICLES
SPACE, ECONOMY AND POPULATION

DOES GEOGRAPHICAL PROXIMITY STILL MATTER FOR INNOVATION? NOTES ON UNIVERSITY-INDUSTRY INTERACTION FROM THE PERSPECTIVE OF A PERIPHERAL CONTEXT

Ana Cristina de Almeida Fernandes[*]
Bruno Campello de Souza[**]
Alexandre Stamford da Silva[***]
João Policarpo Rodrigues Lima[***]

[*]Universidade Federal de Pernambuco, Departamento de Ciências Geográficas, Recife, PE, Brazil
[**]Universidade Federal de Pernambuco, Departamento de Ciências Administrativas, Recife, PE, Brazil
[***]Universidade Federal de Pernambuco, Departamento de Economia, Recife, PE, Brazil

Abstract

Interactions between universities and industry are essential for innovation systems, whereby the process is catalyzed by the proximity between these actors in different dimensions (cognitive, organizational, social, institutional and geographical). The present paper seeks to investigate the specific importance of geographical proximity for university-industry interactions during a specific moment in Brazil's peripheral socioeconomic formation, with the construction of an institutional framework that proved favorable to peripheral innovation and the advancement of information and communication technologies that would dispense with co-location and face-to-face contact in collective learning processes. By applying multiple linear regression analysis and smallest space analysis (SSA) to a database obtained from an extensive survey, it was observed that, associated with the cognitive dimension, geographical proximity still prevails in interactions for innovation in peripheral contexts.

Keywords

Geographical Proximity; University-Industry Interaction in a Peripheral Context; Immature Systems of Innovation; Smallest Space Analysis.

ARTIGOS
ESPAÇO, ECONOMIA E POPULAÇÃO

PROXIMIDADE GEOGRÁFICA AINDA IMPORTA PARA INOVAÇÃO? CONSIDERAÇÕES BASEADAS NA INTERAÇÃO UNIVERSIDADE-EMPRESA EM CONTEXTO PERIFÉRICO

Ana Cristina de Almeida Fernandes[*]
Bruno Campello de Souza[**]
Alexandre Stamford da Silva[***]
João Policarpo Rodrigues Lima[***]

[*]Universidade Federal de Pernambuco, Departamento de Ciências Geográficas, Recife, PE, Brasil
[**]Universidade Federal de Pernambuco, Departamento de Ciências Administrativas, Recife, PE, Brasil
[***]Universidade Federal de Pernambuco, Departamento de Economia, Recife, PE, Brasil

Resumo

Interações entre universidades e empresas são essenciais para sistemas de inovação, com o processo catalisado pela proximidade entre esses atores em diferentes dimensões (cognitiva, organizacional, social, institucional e geográfica). O presente trabalho pretende promover a compreensão da importância da proximidade geográfica para interações universidade-empresa em um momento histórico específico da formação socioeconômica brasileira, quando se observavam a construção de um arcabouço institucional favorável à inovação periférica e o avanço das tecnologias de informação e comunicação que dispensariam a colocalização e o contato face a face em processos de aprendizagem coletiva. A aplicação de análises de Regressão Linear Múltipla e da Smallest Space Analysis (SSA) a uma base de dados obtida em 2008, resultante de uma survey extensiva, permitiu observar que, associada à dimensão cognitiva, a proximidade geográfica prevalece em interações para inovação em contextos periféricos.

Palavras-chave

Proximidade Geográfica; Interação Universidade-Empresa em Contexto Periférico; Sistema de Inovação Imaturo; Smallest Space Analysis.

DOES GEOGRAPHICAL PROXIMITY STILL MATTER FOR INNOVATION? NOTES ON UNIVERSITY-INDUSTRY INTERACTION FROM THE PERSPECTIVE OF A PERIPHERAL CONTEXT[1]

Ana Cristina de Almeida Fernandes
Bruno Campello de Souza
Alexandre Stamford da Silva
João Policarpo Rodrigues Lima

Introduction

Interactions between economic enterprises (hereafter called industry or companies) and universities and public research institutes (henceforth referred to as universities) are revealed as being important constituent elements of innovation systems (LUNDVALL, 1992; FREEMAN, 1995; MOWERY; SAMPAT, 2005). Introducing new products and processes or improving those already in existence demands a complex articulation of different fields of knowledge, from different organizational cultures, temporalities and languages. Even though universities are by no means the only source of knowledge available to industry, they generate knowledge that offers inspiration, helps to conclude new products and processes or enhance existing ones, and provide people with qualifications (MEYER-KRAHMER; SCHMOCH, 1998).

These are relevant observations, although based on empirical contexts specific to countries located at the technological frontier. Which factors would therefore characterize university-industry interactions in countries and regions

1. This paper is part of the research results *Academy-Industry interaction in Brazil: the importance of geographical proximity and implications for STI policy* supported by Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco (FACEPE) - Project FACEPE APQ-1484-7.06/12. [Pernambuco State's Science and Technology Foundation] to which the authors are grateful. The authors also thank the anonymous journal referees who provided valuable inputs to the revisions that undoubtedly improved the paper. Errors, omissions and misinterpretations are the authors' own.

on the so-called periphery of the world-economy? Understood by Furtado (1974) as a central element in the center-periphery relationship, innovative competence in less developed countries and regions is predominantly focused on generating less-complex solutions and adaptations of technologies created in the center (PINHO; FERNANDES, 2015). Such a relationship, on the periphery, impedes the process of industrialization and of constituting science, technology and innovation (ST&I) systems and of funding innovation. This thereby inspired Suzigan and Albuquerque (2011) to identify innovation systems as being immature in peripheral countries, among which those in Latin America are somewhat outstanding, due to the colonial exclusivity that characterized the constitution of their primary-export national economies (PRADO JUNIOR, 2021), and the strong presence of subsidiaries of foreign companies in their most recent productive structure (DUTRÉNIT; ARZA, 2010).

The distance between universities and industry expresses a typical characteristic of immature innovation systems, even though this is frequently reduced to communication difficulties experienced between both, derived from differences in objectives, times and methods, due to the recent advances in terms of stimuli from public policies (CAVALCANTE, 2018). The nature of university-industry interaction observed in these immature systems, however, should not be considered any less relevant since it largely focuses on improvements, incremental changes and adjustments to the specificities of the local market, as indicated by Pinho and Fernandes (2015). To the contrary, herein lies a specificity of the importance this interaction holds for backward economies, and thereby requires closer observation, according to Furtado's definition (1974), if overcoming underdevelopment is placed on the agenda.

Perceiving the university-industry interaction as a central element in innovation processes, even in less developed contexts, the central problem chosen by the investigation that originated this paper was to understand the conditions that favor the proximity between such agents in an immature innovation system, as termed by Albuquerque (1999). This was in line with the interest that the debate regarding clusters, innovative industrial districts, *milieux innovateurs*, etc. had stimulated among scholars from different fields of regional analysis since the 1990s, brought about by the Fordist crisis (FERNANDES, 2001), and which in Brazil translated into the idea of local productive arrangements (LPAs) and local productive and innovative arrangements and systems (LPIAS), proposed by Cassiolato and Lastres (2001; 2003). It was soon understood that geographical proximity facilitates the exchange of information and knowledge intrinsic to the learning process and innovation; it is particularly relevant in relation to tacit knowledge (GARCIA, 2021), which cannot be codified and, therefore, is acquired through shared experiences (NELSON; WINTER, 1982; POLANYI, 1966). Thus, attention within the international debate turned to overcoming the barriers to proximity between such agents (TORRE; RALLET, 2005; TORRE, 2008), and even more to the discussion focused on immature innovation systems, precisely characterized by having reduced points of interaction between universities and industry (ALBUQUERQUE, 1999; SUZIGAN; RAPINI; ALBUQUERQUE, 2011).

On the other hand, the technological advances derived from the microelectronics revolution, by expanding the possibilities of distance communication, awakened an intense debate around the perspective that ICTs (information and communication technologies) could reduce the significance of geographical or physical proximity in learning triggered in interactions, eventually leading to the "death of geography" (MORGAN, 2004). The debate then turned to problematizing the idea of proximity, with the understanding that other dimensions, besides the geographical, also constituted the matter being discussed, in the case of a multidimensional phenomenon. As Gertler (2003) and Morgan (2004), among others, observed, relational and organizational factors also affect the occurrence of closeness. Boschma (2005) then systematized several constraints that take effect in the interaction for learning and proposed decomposing proximity into five dimensions: cognitive, geographical, social, institutional and organizational.

The understanding of this multidimensional character of proximity spread quickly and was also observed on the periphery of the capitalist world, as reported by Garcia et al. (2011). Within these contexts, it is therefore plausible to assume that the degrees of importance of each dimension undergo changes, that different combinations take place between them. Essentially, the decomposition of proximity into different dimensions demonstrates that the specific configuration of the economic-territorial formation affects the nature of organizations, the institutional parameters that govern the behavior of agents and social relationships, thereby conditioning the learning process across the entire spectrum of the capitalist system.

However, the unequal growth and distribution of gains from technical progress between central and peripheral countries has led to profound inequalities in knowledge and learning, compromising the construction of innovative skills (SZAPIRO; MATOS; CASSOLATO, 2021) and specifically interfering with university-industry interaction in economies originating from agricultural exports and late industrialization, as in the case of Brazil (SUZIGAN, 2009). The relatively low complexity of a company's innovation process in this peripheral context reduces the demand for learning in cooperation with the university. These observations have raised the hypothesis that in peripheral or underdeveloped innovation systems, in which the percentage of self-declared innovative companies that launch new products or processes onto the domestic market is significantly reduced – not to mention the international market, as the various editions of Pintec[2] have demonstrated –, geographical proximity has tended to remain particularly relevant for interaction, despite the significant advances in ICTs.

This would be the case of the Northeastern region of Brazil, the focus of this study, where the use of innovation by industry as a competitive strategy is relatively limited, as expressed by the low ratio between private investment in research and development (R&D) and net sales, the low demand of companies for external knowledge and the reduced capacity that they present for remote prospecting, as reported by Pintec (FERNANDES; SILVA; SOUZA, 2011). When a company requires external knowledge, it tends to seek partners in geographical proximity, at more accessible costs, compatible with the complexity of the demand involved. Thus, instead of being a gateway to the exchange of knowledge, interaction in underdeveloped contexts is often triggered by a company as being a substitute for internal research, which ultimately reduces the importance of face-to-face contact, highly emphasized by Storper and Venables (2005), observing frequent knowledge flows between companies and external partners in dynamic centers. Face-to-face contact on the periphery is less due to the learning experience translated into Polanyi's (1966) idea of tacit knowledge, and more to the high costs of prospecting and access to external knowledge located over great distances.

The intention of this paper is to investigate this hypothesis in order to discern the importance of geographical proximity for university-industry interaction in peripheral economic-territorial formation, bearing in mind the progress of ICTs under circumstances where face-to-face contact within these contexts is less important. Previous studies (FERNANDES; SILVA; SOUZA, 2011) have made it possible to understand that a significant part of the observed interactions have received stimuli from outside the region through regional induction instruments from federal innovation policies (Sectoral Funds, Information Technology Law, demands from Petrobras [the majority state-owned Brazilian oil and gas company], etc.). The predominance of interactions stimulated by public policy has been the motivation to investigate the other side of the same coin: the influence of geographical proximity on the relatively low occurrence of knowledge flows

2. *Pesquisa de Inovação* [Innovation Research] by The Brazilian Institute of Geography and Statistics (IBGE). The research investigates the factors that influence the innovative behavior of companies, as well as the strategies adopted, and the efforts and incentives undertaken, the obstacles faced and some results of innovation.

between research groups and companies, while remaining aware that such flows are due to specific demands from the sectors in which the region specializes.

Before presenting the structure of the article, it is necessary to lodge a caveat: the databases used herein have resulted from a nationwide survey[3] that generated a large number of products, including theses, dissertations, articles and books[4], in addition to two large databases: the first, produced by extracting data from the 2004 census (at the time, the most recent) from the Directory of Research Groups (DGP) at National Council for Scientific and Technological Development (CNPq); and the second, called the "Brasil Survey, 2008", subdivided into two others, obtained through surveys carried out in 2008 with (i) leaders of interactive research groups registered in the 2004 Census of the DGP, and (ii) representatives from the research and development area of the companies mentioned by the leaders of the research groups. Although the surveys gathered together a considerable amount of information (1,005 completed questionnaires from interactive research groups against a total of 2,151 groups which, in 2004, declared that they upheld interactions with 3,875 companies; and 326 questionnaires completed by representatives of the companies), the first database, which initiated the research as a whole, has an unprecedented dimension, due to the wealth of systematized data and through the complexity of how it was obtained. Furthermore, the DGP no longer provides data at the level of disaggregation offered at that time, which makes it impossible to update it with the same level of detail.

Thus, the wealth of this database provided a significant source of information on university-industry interaction in Brazil, which is unavailable for more recent years. On the other hand, despite the changes that have occurred since then in the scientific base and in its willingness to interact with the productive sector, the collected data offer a record of a moment in history which took on a broad institutional framework and of financial and fiscal stimuli in order to encourage university-industry interaction, which at that time was incipient in Brazil. In the context of increased economic dynamism, the launch of the Industrial,

---

3. *Interações de universidades e institutos de pesquisa com empresas no Brasil* [The Interactions of universitites and research institutes with Brazilian companies]; A Fapesp Thematic Project (Process number 06/58.878-8) and National Council for Scientific and Technological Development (CNPq) Universal Edict (Process number 401.529/2010-0).

4. Among others, we highlight the books *Em busca da inovação* [In search of innovation] and *Developing national systems of innovation*. SUZIGAN, W.; ALBUQUERQUE, E.; CÁRIO, S. (org.). *Em busca da inovação:* Interações de universidades e institutos de pesquisas com empresas no Brasil. [In Search of innovation: Interactions of universities and research institutes with companies in Brazil] Belo Horizonte: Autêntica, 2011. SUZIGAN, W. (org.). *Developing national systems of innovation. University-industry interactions in the global South*. Cheltenham: Edward Elgar, 2015.

Technological and Foreign Trade Policy (PITCE) signaled the resumption of industrial policies as an instrument of economic development, within the scope of the then recently sanctioned Innovation Law (BRASIL, 2004), which provided for devices to facilitate the academic-industry relationship. Among other objectives, the research has sought to record the first evidence of this new context, for which the first step was an exhaustive survey of the DGP research groups.

One of the main conclusions of the research has revealed a positive perception on the part of the researchers, both in terms of the results and benefits for the research groups, varying according to the areas of knowledge and the size of the companies. The preliminary analysis made it possible to observe the "intermediate stage of the Brazilian innovation system", with universities involved in sophisticated R&D projects in collaboration with industry, but also in less consequential collaboration activities (testing and quality control) (SUZIGAN, 2009). Thus, a research effort was constituted that managed to reveal the transformations that would become evident throughout the following decade. Therefore, not only is there an extensive record to analysis of that particular period, but also material to enable investigation into the still under-explored university-industry interaction within the context of the Northeast region of the country.

The article is structured into three sections, in addition to this introduction. The first presents the conceptual framework concerning the importance of proximity for interactions to take place in immature or underdeveloped innovation systems, taking the international debate as a reference, which will then be contrasted with contributions focused on the Brazilian case. The following section details the methodological procedures used and the research results. In the third and last section, the results are analyzed in view of the adopted theoretical framework and the main conclusions are presented.

1. Geographical proximity in university-industry interaction: elements for characterizing the conceptual framework

By understanding innovation as a collective, interactive, and cumulative process over time, intrinsic to economic development, we adhere to the idea that it is a systemic process, i.e., that it occurs through the joint action of several agents with distinct, complementary skills, as expressed in the concept of a national innovation system (FREEMAN, 1988 LUNDVALL, 1992; NELSON, 1993).[5] Hence, the notion that an innovation system is not the simple sum of parts, but rather a whole that results

5. Based on the original contributions of these authors, the Organization for Economic Cooperation and Development (OECD) conceptualized a national innovation system as a network or complex of interactions between public and private actors, connected through information flows and fundamental technologies for the development of innovations on a national scale. OECD, National Innovation Systems, 1997. Report available at https://www.oecd.org/science/inno/2101733.pdf.

from the interaction between them, affected by conditioning factors of different natures (EDQUIST, 2005). Among the most important relationships observed by Nelson and Rosenberg (1993) in innovation systems is the exchange of knowledge between agents in the productive base and in the scientific and technological base, a relevant source for technical progress.

However, the occurrence of university-industry interaction encounters barriers, due to the difficulty of communication between the academic circles and organizations, because of the difference in language, cultures, times, and objectives of each of the parties. Since communication between agents is an essential element of the system, the problem of geographical proximity has attracted the attention of innovation scholars as a factor that minimizes uncertainties and solves coordination problems (BOSCHMA, 2005). Geographical proximity thus facilitates the innovation process, in general (STORPER; VENABLES, 2004), and the emergence of university-industry interaction, in particular (JAFFE, 1989; AUDRESTCH; FELDMAN,1996; ANSELIN; VARGA; ACS, 1997; ARUNDEL; GEUNA, 2004; D'ESTE; IAMMARINO, 2010; LAURSEN; REICHSTEIN; SALTER, 2011).

Within this line of reasoning, we emphasize that communication difficulties related to culture and language are closely connected to the economic-territorial formation of each country, which, in the case of Brazil, is derived from its historical specialization as a supplier of "exotic products" in the world economy (PRADO JUNIOR, 2021). This formation has introduced constraints, which have contributed to attaching barriers to interaction, among which we place the late industrialization and creation of a scientific and technological base and the predominance of sectors with low technological dynamism, in addition to the profound social inequality that curbs the innovative potential of the population and, consequently, of the economy as a whole. Thus, the very concept of innovation, as claimed by Szapiro, Matos and Cassiolato (2021), is expanded to include not only new products and processes on the international or domestic markets, but also new products and processes for the agent that introduces them. Consequently, analyzing the innovation process, the innovation system and the interactions between the constituent parts of the system in such contexts involves specificities that impose a review of the conceptual framework built with contributions focused on observation of other realities.

However, without diminishing the importance of taking into account the specificities of developing countries, Szapiro, Matos and Cassiolato (2021, p. 339) argued that the literature which inspired the focus of debate around innovation systems was not "disconnected from the thinking generated in developing countries".[6] This was not only because it has been built with contributions by

6. This and all non-English citations hereafter have been translated by the authors.

theorists from these countries, especially from the structuralist/ECLAC school (PEREZ, 1983; PEREZ; SOETE, 1988; AROCENA; SUTZ, 2005; 2010; AROCENA; GÖRANSSON; SUTZ, 2015; CASSIOLATO; LASTRES, 2008), but also because its conceptual pillars have been deeply rooted in the debate on development, thereby benefiting from conceptual and normative implications of its application to the reality of developing countries.

1.1. Proximity matters for university-industry interactions

In the international debate, led by studies focused on advanced economies, such interest has stemmed from observing that the spatial proximity of academic and business agents has been understood by the latter as a condition that aids and enhances their internal innovative efforts. This line of reasoning has inspired numerous studies, conducted with the purpose of empirically testing the argument. The pioneering work of Jaffe (1989) is of particular note, when he demonstrated the existence of important spillovers of knowledge on the local scale.

Audrestch and Feldman (1996) followed along similar lines, suggesting that there is a positive correlation between business innovation and academic research also on a regional scale. Numerous contributions accompanied these arguments, strengthening the constitution of a theoretical field that defended geographical proximity between industry and universities as being a relevant factor for the innovation process (MANSFIELD; LEE, 1996; TORRE; RALLET, 2005; GARCIA et al., 2011) and for the implementation of public policies to promote instruments such as technology parks, local productive arrangements, etc. (VEDOVELLO; JUDICE; MACULAN, 2006).

The arguments highlighted in this literature may be summarized in three main aspects: (i) companies located close to universities take more effective advantage of the spillovers of knowledge produced there; (ii) geographical proximity facilitates the access of companies to knowledge networks, which includes academic researchers; (iii) this proximity favors interactive learning processes within companies, in view of the tacit nature of knowledge. This importance is reinforced in situations where interactive learning processes and forms of knowledge transfer between universities and companies involve more complex, tacit knowledge (ARUNDEL; GEUNA, 2004).

1.2. Proximity: spatial and non-spatial dimensions

Addressing the importance of geographic proximity to produce innovations boosted local and regional development studies. Being located at a geographical distance that may be quickly surmounted would be a vital factor for interactions to take place by facilitating communication between individuals who share the values, cultures, language, and knowledge infrastructures from the same place. Indeed, interactions do not only occur due to the physical proximity of the actors involved, but also refer to aspects of a relational nature. The advancement of ICTs, however, has challenged the focus restricted to geographical proximity, by making it possible to overcome distances to the point of constituting a virtual space where interactions may effectively occur at a distance (HOWELLS; BESSANT, 2012), a phenomenon intensified by the SARS-CoV-2, which accelerated investments in connectivity and reduced the resistance to adopting remote communication practices (FERNANDES, 2021).

Although relativized, the importance of geography for the learning and innovation processes does not disappear (MORGAN, 2004), but rather musters the idea that geographical proximity is one dimension among others that work together in the innovation process, reducing uncertainties and facilitating the coordination of collective learning (BOSCHMA, 2005; NOOTEBOOM et al., 2007; WETERINGS; BOSCHMA, 2009; SHEARMUR, 2011). It may be observed that the notion of proximity goes beyond geographical distance.

An initial effort regarding this issue resulted in identifying organizational proximity or organized proximity, defined by relationships of belonging to the community of agents of an organization (TORRE; RALLET, 2005). Other scholars have returned to the notion of industrial agglomeration (BENKO; LIPIETZ, 1994) and of regional and local innovation systems (COOKE; HEIDENREICH; BRACZYK, 2004; EDQUIST, 2005) in order to reaffirm the importance of geography and geographical context, recognizing that the borders of interactive companies are not only geographical, but also organizational, expressed in the outsourcing of R&D in several countries and in the so-called “open innovation” (HOWELLS; BESSANT, 2012). Given the growing complexity, specialization and fragmentation of knowledge, attention to overcoming distances is replaced by mechanisms, strategies and routines used by companies to innovate, taking advantage of specific conditions within different territories. From this, emerges the idea of “communities of practice”, which ignore territorial limits (HOWELLS; BESSANT, 2012), leading to an understanding of proximity as a multifaceted phenomenon (MATTES, 2012).

Boschma (2005) summarized these efforts arguing that the innovation process is not facilitated solely based on isolated geographical proximity, but in relation to other dimensions: cognitive, organizational, social, and institutional. Boschma considered that geographical proximity per se is neither necessary nor sufficient; it is as a whole that geography and the other dimensions – summarized below – reduce uncertainties and coordination problems:

i. *Cognitive proximity*: the existence of a minimum common knowledge base without which communication, absorptive capacity and knowledge exchange between different agents fail to occur.
ii. *Organizational proximity*: the coordination capacity to organize the exchange of complementary pieces of knowledge accumulated by different actors inside and outside an organization.
iii. *Social proximity*: social ties between agents, such as trust, friendship, common experience, kinship, etc., which reduce uncertainties in relationships, especially in the exchange of tacit knowledge.
iv. *Institutional proximity*: formal (norms, rules, or laws) and informal (habits, routines, established practices, cultural parameters) sets of mechanisms that regulate relationships between people, groups and companies and affect the exchange of knowledge and interactive learning.

Considering, moreover, that ICTs promote the flow of knowledge in networks that are not delimited by physical space, it may be argued that geographical proximity becomes less important when: (i) the tasks to be performed are well defined and coordinated and when partners share the necessary common knowledge base (epistemic communities); (ii) the exchange of tacit knowledge only requires sporadic face-to-face contact, it does not require permanent co-location; and (iii) knowledge networks are supported by social constructions that exclude outsiders, whether they are local actors or not. Balland, Boschma and Frenken (2014) however, warn that these dimensions are not static; but rather, they change over time through processes of learning, integration, dissociation, institutionalization, and agglomeration, which affect cognitive, organizational, social, institutional, and geographic proximity, respectively. It should also be mentioned that changes in one will affect the others.

Boschma (2005) had observed, however, that cognitive proximity is a prerequisite for the interactive production of knowledge. This, combined with the geographical dimension, is sufficient for interactive learning to take place, even though maintaining strong ties with other innovative agents may compensate for the geographical distance, also owing to the lock-in effects that co-location may generate (BALLAND; BOSCHMA; FRENKEN, 2014). Furthermore, as an effect of geographical proximity, social and cultural proximity enable frequent interactions, strengthening trust and knowledge exchange (MAHDAD et al., 2020). In view of these different possibilities, it is important to contend here that the effects of geographical proximity vary greatly in different spatial contexts, depending on factors such as the knowledge base shared by the actors, the level of complexity required by the companies, and the degree of market dynamism where they are active. These are effects that may only be verified through empirical studies that envisage the control of other dimensions. It is to this challenge that we now turn our attention, considering the specific condition of the peripheral regional economy as our object of study.

1.3. The economic-territorial formation also matters

Technologically backward countries or regions generally concentrate their research competencies in universities. On the other hand, reduced internal research competence within companies restricts interactive learning and cognitive proximity between industry and universities. In Brazil, the phenomenon has been no different: late industrialization based on the importation of technological packages curbed the business demand for knowledge and technology and forged a productive base in which sectors of low and medium-low technological intensity predominated, expressed in the reduced rate of innovation evidenced in successive editions of the Pintec/IBGE. A low demand for knowledge restricts communication in external knowledge networks, orienting the universities towards training people and research agendas distanced from the outside world. It makes sense, therefore, to intuit that this process, illustrated in Figure 1, has forged an immature innovation system in Brazil, as argued by Albuquerque (1999).

However, despite the constraints of the peripheral economic structure, the aggregated data for the Brazilian economy as a whole produced by the broader research, which gave rise to this paper (SUZIGAN; RAPINI; ALBUQUERQUE, 2009), exhibited the occurrence of bilateral communication channels,[7] which generated innovative and productive benefits for industry and intellectual and economic benefits for the research groups. On the other hand, although interactions became established in relatively few economic sectors of knowledge (when compared to those that exist in the dynamic core countries), the relationships originated for the provision of technological services, considered as being knowledge of a lesser intensity and monodirectional, were particularly positive in the Brazilian context, since they are the gateway to more complex ensuing interactions (FERNANDES et al., 2010). This evidence signaled a significant change in the course of the Brazilian innovation system, possibly already in tune with the public policies to stimulate innovation, in general, and university-industry interaction, in particular, which were in progress at the time.

---

7. Bidirectional channels are those in which knowledge flows in both directions, from the university to industry – more frequently in situations of less dynamic economies – and from industry to the university, suggesting a relatively high level of mutual learning and interaction for innovation.

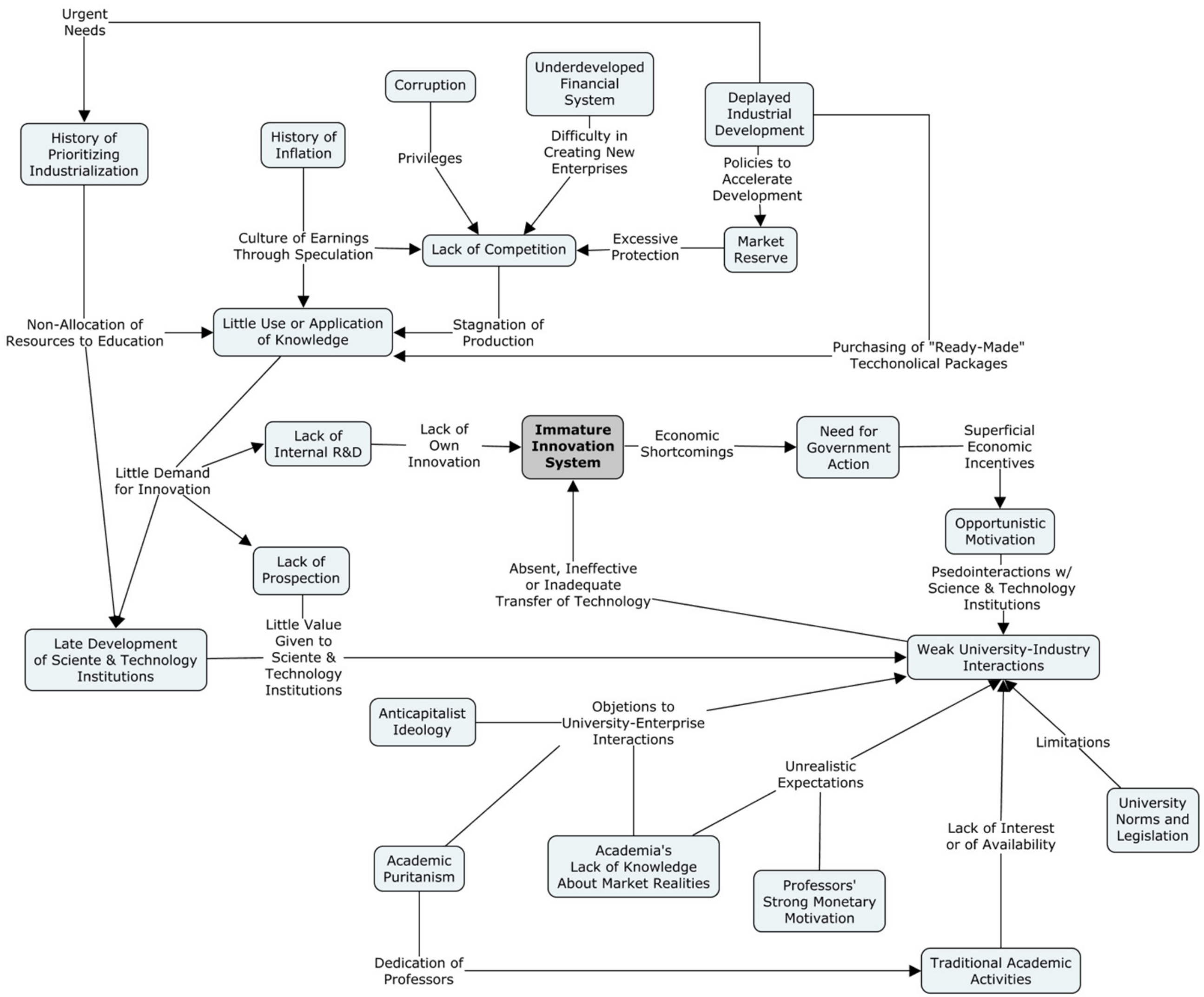


Figure 1. The hypothesis of the immature innovation system

Source: Fernandes, Silva and Souza (2011).

The reduced occurrence of points of interaction observed in the less dynamic regions of the country revealed, however, the permanence of structural factors that hindered the transformation process, thereby accentuating historical regional disparities. Structural factors appeared to be relevant for the national economy as a whole, given the regressive effects caused by the ongoing dismantling of the institutional and development framework that has strengthened the Brazilian innovation system over the past years. Thus, based on Furtado (1974), it is assumed that the instability of ST&I public policy expresses the fragile condition of a country subordinated to the economies of the "dynamic core" of the world-system, which leads to an understanding that the Brazilian innovation system, rather than being termed immature, could be renamed underdeveloped. For Furtado, underdevelopment is characteristic of countries that have been inserted into the capitalist world-economy as suppliers of raw materials, an insertion which, in the absence of structural ruptures, conditions the late processes of industrialization based on foreign technologies and capital. Combined with markets "entrapped" by a deep concentration of wealth, these processes of integration into the world-economy function as a manner of renewing, throughout time, the subordination of these countries to each great wave of technological advances.

Such reasoning leads to the problematization of the term *immature* used by Albuquerque (1999) to define the Brazilian innovation system. It would therefore be appropriate to name it an *underdeveloped* innovation system, given the dysfunctions conditioned by underdevelopment that periodically renew its insertion subordinated to and dependent on the technological dynamics of central countries, thereby, as Paulani (2020) argues, hindering the catching up process. Reaching maturity requires overcoming structural challenges, which involves what Furtado (1990) called social homogenization.[8] It should be remembered that reducing inequalities stimulates the expansion of "epistemic communities", and this, in turn, intensifies fundamental knowledge flows to the innovation system, leading the national economy on to technologically more dynamic levels. In the absence of a structural rupture, the scenario remains deferred, blockading Brazil's insertion into the world-economy, reaffirming its specialization in less knowledge-intensive sectors. The current reprimarization, or "great renunciation", as indicated by Pochmann (2022), expresses the strength of the mechanisms kept active by the legacies of the agricultural export formation, questioning the idea of immaturity

8. According to Furtado (1990), more than raising the average standard of living of the population, social homogenization concerns improving well-being and satisfying the needs of large sections of society, which stimulates the expansion of critical mass and contingents of the population engaged in local technological development, as opposed to the assimilation of exogenous technology.

of the innovation system built into this context. With this reflection, we stand in agreement with Szapiro, Matos and Cassiolato (2021, p. 348), for whom “the focus on interactive learning processes inherent to innovation processes may lead to the underestimation of conflicts over income and different forms of power”.

An analysis of the university-industry interactions confirmed in the economy of North-eastern Brazil, considered one of the least developed regions of the country, illustrates the rationale on a subnational scale. According to DGP/CNPq data, interactions in the Brazilian Northeast are less frequent when compared to the more dynamic regions, while the South-eastern and Southern regions account for a high concentration of interactive groups and companies (more than 70%). This situation may be attributed to the later constitution of a scientific and technological base and the widespread representation of sectors with low and medium-low technological intensity in the north-eastern productive base (FERNANDES; SILVA; SOUZA, 2011). This finding has inspired the hypothesis that, in peripheral regions, interaction with academic partners works predominantly as a kind of outsourced unit for a company’s R&D. More restricted knowledge flows make it difficult to build cognitive proximity, thereby emphasizing the importance of geographical proximity. This tends to prevail, since the technological problems involved are not so complex and may be solved by existing nearby ICTs. Moreover, the costs of overcoming long physical distances are too high for agents based in the regions in focus. There, the importance of the social dimension also grows, since the technological problems of industry are often brought to the university by former students, while the institutional proximity, associated with the geographical proximity, is facilitated by the sharing of cultural values and attitudes. However, there are still significant differences in the objectives, knowledge, and internal practices of each of the parties involved in the interaction, which ultimately hinders organizational proximity. The research results have enabled us to verify this hypothesis.

2. The importance of proximity in an underdeveloped context: database analysis

2.1 Methodological considerations

The investigation produced a database formed through two sets of information constituted in previous stages, supported by two questionnaires, which in 2008, were sent to leaders of the 2,151 interactive research groups listed on the current base of the DGP/CNPq from 2004 (base year of the broader research that originated the present work) and to 1,688 representatives of the companies mentioned by these leaders. The return rate of the questionnaires (answered electronically) was, respectively, 46.7% (1,005 research groups located in 25 states of the federation and in the Federal District) and 19.3% (326 companies). The answers were then consolidated and systematized in two databases, one for the groups and the other for the companies.

The overview presented in Table 1 demonstrates that engineering accounts for most of the 1,005 interactive groups that make up the research database, in line with the international literature. Next comes Biological and Life Sciences and then Agronomy, thus reflecting the importance of sectors related to human health and agricultural activities, both aspects encouraged in Brazil by significant public policies (FERNANDES; SILVA; SOUZA, 2011). With regard to the companies, those considered large (more than 116 employees) accounted for most of the sample (202 of the 325 that responded), followed by small (77) and medium (46). In all three cases, most were national private equity companies.

Main field of knowledge	Research groups		Ranking
	n	%	
Engineering	323	32.14	1
Biological and life sciences	221	22.00	2
Agronomy	200	19.90	3
Exact and natural sciences	158	15.72	4
Humanities	103	10.25	5
Total	1,005	100.00	

Table 1. Brazil: number of research groups per main fields of knowledge (2008)
Source: Own elaboration (2022).

In view of the information provided in the applied questionnaires,[9] the importance of proximity in the interactions studied was obtained through the following procedures: (i) measuring the importance of the logistical, intellectual, bureaucratic, cultural and interpersonal "strengths", which depend, respectively, on the geographical, cognitive, organizational, institutional, and social "distances" (although not only this); (ii) adopting the assumption that groups decide to allocate their resources (time, effort and/or capital) depending on the intensity of the forces acting upon them, among other factors; (iii) dependence on the group decisions regarding the allocation of their resources, chiefly on the combination of their characteristics (area of knowledge, as well as the number and qualification of its members), the public funding received, the type of relationship with companies and the forces acting upon them.

9. The questionnaires were developed jointly with the broader research teams. No specific questions were included for dimensions of proximity other than geographical.

The consequence of these decisions is that group leaders are able to identify "better" or "poorer" results, which thereby generates stimuli for the leader to allocate either more or less time to the interaction. The next step was to perform a multiple linear regression.

2.2 Multiple Linear Regression

In the regression, the results of the interactions were used as a dependent variable and the independent variables were the relationship difficulties, the interaction channels, the funding sources and the characteristics of the group and its leader. All variables were collected directly from the responses to the questionnaire completed by the leaders of the research groups. The constructs of the SSA model were also used, which consisted of an average of the variables of which it is composed (for a better understanding, see these models in Figures 2 and 3). The final model, which best suited the data, contained the independent variables listed in Table 2, which summarizes the statistical findings of the regression.

Multiple R = 0.92, Multiple R^2 = 0.68, Corrected Multiple R^2 = 0.67						
Standard Error of Estimate = 0.43; F(12,871) = 151.87; p < 0.01						
	Beta	**EP**	**b**	**EP**	**t(871)**	**p**
Interception			0.5837	0.114	510.242	<0.01
Being from the Northeast (yes/no)	0.06	0.020	0.10	0.032	3,028	<0.01
Experience in engineering (yes/no)	0.07	0.020	0.12	0.033	3,589	<0.01
Have worked at other universities (yes/no)	0.04	0.019	0.07	0.032	2,282	0.02
Funding received by National Public Institutions (% of the Total)	0.05	0.020	0.00	0.000	2,545	0.01
No. of registered software	0.04	0.019	0.02	0.011	2,209	0.03
Age of research group leader	-0.04	0.020	0.00	0.002	-2,166	0.03
Interaction via services	0.13	0.025	0.11	0.021	5,,043	<0.01
Interaction via knowledge transfer	0.21	0.028	0.16	0.021	7442	<0.01
Interaction via research and development activities	0.29	0.026	0.22	0.020	11,012	<0.01
Logistics strength (dependent on geographical distance)	0.05	0.021	0.04	0.015	2,544	0.01
Bureaucratic strength (dependent on organizational distance)	0.05	0.021	0.05	0.020	2,459	0.01
Innovation and entrepreneurship communication channels	0.29	0.026	0.25	0.023	10,998	<0.01

Table 2. Multiple regression model of the results
Source: Own elaboration (2022).

Multiple Linear Regression enables the findings to be organized into categories of analysis, as follows:

a) Interaction results

Based on the group characteristics such as the way they were constituted, public funding received, type of relationships with the companies and the acting forces, it was possible to explain 67% of the variance in the results of interaction. Moreover, the regression revealed the relative weight of each variable for the results, from which, it should be noted: (i) the positive weight of being from the Northeast of Brazil and from the field of engineering, the negative weight of the age of the group leader and the lack of an effective interpersonal (dependent on social distance)[10], intellectual (dependent on cognitive distance) and cultural (dependent on institutional distance) forces; (ii) the expressive participation to compose the results of the interaction via R&D activities and channels of communication, innovation and entrepreneurship; (iii) the relevant participation also in interactions via knowledge transfer and via services. Despite being positive, logistical (dependent on geographic distance) and bureaucratic (dependent on organizational distance) forces, as well as the number of software registrations, contributed four to six times less than the abovementioned variables.

With the linear regression performed, we turned to a procedure based on the so-called facet theory. This is because research in human, social and environmental sciences frequently involves a large number of variables with multiple linear and non-linear interactions between them, in which the relationship between A and B depends on C, and so on. This creates analytical challenges that are difficult to address with traditional inferential statistical techniques or even with most multivariate methods. The facet theory is a scientific approach that can deal effectively with multivariate phenomena of complex interrelationships through procedures that generate results in a visual, intuitive manner, in addition to closely integrating theory and evidence. Its fundamental logic is the application of SSA to a database, with the choice of a convenient measure of association between variables ("metric" or "distance"), as well as an algorithm to condense multiple dimensions into a smaller number of Cartesian coordinates ("amalgams").

With this, a diagram is produced that contains the number of dimensions that need to be observed (generally opting for only two or three), in the space of which each variable of the analysis is represented as a point, and the distance between each two points is inversely proportional to the association between the two corresponding variables (e.g., the greater the association, the shorter the distance between the points/variables). In a representation such as this, the dimensions

10. The information obtained from the questionnaires express sensitivity to distances, rather than proximity. Henceforth, therefore, proximity will be referred to by its opposite.

or axes have no intrinsic meaning, i.e., they are not interpreted as magnitudes of a greater or lesser intensity, they just constitute a geometric space where all the associations between all the variables are expressed at the same time, depending on their positions. Thus, a visual representation is obtained of the relational structure of the set of variables (ROAZZI; SOUZA, 2019).

In an SSA, the manner with which to identify a grouping of variables that expresses a construct is through geometric profiles (partitioning) of regions of the space defined by the dimensions. Variables within the same partition are interpreted as the constituents of a cluster, factor and/or construct. The architecture of the partitioning defines logical conceptual structures for the set of constructs, according to three basic patterns, namely: (i) axial (parallel lines), (ii) modular (concentric rings) and (iii) polar (oblique lines starting from a same central point). With this, it is possible to identify the way in which the constructs are related (MASCARENHAS et al., 2018).

Using the SSA diagram and the facet theory not only enables a multivariate analysis to be performed and to identify the complex interrelationships, but also for a corresponding conceptual structure based on constructs to be juxtaposed with the results. Thus, empirical and theoretical aspects of a scientific investigation may be thought of in an integrated manner (MASCARENHAS et al., 2018). By using principles from the facet theory (GUTTMAN, 1954) and its associated non-metric analysis technique (SSA), a non-metric multidimensional scaling procedure that has been successfully applied in several studies (CANTER; FRITZON, 1998; CANTER; WENTINK, 2004), it has been possible to verify several formations, using the database related to the research group leaders, as follows.

b) Relationship difficulties and proximity/distance

The SSA diagram (Figure 2) presented a structure that may be divided into four partitions according to a polar structure, in which each partition contains variables referring to one type of distance: geographical, institutional, organizational, and cognitive. Geographical distance is formed by a single variable; institutional distance is made up of four: (i) intellectual property (IP) rights; (ii) divergence regarding deadlines; (iii) difference in priorities; and (iv) a problem of reliability. Organizational distance is composed of three variables: (i) company bureaucracy; (ii) university/research institute bureaucracy (uni/inst); and (iii) research funding. Cognitive distance, in turn, is formed of four variables: (i) a lack of personnel to enter into dialogue with the university/research institute; (ii) a lack of personnel to enter into dialogue with the company; (iii) the company's lack of knowledge regarding the university/research institute; (iv) the university/research institute's lack of knowledge regarding the company. The variables, except for geographical distance, constitute the respective constructs.

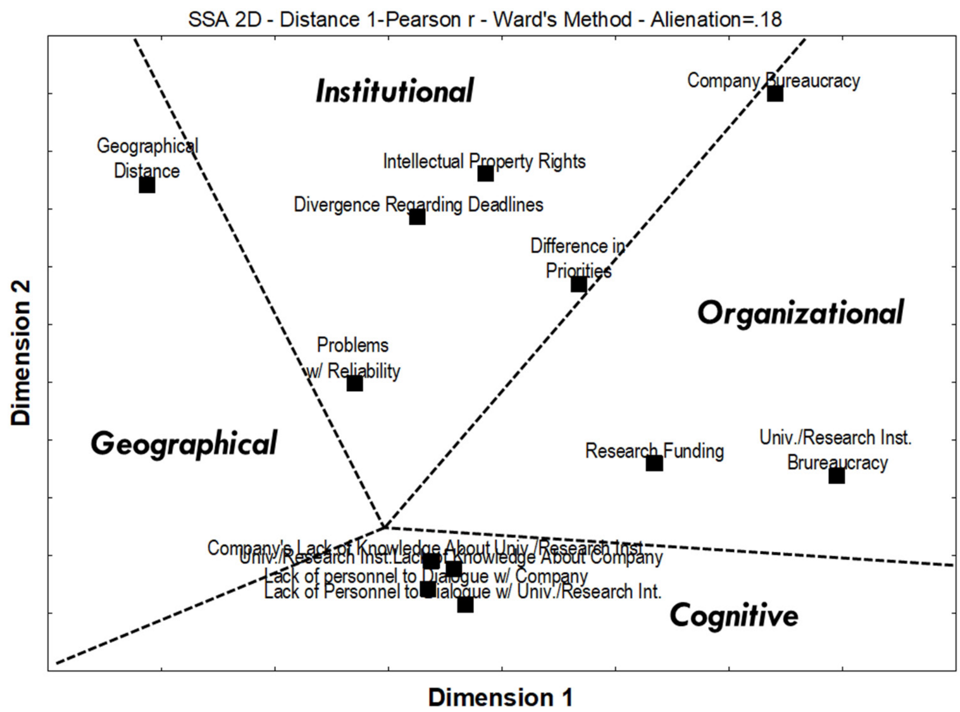


Figure 2. The SSA of proximities/distances
Source: Own elaboration (2022).

The multidimensional analysis suggests that the relational structure of the relationship difficulties helps to identify four constructs, referring to the dimensions of geographical, institutional, organizational and cognitive proximity. We may conclude, therefore, that the theoretical conceptions of proximities proposed by Boschma (2005) emerge from the collected data, indicating the composition of these distances, which go beyond that of the geographical. Social distance cannot be perceived in this first analysis, but subsequently, with the use of information channels, the composition of this dimension may also be perceived.

c) Channels of information and social proximity/distance

The SSA diagram with these new variables (Figure 3) presented a structure that may be divided into three partitions, according to an axial structure, in which each partition contains variables referring to a type of information channel used in the interaction: innovation and entrepreneurship, social contacts and scientific production. Social proximity/distance is formed by the variables individual consultancy, informal exchange of information, personnel training, staff exchange and hiring graduates. The partition related to social contacts may theoretically be interpreted as an indicator of social proximity/distance. The exercise has demonstrated that, once again, the theoretical conceptions of distances presented in Boschma (2005) emerge from the collected data, which also points toward the composition of social distance.

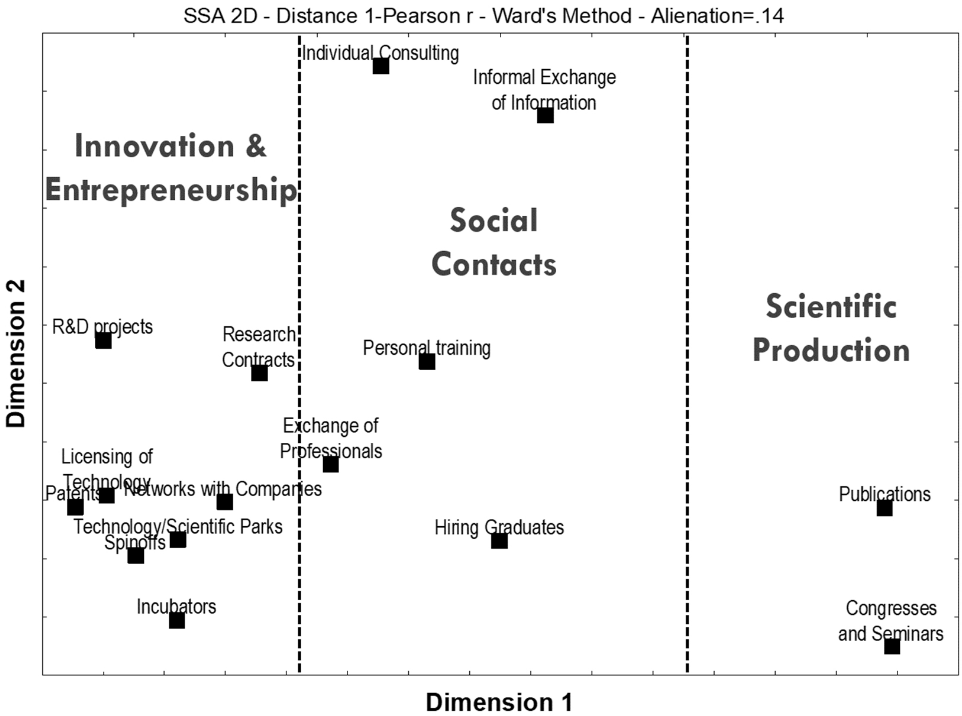


Figure 3. SSA of information channels and social distance

Source: Own elaboration (2022).

d) Constructs of proximity/distance

It was observed that the constructs related to proximity/distance identified in the SSA (taken as the mean of the constituent items) were all statistically consistent according to Cronbach's Alpha (Table 3), a conservative measure of statistical internal consistency.

Construct	Cronbach Alpha
Organizational	0.56
Institucional	0.73
Cognitive	0.75
Social	0.77
Geographical Distance	*

Table 3. Reliability analysis of constructs related to proximity/distance

Legend: *Could not be calculated since it only contains one item (i.e., it is not a construct, but an isolated variable).

Source: Own elaboration (2022).

As a general conclusion of the SSA models, we understand that each of the four identified constructs may be viewed as a measure of a reasonably reliable latent dimension. Since geographical distance was a variable treated objectively in one of the questions on the form, it does not constitute a construct in the sense used in the facet theory. Therefore, the Cronbach's Alpha calculation for this variable neither makes sense nor is it applicable.

Constructs have now been achieved that may be used to verify the importance of these distances in the results and benefits obtained by the research groups, as presented in Table 3.

e) Regions and group-company and company-group interactions

After constructing a correlation matrix (Table 4) with the groups and companies gathered together according to their regions, it may be observed that the probability of interaction between groups and companies from the same region was quite high (over 90% for all regions), while the fraction of interactions between groups and companies from different regions was much smaller (from 0% to 23.6% depending on the region and direction of interaction).

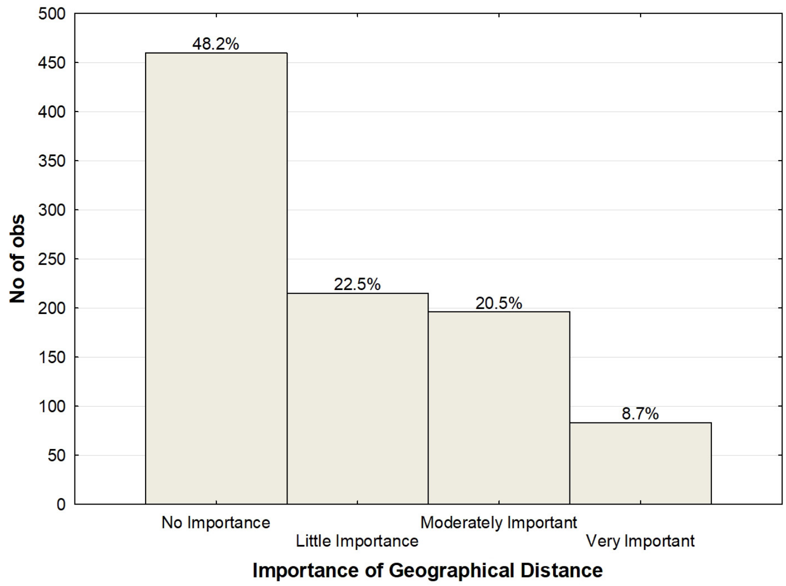
		Groups				
		North	Northeast	Midwest	Southeast	South
Companies	North	**93.80%**	0.70%	2.20%	3.10%	0.80%
	Northeast	0.00%	**91.10%**	7.90%	5.00%	2.30%
	Midwest	9.20%	8.10%	**91.00%**	9.60%	5.40%
	Southeast	15.40%	23.60%	21.30%	**95.40%**	21.80%
	South	1.50%	3.70%	9.00%	8.80%	**92.30%**

Table 4. Correlation matrix between groups and companies per region
Source: Own elaboration (2022).

The much greater probability of interaction between groups and companies in the same region, in contrast to that of interactions between different regions, corroborates the hypothesis that greater geographical proximity increases the chance of interaction taking place.

f) Distribution of the importance of geographical distance

From the responses of the group leaders (Graph 1), we observed that around 70.7% of the groups assessed that geographical distance is of little or no importance, probably due to the majority of interactions occurring within the same region, as presented in Table 4.

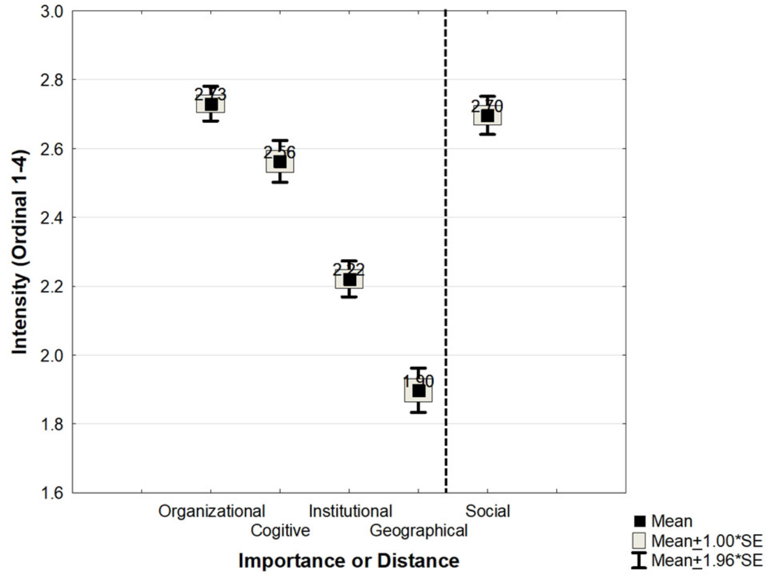


Graph 1. Distribution of the importance of geographical distance
Source: Own elaboration (2022).

The concentration of interactive groups in the least important geographic distance ranges (70.7%) suggests that greater proximity increases the probability of interaction.

g) Comparing the distances

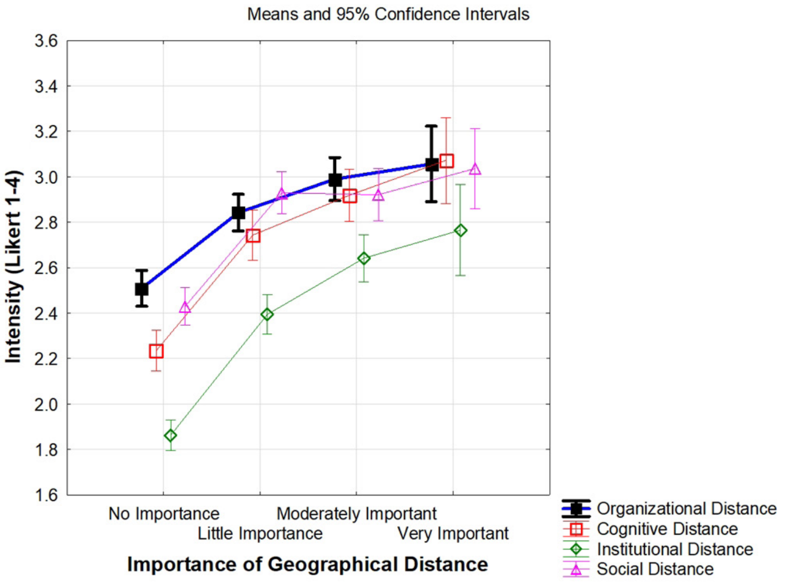
With regard to the dimensions of proximity and distance, the organizational dimension presented the highest average importance, followed by cognitive, institutional and, finally, geographical (Graph 2). The social distance is not directly comparable, since, as demonstrated, it was calculated by an SSA model, keeping in mind that the other distances did not participate, as presented in Figures 2 and 3. Thus, given the way of calculating the social distance, we have decided to represent it separately, although on the same graph, since it is located at the top of the scale from 0 to 4. In other words, while the distances have the same scale, the social distance was obtained from a different model.



Graph 2. Mean values of the importance of distances given by the groups
Source: Own elaboration (2022).

h) Geographical proximity/distance vs. other proximities/distances

The importance given to geographical distance (Graph 3) was positively associated with the others, with the Spearman correlation being higher for institutional distance (Rho = 0.44), followed by cognitive (Rho = 0.34), social distance (Rho = 0.28) and, finally, organizational (Rho = 0.26), all statistically significant for $p < 0.01$. The association of geographic distance with all other distances suggests that greater geographic proximity favors all other forms of proximity.

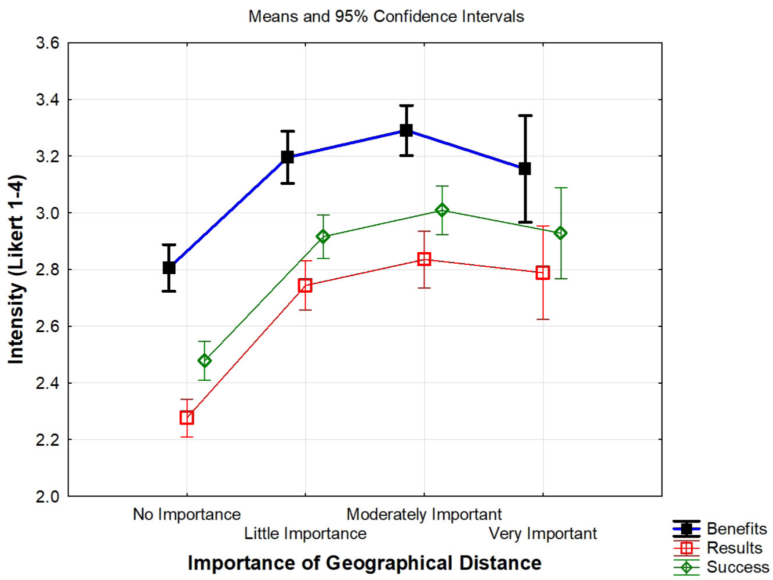


Graph 3. Importance of geographical distance and other distances
Source: Own elaboration (2022).

i) Distance vs. rewards

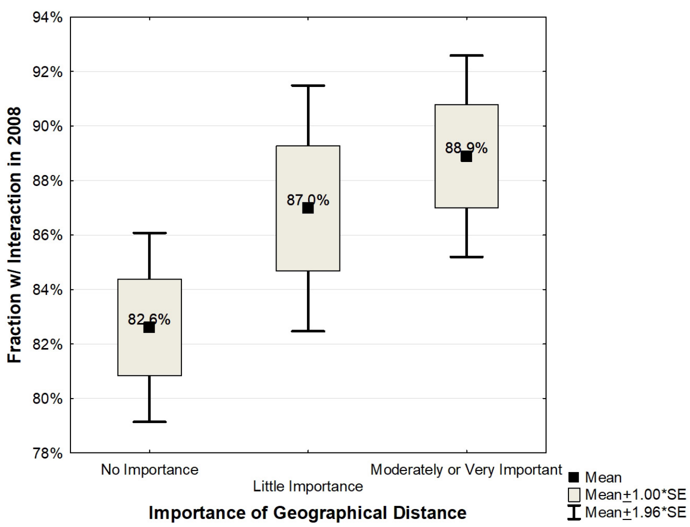
The major importance given to geographical distance demonstrated a positive and statistically significant Spearman correlation for $p < 0.01$ with results (Rho = 0.32), benefits (Rho = 0.23) and success (Rho = 0.31).

The exercise (Graphic 4) suggests that, in most cases, the best prospects in terms of rewards obtained from an interaction are precisely those in which the actors involved attribute greater importance to distance. This seems to confirm, therefore, that the best prospects for an interaction are, in fact, those in which the importance given to distance is greater.



Graph 4. The importance of geographical distance in relation to benefits/results/success

Source: Own elaboration (2022).



Graph 5. The importance of geographical distance in relation to benefits/results/success

Source: Own elaboration (2022).

Final considerations

The exercise carried out suggests that geographical proximity in university-industry interactions, in the specific context of the analyzed peripheral economy – the Brazilian Northeast – is still an important aspect, although associated with other dimensions of proximity, particularly the cognitive dimension. On the other hand, geographical proximity is less important when: (i) the demands of companies for knowledge are more complex; and (ii) expectations of a high return offset transaction costs (identification of competences, displacement and monitoring of interaction at a distance).

Despite the fact that, as noted, the databases have been built for some time, the contribution to the perceptions of the constructs is significant and is supported by the theoretical framework adopted. Statistical validation of the presented distance constructs is, in itself, an important finding. It signifies that the studied concepts, including that of success, are reliable theoretical categories for the empirical observations. The contribution of relationships, difficulties, channels and initiatives to the success of interactions represents an empirical confirmation of the expectation indicated by the literature. The scalograms demonstrate this; it should also be added that each of these elements has a parallel and independent role, i.e., there is no sequential hierarchy or co-dependencies, which could not be previously stated, despite the fact that the literature regarding proximity developed in central countries defends the prevalence of the cognitive dimension over the others (BOSCHMA, 2005) and provides the finding that different combinations could explain interactions in specific empirical situations (LAGENDIJK; LORENTZEN, 2007). Linear regression expresses the specific weight of each component of these constructs in the success of the interaction. It also derives the important result that the area of knowledge has no effect *per se*.

The results have also revealed that the social dimension of proximity (interpersonal relationships) explains a significant portion of the observed interactions, confirming our hypothesis. However, it not only involves graduates formed by members of the research groups studied, but also other profiles of individuals, through which researchers access the technological problems that will be faced in the interaction. Therefore, it may be said that social proximity seems to prevail over cognitive proximity in the peripheral context studied herein and that, moreover, there is a specific combination between both, since former students or other individuals who act as a bridge between university and industry hold the minimum common knowledge base necessary for the emergence of interactions. Furthermore, thanks to the results expressed in the more general scalogram, it is now possible to state that overcoming distances is related to the success of the interaction, possibly presenting an oppositional relationship with the initiatives, whether by researchers or by companies.

Our attention was drawn to the central tendency of the importance attributed to geographical distance, which was revealed as being below those relative to all other distances; it was the only one to present a mean score of below 2 ("Not at all important") on the Likert scale. Indeed, more than 70% of the groups declared it to be of little or no importance. However, it was observed that the vast majority of university-industry interactions tend to occur within the same region (Table 4), and this suggests that geographical distance has, at some point, impacted the propensity for such interactions. The apparent paradox of this evidence may be explained if the possibility were to be considered that geographical distance is indeed important, although the research groups did not describe it as such because there was simply no relevant shortage of nearby companies with which to interact. A further hypothesis may also be put forward: companies with less innovative dynamism, characteristic of peripheral economies, tend to have a reduced demand for complex technological solutions, thereby minimizing the need to access research groups located at long distances.

It is also relevant to observe that the positive correlation between the importance attributed to geographical distance and the results and benefits of interactions suggests that, when there is a sufficiently high potential for exceptionally valuable gains, it is worth overcoming the obstacle represented by the spatial barrier. This occurs when the competences and intellectual property of the groups meet the needs and opportunities of the companies, providing them with strategic inputs, which will be sought even in distant places. This movement seems to be more effective with companies located in the Southeast, perhaps because the most technologically dynamic companies in the Brazilian economy are located in this region. For research groups, the movement to meet the demands of companies located in other regions seems to be a more intense trend in the Midwest and Northeast, perhaps because there is a greater discrepancy between the relatively high scientific and technological capacity of the groups and the relatively limited knowledge demands of local companies.

The geographical dimension of proximity thus seems to still affect the occurrence of university-industry interactions, proving to be more relevant in less developed contexts, probably in view of the lesser complexity of business demands, which may be met by local research groups, with more affordable transaction costs, and dispensing with long-distance travel. However, in a peripheral context, the association of geographical distance with all other distances suggests that greater geographic proximity favors all other forms of proximity. The results therefore have confirmed the hypothesis that the effects of geographical proximity vary greatly in different spatial contexts, depending on factors such as the knowledge base shared by the actors, the level of complexity required by the companies and the degree of dynamism of the market in which they are active.

References

ALBUQUERQUE, E. National Systems of Innovation and Non-OECD countries: Notes about a rudimentary and tentative "typology". *Brazilian Journal of Political Economy*, v. 4, n. 19, p. 35-52, 1999.

ANSELIN, L.; VARGA, A.; ACS, Z. Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, n. 42, p. 422-448, 1997.

AROCENA, R.; GÖRANSSON, B.; SUTZ, J. K. Knowledge policies and universities in developing countries: inclusive development and the "developmental university". *Technology in Society*, v. 41, p. 10-20, 2015. DOI: 10.1016/j.techsoc.2014.10.004.

AROCENA, R; SUTZ, J. Innovation systems and developing countries. *Druid Working Paper*, n. 2-05, 2005.

_________. Weak knowledge demand in the South: learning divides and innovation policies. *Science and Public Policy*, v. 37, n. 8, p. 571-582, 2010.

ARUNDEL, A.; GEUNA, A. Proximity and the use of public science by innovative European firms. *Economics of Innovation and New Technologies*, n. 13, p. 559-580, 2004.

AUDRESTCH, D.; FELDMAN, M. R&D spillovers and the geography of innovation and production. *American Economic Review*, n. 86, p. 630-640, 1996.

BALLAND, P.-A.; BOSCHMA, R.; FRENKEN, K. Proximity and innovation: From statics to dynamics. *Regional Studies*, DOI: 10.1080/00343404.2014.883598, 2014.

BENKO, G.; LIPIETZ, A. (ed.). *Las regiones que gañan*. Valencia: Edicions Alfons el Magnànim, 1994.

BOSCHMA, R. Proximity and innovation. A critical assessment. *Regional Studies*, n. 39, p. 61-74, 2005.

BRASIL. Lei nº 10.973, de 2 de dezembro de 2004. Dispõe sobre incentivos à inovação e à pesquisa científica e tecnológica no ambiente produtivo e dá outras providências. *Diário Oficial da União*: Brasília, DF, 3 dez. 2004, retif. 16 maio 2005.

CANTER, D. V.; FRITZON, K. Differentiating arsonists: A model of firesetting actions and characteristics. *Journal of Legal and Criminological Psychology*, n. 3, p. 73-96, 1998.

CANTER, D. V.; WENTINK, N. An empirical test of Holmes and Holmes serial murder typology. *Criminal Justice and Behavior*, n. 31, p. 489-515, 2004.

CASSIOLATO, J. E.; LASTRES, H. M. M. Arranjos e sistemas produtivos locais na indústria brasileira. *Revista de Economia Contemporânea*, v. 5, n. esp., 2001.

_________. Novas políticas na era do conhecimento: o foco em arranjos produtivos e inovativos locais. *Parcerias Estratégicas*, v. 8, n. 17, p. 5-29, 2003.

_________. Discussing innovation and development: converging points between the Latin American school and the innovation systems perspective? *Globelics*, working paper, n. 2, 2008. Available at: http://www.redesist.ie.ufrj.br/ga2012/textos/Cassiolato/Lecture17_GA2008.pdf.

CAVALCANTE, L. R. Misty consensus, messy dissensus: paradoxes of the Brazilian innovation policies. *Innovation & Management Review*, n.15, v. 4, p. 373-385, 2018.

COOKE, P.; HEIDENREICH, M.; BRACZYK, H (ed.). *Regional innovation systems. The role of governance in a globalized world.* London: Routledge, 2004.

D'ESTE, P.; IAMMARINO, S. The spatial profile of university-business research partnerships. *Regional Science*, n. 89, v. 2, p. 336-350, 2010.

DUTRÉNIT, G.; ARZA, V. Channels and benefits of interactions between public research organisations and industry: Comparing four Latin American countries. *Science and Public Policy*, n. 37, v. 7, p. 541-553, 2010.

EDQUIST, C. Systems of innovation: perspectives and challenges. In: FAGERBERG, J.; MOWERY, D. C.; NELSON, R. R. (ed.). *The Oxford handbook of innovation*. New York: Oxford University Press, 2005. p. 181-208.

FERNANDES, A. C. Da reestruturação corporativa à competição entre cidades: lições urbanas sobre os ajustes de interesses globais e locais no capitalismo contemporâneo. *Espaço e Debates*, n. 41, p. 26-45, 2001.

_________. Da urbanização caótica à hiperperiferia da rede urbana global: memórias sobre o pensamento de Wilson Cano para ler o urbano brasileiro contemporâneo. In: SANTOS, A. Q. et al. (org.). *Wilson Cano:* A questão regional e urbana no Brasil. São Paulo: Fundação Perseu Abramo: Expressão Popular: Abed, 2021. p. 237-264.

FERNANDES, A. C. et al. Academy-industry links in Brazil: evidence about channels and benefits for firms and researchers. *Science and Public Policy*, v. 7, n. 37, p. 485-498, 2010.

FERNANDES, A. C.; LIMA, J. P. R.; SILVA, A. S. da; SOUZA, B. C. de. *Interação universidade-empresa no Brasil:* a importância da proximidade geográfica e implicações para a política de CT&I. Relatório de Pesquisa. Recife: UFPE, 2017, mimeo.

FERNANDES, A. C.; SILVA, A. S. da; SOUZA, B. C. de Demanda e oferta de tecnologia e conhecimento em região periférica: a interação universidade-empresa no Nordeste brasileiro. In: SUZIGAN, W.; ALBUQUERQUE, E.; CÁRIO, S. (org.). *Em busca da inovação:* Interações de universidades e institutos de pesquisas com empresas no Brasil. Belo Horizonte: Autêntica, 2011. p. 341-401.

FREEMAN, C. The "National System of Innovation" in historical perspective. *Journal of Economics*, v. 1, n. 19, p. 5-24, 1995.

_________. Japan: a new national system of innovation? In: DOSI, G. et al. (ed.). *Technical change and economic theory*. London: Pinter, 1988. p. 330-348.

FURTADO, C. *O mito do desenvolvimento econômico*. Rio de Janeiro: Paz e Terra, 1974.

_________. Discurso proferido na cerimônia de outorga do título de Doutor *Honoris Causa* pela Unicamp em 21 de agosto de 1990. Available at: https://youtu.be/6oIP-GDdYWo.

GARCIA, R. Geografia da inovação. In: RAPINI, M. S.; RUFFONI, J.; SILVA, L. A.; ALBUQUERQUE, E. da M. e (org.). *Economia da ciência, tecnologia e inovação: fundamentos teóricos e a economia global*. Belo Horizonte: FACE-UFMG, 2021. p. 266-293.

GARCIA, R. et al. Os efeitos da proximidade geográfica para o estímulo da interação universidade-empresa. *Revista de Economia*, UFPR, v. 37, n. esp., p. 307-330, 2011.

GERTLER, M. Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there). *Journal of Economic Geography*, v. 1, n. 3, p. 75-99, 2003.

GUTTMAN, L. A new approach to factor analysis: the Radex. In: LAZARSFELD, P. F. (ed.). *Mathematical thinking in the social sciences*. New York: Free Press, p. 258–348, 1954.

HOWELLS, J.; BESSANT, J. Introduction: innovation and economic geography: a review and analysis. *Journal of Economic Geography*, v. 12, p. 929-942, 2012.

JAFFE, A. Real effects of academic research. *American Economic Review*, n. 79, v. 5, p. 957-970, 1989.

LAGENDIJK, A.; LORENTZEN, A. Proximity, knowledge and innovation in peripheral regions. On the intersection between geographical and organizational proximity. *European Planning Studies*, v. 15, n. 4, p. 457-466, 2007.

LAURSEN, K.; REICHSTEIN, T.; SALTER, A. Exploring the effect of geographical proximity and university quality on university-industry collaboration in the United Kingdom. *Regional Studies*, n. 45, v. 4, p. 507-523, 2011.

LUNDVALL, B. *National Systems of Innovation:* Towards a theory of innovation and interactive learning. London: Pinter, 1992.

MAHDAD, M. et al. A. Joint university-industry laboratories through the lens of proximity dimensions: moving beyond geographical proximity. *International Journal of Innovation Science*, v. 12 n. 4, p. 433-456, 2020.

MANSFIELD, E.; LEE, J. The modern university: Contributor to industrial innovation and receipt of industrial R&D support. *Research Policy*, n. 25, p. 1047-1058, 1996.

MASCARENHAS, S. A. N. et al. A Teoria das Facetas como forma privilegiada de estudar fenômenos sociais e humanos: uma aplicação no estudo das relações entre etnia e traços psicológicos na Amazônia brasileira. *Revista Amazônica*, n. 21, p. 321-343, 2018. [on-line]

MATTES, J. Dimensions of proximity and knowledge bases: Innovation between spatial and non-spatial factors. *Regional Studies*, n. 46, v. 8, p. 1085-1099, 2012.

MEYER-KRAHMER, F.; SCHMOCH, U. Science-based technologies: university-industry interaction in four fields. R*esearch Policy*, v. 8, n. 27, p. 835-851, 1998.

MORGAN, K. The exaggerated death of geography: learning, proximity and territorial innovation systems. *Journal of Economic Geography*, n. 4, p. 3-21, 2004.

MOWERY, D.; SAMPAT, B. University in National Innovation Systems. In: FAGERBERG, J.; MOWERY, D.; NELSON, R. (ed.). *The Oxford handbook of innovation.* Oxford: Oxford University Press, 2005, p. 209-239.

NELSON, R. (ed.). *National innovation systems:* a comparative analysis. New York: Oxford University Press, 1993.

NELSON, R.; ROSENBERG, N. Technical innovation and national systems. In: NELSON, R. (ed.) *National innovation systems:* A comparative analysis. Oxford; New York: Oxford University Press, 1993. p. 3-27.

NELSON, R.; WINTER, S. *An evolutionary theory of economic change.* Cambridge, MA: Harvard University Press, 1982.

NOOTEBOOM, B. et al. Optimal cognitive distance and absorptive capacity. *Research Policy*, n. 36, p. 1016-1034, 2007.

PAULANI, L. Dependência 4.0: considerações teóricas e o caso do Brasil. XXVI Encontro Nacional de Economia Política, Goiânia, 2021. *Anais [...]*. Goiânia: Enep, 2021.

PEREZ, C. Structural change and the assimilation of new technologies in the economic and social system. *Futures*, n. 15, p. 357-375, 1983.

PEREZ, C.; SOETE, L. Catching-up in technology: entry barriers and windows of opportunity. In: DOSI, G. et al. (ed.). *Technical change and economic theory.* London: Pinter Publishers, 1988.

PINHO, M.; FERNANDES, A. C. Relevance of university-industry links for firms from developing countries: Exploring different surveys. In: SUZIGAN, W. et al. (org.). *Developing national systems of innovation. University-industry interactions in the global South.* Cheltenham: Edward Elgar, 2015. p. 145-163.

POCHMANN, M. *A grande desistência histórica e o fim da sociedade industrial*. São Paulo: Ideias e Letras, 2022.

POLANYI, M. *The tacit dimension*. London: Routledge Kegan Paul, 1966.

PRADO JÚNIOR, C. *História e desenvolvimento*. São Paulo: Boitempo, 2021.

ROAZZI, A.; SOUZA, B. C. Advancing Facet Theory as the framework of choice to understand complex phenomena in the social and human sciences. In: KOLLER, S. H. (org.). *Psychology in Brazil:* Scientists making a difference. New York: Springer, 2019.

SHEARMUR, R. Why local development and local innovation are not the same thing. In: SHEARMUR, R.; CARRINCAZEAUX, C.; DOLOREUX, D. (ed.). *Handbook on the geographies of innovation.* Cheltenham: Edward Elgar, 2011, p. 432-446.

STORPER, M.; VENABLES, A. J. Buzz: face-to-face contact and the urban economy. *Journal of Economy Geography*, n. 4, v. 4, p. 351-370, 2004.

SUZIGAN, W. (coord.). *Interações de universidades e institutos de pesquisa com empresas no Brasil.* Campinas: IG/Unicamp, Relatório de Pesquisa, mimeo, 2009.

SUZIGAN, W.; ALBUQUERQUE, E. M. The underestimated role of universities for the Brazilian system of innovation. *Brazilian Journal of Political Economy*, v. 1, n. 31, p. 3-30, 2011.

SUZIGAN, W.; RAPINI, M. S; ALBUQUERQUE, E. *A changing role for universities in the periphery:* Notes about a tri-continental research project. Belo Horizonte: Cedeplar/ UFMG, [draft paper], 2009.

SZAPIRO, M.; MATOS, M.; CASSIOLATO, J. E. Sistemas de inovação e desenvolvimento. In: RAPINI, M. S.; RUFFONI, J.; SILVA, L. A.; ALBUQUERQUE, E. da M. (org.). *Economia da ciência, tecnologia e inovação: fundamentos teóricos e a economia global.* Belo Horizonte: FACE-UFMG, 2021. p. 323-349.

TORRE, A. On the role played by temporary geographical proximity in knowledge transmission. *Regional Studies*, n. 42, p. 869-889, 2008.

TORRE, A.; RALLET, A. Proximity and localization. Regional Studies, v. 1, n. 39, p. 47-59, 2005.

VEDOVELLO, C.; JUDICE, V.; MACULAN, A. Revisão crítica às abordagens a parques tecnológicos: alternativas interpretativas às experiências brasileiras recentes. *Revista de Administração e Inovação*, n. 3, v. 2, p. 103-118, 2006.

WETERINGS A.; BOSCHMA R. Does spatial proximity to customers matter for innovative performance? Evidence from the Dutch software sector. *Research Policy*, n. 38, p. 746-755, 2009.

Ana Cristina Fernandes

Graduated in architecture and urbanism at the Universidade Federal de Pernambuco (UFPE, 1981). She holds a master's degree in sociology from the Universidade Estadual de Campinas (Unicamp, 1989) and a PhD in geography from the University of Sussex, UK (1996). She was a professor in the Department of Civil Engineering at the Universidade Federalde São Carlos (UFSCar) and a guest professor in the Instituto de Economia at Unicamp. She is currently a full professor and leading researcher in the Grupo de Pesquisa em Inovação Tecnologia e Território [Research Group on Innovation, Technology and Territory] (GRITT) at UFPE. She was the director of innovation at UFPE, where she also served as coordinator of the Articulação e Promoção de Parcerias Estratégicas [Articulation and Promotion of Strategic Partnerships]. She was director of Política, Articulação e Coordenação [Policy, Articulation and Coordination] for the Secretariat of Science, Technology and Innovation for the State of Pernambuco. She has been editor of the *Revista Brasileira de Estudos Urbanos e Regionais* [Brazilian Journal of Urban and Regional Studies] and is currently an associate editor of the Revista Brasileira de Inovação [Brazilian Journal of Innovation]. She is a CNPq Scholarship Fellow 1B, supervising theses and dissertations on the Postgraduate Program in Geography at UFPE, of which she was coordinator from 2011 to 2013. Her research interest focuses on the area of economic geography, mainly on the following themes: political geography of innovation, territorial innovation system, spatial dimension of technical progress, scientific and technological policy, urban and regional development and policy, inequalities and spatial polarization, accumulation crisis, technology and territory.

Email: ana.afernandes@ufpe.br

ORCID: 0000-0002-2641-5525

Authorship contribution: conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, resources, validation, visualization, writing – original draft, writing – review and editing.

Bruno Campello de Souza

Graduated in Psychology, with a master's degree and PhD in cognitive psychology, all at the Universidade Federal de Pernambuco (UFPE). He is an associate professor at UFPE, he is a permanent professor on the Postgraduate Program in Business Administration (PROPAD) and on the Professional Master's Degree in Business Administration (MPA). He conducts research focused on the relationships between digital technologies and individuals and organizations, innovation and entrepreneurship, criminology and policing, cognition, psychological and social processes, people management, psychology of politics, human values, medicine and the application of statistical methods in any context. Since March 2020, he has undertaken research involving data analysis related to the epidemiology, diagnosis and treatment of Covid-19.

Email: bcampello@uol.com.br

ORCID: 0000-0002-6402-0233

Authorship contribution: conceptualization, data curation, formal analysis, investigation, methodology, software, validation, visualization, writing – original draft.

Alexandre Stamford da Silva

Graduated in electrical engineering, electronic modality, at the Universidade Federal de Pernambuco (UFPE, 1991), with a master's degree in electrical engineering (1994) and a PhD in economics (1999), also at UFPE. He undertook a post-doctorate in France, at the Université Paris 1 Panthéon-Sorbonne (Paris), in economic development, and at the Université Robert Schuman/International Center for Intellectual Property, (Strasbourg), in intellectual property. He is the former director of innovation at the Secretariat of Science, Technology and Innovation of Pernambuco. He is currently an associate professor at UFPE in the Department of Economics. He has experience in the field of economics, with an emphasis on mathematical methods and models, working mainly on the following topics: health economics, intellectual property, patent writing, entrepreneurship, game theory and economic growth. In the field of engineering area, he has experience in production engineering, project management and information management and, in the field of electrical engineering, in risk management and reliability engineering.

Email: alexandre.silva@ufpe.br

ORCID: 0000-0002-9188-4598

Authorship contribution: conceptualization, formal analysis, investigation, methodology, writing – review and editing.

João Policarpo Rodrigues Lima

Graduated in economics at the Universidade Federal de Pernambuco (UFPE, 1973), with a master's degree in economics also at UFPE (1977) and a PhD in economics at the University of London (1988), with a postdoctoral degree at the University of North London (2000). He is currently a professor at UFPE. He has experience in economics, with an emphasis on applied economics, working mainly on the following topics: Brazilian economy, regional development, North-eastern Brazil, sugarcane agroindustry, productive arrangements, innovation and local development.

Email: policarpo.lima@ufpe.br

ORCID: 0000-0003-1485-0025

Authorship contribution: conceptualization, resources, validation, writing – review and editing.

Submitted: February 28, 2022.

Approved: October 22, 2022.

How to cite: FERNANDES, A. C.; SOUZA, B. C. de; SILVA, A. S. da; LIMA, J. P. R. Does geographical proximity still matter for innovation? Notes on university-industry interaction from the perspective of a peripheral context. *Revista brasileira de estudos urbanos e regionais*. v. 25, E202310en, 2023. https://doi.org/10.22296/2317-1529.rbeur.202310en.