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The trade-offs of brokerage in inter-city innovation networks

Carlos Bianchi^a , Pablo Galaso^b  and Segio Palomeque^c 

ABSTRACT

Brokers play a critical role in the evolution of innovation systems by accessing and diffusing external knowledge. However, while brokers' activity allows benefits for the entire system, it entails costs for those who play the broker role. Using patent data to analyse inter-city networks in Latin America, we identify broker cities and estimate the effects of brokerage on patenting outcomes between 2006 and 2017. Our findings reveal that cities holding a central position in the network show higher patenting activity; however, being a broker, particularly connecting Latin American cities with the rest of the world, negatively influences patenting outcomes.

KEYWORDS

inter-city networks; patents; brokerage; innovation systems; Latin America

JEL D85, O18, O31, O34

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INTRODUCTION

Cities have gained growing attention in the research agenda of both regional and innovation studies (e.g., Cooke, 2001; Florida et al., 2017; Johnson, 2008; Neal, 2012). These intrinsically intertwined bodies of literature have analysed cities as locally embedded networks, where interactive linkages transmit and reproduce knowledge within the network and develop collaborative channels with global networks. In these works, agglomeration features associated with demographic density, infrastructure facilities and localized capacity-building processes are considered mechanisms that determine the innovative performance of cities. In this regard, an extensive and plural stream of research has analysed city networks as a critical resource for local development, territorial policies and human mobility, among other relevant topics (e.g., Fischer et al., 2018; Johnson, 2008; Rantisi, 2002; Sigler & Martinus, 2017; Simmie et al., 2002; Verginer & Riccaboni, 2020).

A smaller but growing number of studies have recently analysed inter-city networks, shedding light on the role of cities as components of national, regional or global knowledge networks (e.g., Cao et al., 2021; Fan et al., 2020; Guan et al., 2015; Maisonobe et al., 2016; Yao et al., 2020). Following a systemic approach, our paper

contributes to this literature by analysing brokerage in Latin American inter-city patenting networks. We revise recent contributions that highlight the positive effects of centrality and brokerage on innovation networks (Yao et al., 2020) by adding the analysis of the relative costs of networking, mostly inspired by the current discussion on the non-linear effects of external knowledge sourcing from the firm's innovation studies (e.g., Arora et al., 2016; Laursen & Salter, 2014). As a result, our general research question aims to identify the effects of the inter-city collaborative network on innovation processes.

Laursen and Salter (2014) used the expression 'openness paradox' to describe, mostly for firms, the trade-offs that innovation agents face when looking for external knowledge. External knowledge is a critical resource for innovation systems (IS). However, accessing and using it entail costs and require internal capacities (Arora et al., 2016; Laursen & Salter, 2014). Hence, according to their capacities, different agents will face different relative costs in these processes. In addition, due to the attributes of knowledge, networks will spur heterogeneous effects on the whole system rather than only influence the connected agent (Antonioli et al., 2017; Grimpe & Kaiser, 2010; Kauffeld-Monz & Fritsch, 2013). Therefore, playing the role of broker – that is, intermediating between disconnected agents – implies benefits, mostly associated with

CONTACT

^a  carlos.bianchi@fcea.edu.uy

Facultad de Ciencias Económicas y de Administración, Instituto de Economía, Universidad de la República, Montevideo, Uruguay.

^b **(Corresponding author)**  pablo.galaso@fcea.edu.uy

Facultad de Ciencias Económicas y de Administración, Instituto de Economía, Universidad de la República, Montevideo, Uruguay.

^c  sergio.palomeque@fcea.edu.uy

Facultad de Ciencias Económicas y de Administración, Instituto de Economía, Universidad de la República, Montevideo, Uruguay.

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access to diverse, non-redundant knowledge. However, it also implies costs related to time and resources necessary to maintain links with different actors that are disconnected from each other (Antonioli et al., 2017; Kauffeld-Monz & Fritsch, 2013).

We contribute to the literature by adapting these concepts about the trade-offs of networking, which were developed to analyse firms' open innovation strategies (Arora et al., 2016; Bogers et al., 2018; Laursen & Salter, 2014), to the studies on regional ISs. We also focus on the brokerage role that certain cities can play in inter-city networks on a continental scale. Hence, we consider cities as innovation agents participating in the collaborative knowledge fluxes within the Latin American IS. We focus on the brokerage role of Latin American cities, comparing their intra-regional connections with their extra-regional collaborations. Analysing the role of broker cities located in a peripheral region, as is the case of Latin America, is particularly relevant given the great dependence the continent has on foreign connections in its innovation processes (Delvenne & Thoreau, 2017; Montobbio & Sterzi, 2011).

Using patent data, we build inter-city collaboration networks between 2006 and 2017. Based on the work of Gould and Fernandez (1989), we distinguish two types of brokerage roles that can be played by cities: (1) those brokers that intermediate between other cities in the region (i.e., coordinators); and (2) those that intermediate between Latin American and extra-regional cities (i.e., gatekeepers). We estimate negative binomial models that allow us to understand the influence of networks, particularly the brokerage effects, on patenting outcomes achieved by cities. We also estimate the influence of intra- versus extra-regional links on patenting levels of Latin American cities.

In line with previous research, our results show that cities holding a central position in the network are likely to be more innovative. Moreover, we show that most central cities in Latin America maintain linkages with external agents. Hence, a number of Latin American cities seem to play a particularly relevant role in shaping the regional network as well as in connecting the region to global centres of innovation. Such Latin American cities can thus be considered *relational cities*, that is, cities that intermediate between global and regional knowledge networks (Sigler & Martinus, 2017).

However, we find that not all collaborative links have the same effect on innovation: while links with other Latin American cities do not seem to influence innovation, connections with cities in other parts of the world do generate positive impacts. In addition, we find that being a broker or a gatekeeper city seems to negatively affect future patenting levels. Hence, while knowledge networks can show mostly benefits for the whole system, those cities that intermediate both within the region and between the region and other parts of the world experience negative effects in their innovation performance.

Analysing these results on the backdrop of the current knowledge of Latin American ISs functioning, we find evidence highlighting the systemic weaknesses and the

outward orientation of these ISs. Latin American ISs have been characterized as immature, with actors and territories operating mainly in isolation (Rapini et al., 2009). Such systems are composed of heterogeneous agents, and most dynamic activities have usually been concentrated around regional nodes, regularly composed of public research institutes and dynamic firms. This situation has received great attention, in particular regarding the concentration and unequal development of research and innovation capacities at the regional level (de Araújo et al., 2019; Fischer et al., 2018; German-Soto & Gutiérrez Flores, 2015; Montaña & González, 2007; Niembro, 2020). However, this issue has rarely been studied from a continental systemic approach (Confraria & Vargas, 2019).

Our results corroborate that, even though a growing number of innovators are collaborating from different cities in the region, the Latin American innovation network still reflects great concentration in its main metropolitan regions. We contribute to this extensive literature by showing that most dynamic agents (i.e., broker cities) face high costs associated with coordination efforts as well as to knowledge access and diffusion. Therefore, we highlight the relevance of public policies oriented to deal with the inherent uncertainty of the openness process and to support the cost of networking.

THEORETICAL FRAMEWORK

According to the building blocks of the systemic approach to innovation, ISs are dynamic networks of agents' interactions, where internal and external knowledge is exchanged, used and reproduced (Freeman, 1991). This approach also emphasizes the uneven ISs' evolution paths where different components play different roles which allows a final emergent (i.e., innovation) that is not equal to the sum of the components (Erbes et al., 2010).

These IS attributes are basic milestones in the systemic approach, and they are potentially observable in any system (Katz & Ronda-Pupo, 2019). However, it is particularly relevant for the study of the Latin American IS. From the extensive literature on innovation and development in Latin America, we know that heterogeneity prevails in the continent. The whole regional system shows, on average, low innovation intensity, especially associated with the lack of systemic linkages between research and innovation spheres. Meanwhile, there are also poles of remarkable development of research and innovation capabilities (Arocena & Sutz, 2010; Castellacci & Natera, 2016; Confraria & Vargas, 2019). These poles have emerged around cities, usually where main universities, research centres, industry or public services are located (de Araújo et al., 2019). Furthermore, due to its peripheral position in the global knowledge network, the Latin American IS is critically dependent on external knowledge flows (Delvenne & Thoreau, 2017; Montobbio & Sterzi, 2011). To better understand these dynamics of interaction, we propose to study inter-city knowledge networks.

Cities as nodes in knowledge networks

As Johnson (2008) has claimed, cities work as a problem-solving environment in a national or regional IS. According to this view, cities are one type of IS whose internal dynamics are determined by: the city's specialization; the benefits that such specialization generates for the agents that compose the IS and, especially, by the interactive dynamics between people and organizations that exchange and produce knowledge. Johnson's contribution is in line with more recent works from urban and regional studies that highlight cities as complex collective agents. According to this view, cities manage to build a particular environment associated with their specialization, which is usually supported by the main organizations located in the city and the public policies at both regional and local levels. Furthermore, such environment is related to the cumulative knowledge interaction that is intrinsically associated with the historical process of each urban territory and is hardly transferable to other places (e.g., Breschi & Lenzi, 2015; Makkonen et al., 2018).

Many of these knowledge interactions take place at a local level, connecting actors located in the same territory. Yet, other collaborations transcend territories and connect actors located in different cities and even countries. These connections create inter-city networks in which the nodes are localities and the links represent collaborative relationships associated with innovation processes carried out by actors located in different cities (Fan et al., 2020; Maisonnobe et al., 2016). Links in inter-city networks, as in other innovation networks, can generate both benefits and costs for the interconnected cities, which, in turn, will depend on the role the city plays in the network.

In this regard, it is expected that different cities will play different roles and that the functioning of the urban IS will depend on who the city interacts and exchanges knowledge with (Johnson, 2008). This simple but consistent theoretical basis from the IS approach meet the contributions from network studies, which identify different roles as well as different internal and external effects associated with the position of nodes in networks.

As a general hypothesis we propose that intercity networks are relevant to determine the city innovation outcomes. The literature on clusters offers theoretical arguments that can contribute to frame this general hypothesis. Clusters, understood as territorial agglomerations of firms and organizations with a certain sectoral specialization (Porter, 1990), can encourage innovation processes, especially when they are dynamic and knowledge-based clusters (Koo, 2005; Saxenian, 1994). According to the so-called buzz-pipeline approach (Bathelt et al., 2004), innovation in clusters depends on adequately combining local interactions (local buzz) with connections outside the territory (global pipelines). The local buzz allows discussing and contrasting ideas, disseminating tacit knowledge within the territory and, therefore, it permits the enrichment of the industrial atmosphere (Marshall, 1879). Therefore, collaborative links connecting firms located in clusters can be a valuable resource for enhancing

exports (Brache & Felzensztein, 2019; Felzensztein et al., 2019) and innovation (Galaso et al., 2019; Innocenti et al., 2020). However, these local interactions alone can lead to lock-in situations derived from the recirculation of homogeneous and redundant knowledge (Bettencourt et al., 2007; Lobo & Strumsky, 2008). Global pipelines are fundamental to deal with this problem since they manage to introduce into the territory external new knowledge that can be vital in innovation processes (Bathelt et al., 2004; Owen-Smith & Powell, 2004; Wolfe & Gertler, 2004).

Knowledge-based clusters with high levels of innovation are not homogeneously distributed in the territory. The concentration of patents and scientific publications in certain territories has been widely used to identify such clusters (e.g., Bergquist et al., 2018), which seem to be mostly located in large cities (Balland et al., 2020). Accordingly, the links in our inter-city networks can be considered global pipelines and, therefore, we can expect them to be a determining factor of innovation outcomes in cities.

The number of links connecting to a node determines its centrality in the network. This property, which has been widely studied by the literature on social network analysis, essentially reflects the prominence or relative importance of nodes, their capacity to influence other actors and also their capacity to access the resources that flow through the network (Borgatti, 2005; Wasserman & Faust, 1994). Therefore, we can expect that occupying a central position in the network, through the maintenance of different collaborative links with other cities, will improve innovation performance.

Hypothesis 1. Centrality in the collaboration network improves the city's innovation performance.

However, being central by having many links does not necessarily mean playing a brokerage role. The concept and typologies of brokerage allow us to understand how certain actors contribute to disseminating knowledge among the components of ISs and/or manage to introduce external knowledge into the local IS. We define broker cities as those that link others that are disconnected from each other, intermediating in knowledge flows within the regional IS. This role is associated with the formation of a regional network, and it contributes to the dissemination of knowledge at a Latin American level. The challenge now is to analyse the effects of knowledge networks in the light of the costs and benefits involved in playing that role.

On the trade-offs of brokerage

Innovation is an essentially interactive process that relies heavily on collaborative networks (Freeman, 1991). The linkages of a network operate as a sort of channel where knowledge and information are exchanged in a more or less inbound/outbound fluxes composition.

Critical attributes of knowledge affect both the structure and the effects of these channels and processes. A

rich long run debate on the codified and tacit properties of knowledge has converged into a non-dichotomist but gradualist and continuous definition of knowledge, where purely tacit or codified knowledge is a theoretical tool rarely observed in the empirical research (Johnson et al., 2002; Malerba & Orsenigo, 2000). Therefore, channels involving knowledge and information exchange embrace both codified and tacit knowledge, which implies different capacities and costs. While knowledge codification softens access barriers to general principles potentially usable in many contexts, tacit knowledge usually requires high capacities and repeated interactions, but, except in theoretical scenarios, knowledge access always requires a minimal threshold of capacities to understand the code (language) and resources to sustain the channels (interactive linkages) (David & Foray, 1996).

Considering the attributes of knowledge as an economic good, many authors have stressed that the social (systemic) benefits may be greater than the private ones due to the non-rivalry and partially excludable properties of knowledge (Foray, 2004). These attributes of knowledge may explain why more connected agents may incur in relatively higher costs because they reduce access costs for their followers. By connecting other agents who would otherwise be disconnected, the actors who perform the role of brokers can make a particularly valuable contribution to knowledge dissemination.

At the micro scale, this issue has been analysed in the literature on firm innovation and networks. While inter-organizational networks are crucial for innovation processes, neither do all firms contribute equally to the overall cohesion of networks, nor do they all benefit equally from their knowledge flows (Giuliani & Bell, 2005). Some studies have reported that being a broker positively influences the innovation processes of the firms that occupy this position since it gives access to diverse sources of knowledge (Ahuja, 2000; Belso-Martínez et al., 2015; Galaso et al., 2019). However, other studies point to the costs associated with this position due to the time and resources that the firm must devote to maintaining links (Giuliani & Bell, 2005), and because it may involve knowledge leaks to competitors (Khanna et al., 1998). Certain organizations that interact with firms, such as business chambers, government agencies or research centres, play a fundamental brokerage role not only by contributing to the overall cohesion of networks, but also by fostering the innovation performance of the firms between which they intermediate (Galaso & Rodríguez Miranda, 2020). We propose here a similar approach to brokers, but moving up from the micro perspective (of firms and organizations) to a meso perspective, where we consider cities as nodes in inter-city collaboration networks.

This view on the roles of cities as knowledge brokers may contribute to analysing the policy implications for local ISs (Bogers et al., 2018). From a classic perspective of appropriation failures, the gap between the systemic and the city benefits justified the public interest in supporting the knowledge channels of the system. However, as the literature on firms and public sector open innovation

has emphasized, rather than matching the local and the system return, public policies for open innovation practices should contribute to the creation of a systemic infrastructure and knowledge fluxes (de Jong et al., 2010).

In this regard, there are two reasons why brokers are particularly relevant in peripheral regions of the world economy such as Latin America. First, because, due to external orientation of knowledge flows, networks in these regions normally have less internal connections between their nodes. In this sense, brokers contribute to keeping the network connected at a regional level. Second, because innovation processes depend substantially on other regions of the world. In this sense, brokers can bring knowledge flows to the region from leading cities in other parts of the world (Confraria & Vargas, 2019; Reis et al., 2018).

The brokerage positions in the networks can entail both costs and benefits for the broker (Kauffeld-Monz & Fritsch, 2013). On the benefits side, broker cities may have good access to non-redundant knowledge, which can be very valuable in innovation processes (de Araújo et al., 2019; Yao et al., 2020). However, holding a broker position entails a high openness orientation, maintaining links with cities that are disconnected from each other, which requires important coordination efforts in order to deal with high uncertainty. In the particular case of peripheral cities, these coordination costs associated with brokerage may exceed the benefits in terms of access to knowledge flows. There are two reasons supporting this argument. First, on the cost side, the heterogeneity and disconnection inherent in Latin American ISs require greater coordination efforts to keep the system's agents connected compared to the efforts required in more developed ISs. Second, on the benefits side, the wealth and diversity of knowledge that flows in intra-regional collaborations may be of limited value, given the region's structural lag in research and innovation activities.

Hypothesis 2. Being a broker in the inter-city network reduces innovation results.

The effects that networks can generate on innovation in cities will depend substantially on where the interconnected cities are located since the available knowledge and innovative capabilities vary substantially from one region of the world to another. In our study, the network integrates both Latin American cities and cities located outside the region, some of them in the world centres of innovation development. As a result, we can ask if intra-regional links influence innovation in the same way as links connecting to cities outside Latin America.

Given the region's weaknesses in generating knowledge and innovations, we can expect the effects of networks on Latin American cities to differ, depending on whether we consider the links they maintain with other cities in the region or those that connect them to cities in other parts of the world, particularly with global centres of technological development.

Hypothesis 3. Extra-regional collaborations improve innovation while intra-regional collaborations do not.

DATA AND METHODS

We use data from the US Patent & Trademark Office (USPTO) retrieved from the PatentsView database. Such database incorporates disambiguated identifiers for inventors and innovators, which is critical for building collaboration networks. Since our research focus is on Latin American cities, we search for patents involving at least one inventor located in a Latin American country.¹

The nodes of our networks are the cities where the owners of the selected patents are located. Patent owners are mostly firms, but research centres, universities, public agencies and even individuals can also own patents. Some inventions are co-patented by different innovators (i.e., patent owners), which often reflects a collaborative innovation process involving different actors. When these actors are located in different cities, then we establish a collaboration link between those cities. Some of the selected patents are co-owned by actors located outside Latin America. This leads us to include in our networks not only Latin American cities, but also locations from other parts of the world, which allows analysing intra- versus extra-regional collaboration links.²

In order to focus on the most relevant nodes and links, we apply backbone extraction methods, which allows determining statistically significant links among the innovators (patent's owners), based on the number of co-patents (Neal, 2014).³ Once the existence of each connection between cities has been determined through this method, our networks consider only binary, unweighted links.

Between 2006 and 2017, particularly until 2014, the region experienced a process of economic growth, largely driven by increased international demand and prices for raw materials. Along with economic growth, the region increased its patenting levels during those years (Bianchi et al., 2020; World Intellectual Property Organization (WIPO), 2018). This is the main reason for choosing this period of analysis, since, although data is available prior to 2006, the number of Latin American inventions is very low, so the networks prior to our period have very few cities and are highly disconnected.

We build four-year windows and elaborate one network for each time window.⁴ We then calculate different network statistics that measure the brokerage roles of each city and compare intra-regional collaborations with connections to other regions of the world.

We test our hypotheses using panel data regression models that allow us to estimate how brokerage and intra-versus extra-regional connections may influence the innovative performance of cities. The dependent variable in our models is an indicator of cities' innovation results: the number of patents registered by actors located in each city in each sub-period. The use of patents as an indicator of innovation has been widely discussed in the literature

(Archibugi, 1992; Griliches, 1990) and has been used by similar studies (De Noni et al., 2017; Yao et al., 2020). Being aware of its limitations, we consider that this indicator is consistent since it captures knowledge creation involving Latin American innovators and, even under-registering the wide variety of non-patentable innovation outcomes, it offers homogeneous information for the entire regional IS. In addition, at the Latin American level, there are no other indicators that allow us to compare the evolution of innovation activities in cities.

The independent variables used in our models measure the relative position of each city in the network as well as the connections it maintains with different regions of the world. All these variables (along with the control variables that will be explained below) are calculated with a one-period lag. Thus, our models estimate whether the network characteristics at time t influence the level of patenting obtained by cities at time $t + 1$.

In order to test our first hypothesis, we measure centrality of Latin American cities in the network and their brokerage role. *Degree centrality* measures the number of links adjacent to each city. It is used as a measure of its prominence or relative importance in the network (Wasserman & Faust, 1994). The brokerage role played by cities is measured using Gould and Fernandez (1989) indicators. To do so, we group the cities in two broad categories: Latin American and non-Latin American locations. This allows us to measure two different brokerage roles. First, the *coordinator* role accounts for intermediation between pairs of Latin American cities. Second, the *gatekeeper* role measures the intermediation between extra-regional cities and Latin American cities.⁵ For details on the calculation and interpretation of these network variables, see Appendix A1 in the supplemental data online.

In order to test our third hypothesis, we use variables that account for intra- versus extra-regional connections. In particular, we calculate the number of links connecting each city with other Latin American cities, and the number of links with cities located in other parts of the world. Finally, we disaggregate this last variable, differentiating between connections with European cities, links with cities located in the United States and Canada and links with East Asian cities.

Of course, other factors may determine the propensity to patent in cities. To account for these factors, our models include the following control variables. First, to control for the size of the city and the agglomeration of innovators, we consider the number of inventors and the number of patent owners located in each city. Second, we account for the number of technological fields in which the city patents in order to control for the technological specialization and diversification of cities. Third, the number of patents in the previous year is used to account for other unobserved types of heterogeneity in cities' propensity to patent, such as the evolution of local economic activity or investments in technology. Finally, in line with the argument developed above, we include city fixed effects in order to control for unobserved structural dimensions

of cities related to their accumulation of capacities that may be influencing their patenting levels (e.g., the education level, the institutional framework or the industrial atmosphere).

The number of patents, inventors, innovators and technologies are strongly correlated, which may lead to collinearity problems. (Appendix A2 in the supplemental data online illustrates the multicollinearity problems between these four variables.) Therefore, we perform a factor analysis in order to group them into fewer dimensions. We find that a single factor is adequate to replace these four control variables, even maintaining more than 90% of the variance that they provide (see Appendix A3 online). Consequently, we create the variable *factor* that will be included in the models, as the control variable, along with the city-level fixed effects.

Since the dependent variable (i.e., the number of patents) is a count variable that takes strictly positive integer values and presents overdispersion, negative binomial models are the most suitable for our regressions. Such models are extensively used in the literature studying patent data (Fleming et al., 2007; Galaso & Kovářík, 2021; Owen-Smith & Powell, 2004; Schilling & Phelps, 2007; Yao et al., 2020). The use of patent data both as a dependent variable and for constructing network indicators may lead to endogeneity issues. Although the scarcity of data available at the city level in Latin America reduces the options to deal with these issues, several aspects of our study can mitigate them. On the one hand, potential endogeneity problems caused by reverse causality or the omission of variables that vary in each period can be mitigated by the use of control variables that vary between each period and by the use of explanatory variables of interest lagged behind the dependent variable.⁶ On the other hand, our econometric strategy controls for the effect of omitted variables related to structural characteristics of cities, which can be considered constant across the selected periods, by including city-level fixed effects (Allison, 2009; Hill et al., 2021; Li, 2013). These econometric strategies have been widely used in the empirical literature on patent networks facing similar endogeneity problems (de Araújo et al., 2019; Fleming et al., 2007; Galaso & Kovářík, 2021; Schilling & Phelps, 2007; van der Wouden & Rigby, 2019); however, the results should be evaluated with caution.

Furthermore, in our estimations we follow the so-called within-between approach (Allison, 2009; Bell et al., 2019; Schuknecht & Siegerink, 2020). This approach allows us to explicitly model variations in patenting levels explained by cities' characteristics as well as by variations in such characteristics through time. Within-between models combine the advantages of fixed and random effects models, while partially offsetting their respective disadvantages (Schulz, 2020).

RESULTS

A descriptive analysis of our networks is presented in Table 1. Latin American cities represent only between a

quarter and a fifth of the networks' nodes. Furthermore, extra-regional links (i.e., collaborations between Latin American cities and cities in other parts of the world) are three times more numerous than intra-regional connections. This evidence gives us a first overview of the weak collaboration among the cities of the region, and it shows that innovation in Latin America strongly relies on connections with other parts of the world.

Figure 1 depicts a representation of the network in the last period (between 2014 and 2017). In addition, for the list of the Latin American cities that are part of our network, along with their levels of patenting, see Appendix A4 in the supplemental data online. The network map corroborates the disconnection among Latin American cities that are mainly linked to cities in the United States and (although to a lesser extent) to cities in Europe and other parts of the world. The map also allows observing certain strong connections between Latin American cities, such as the links between Mexico City and South American cities, in particular with Buenos Aires (Argentina), which is arguably the result of the long tradition of Mexican research on both outward and inward Latin American collaboration networks (Morales Valera & Sifontes, 2014).

In order to test our hypotheses, we estimate the influence of different network variables on patents outcomes. For descriptive statistics and correlations between variables, see Appendix A5 in the supplemental data online. Models 1–3 in Table 2 allow us to test the first two hypotheses by analysing the effects of centrality and brokerage on patenting results. The between-city effects indicate how the average level recorded by cities for each independent variable influences their average level of

Table 1. Inter-city network characteristics.

	2006– 09	2010– 13	2014– 17
Number of cities (nodes)	254	348	284
Latin American (LA) cities	62	71	51
European cities	70	86	72
North American cities	111	151	149
East Asian cities	5	26	3
Cities in the rest of the world	6	14	9
% LA cities	24.4	20.4	18.0
% non-LA cities	75.6	79.6	82.0
<i>Links</i>	623	979	762
LA–LA links	47	75	42
LA–Europe links	46	89	76
LA–North America links	115	124	127
LA–East Asia links	0	10	4
LA–non-LA links	163	233	216
Non-LA–non-LA links	413	671	504
% LA–LA links	7.5	7.7	5.5
% LA–non-LA links	26.2	23.8	28.4
% non-LA–non-LA links	66.3	68.5	66.1

Source: Authors based on PatentsView data.



Figure 1. Inter-city collaboration network in Latin America.
Source: Authors based on PatentsView data.

patenting. On the other hand, the within-city effects can be interpreted as the influence of variations each city records in its independent variables on changes in its future level of patenting.

The estimations show that the between-city effects are clearly more relevant than the within-city effects. Most importantly, these results provide empirical evidence to support our first two hypotheses. We observe that being a central city in the network (measured by its degree centrality) is associated with obtaining better innovative performance (measured by its number of patents). Second, we find that being a broker in the network seems to negatively influence patenting levels of cities. The negative effect of being a broker is observed for both types of roles: coordinator and gatekeeper. Yet, model 3 reveals that playing a gatekeeper role, that is, intermediating between extra-regional cities and Latin American cities, seems to be particularly costly in terms of the lower patenting levels involved.

Further investigating the geographical scope of collaborations, we find that the effects of networks on innovation vary when we differentiate between intra- and extra-regional collaboration links. This evidence, reported in Table 3, supports our third hypothesis: links with other Latin American cities do not seem to influence innovation through patents, while connections with cities outside the continent do generate positive impacts on patenting levels. Again, only the between-city effects are relevant.

Given the crucial role that extra-regional collaborations seem to play in Latin American innovation, we

finish our analysis further investigating the orientation of these inter-city connections. To do so, we analyse separately the effects of collaborating with cities located in Europe, Anglo-Saxon North America and Asia.

Table 4 summarizes our findings from such analysis. As reported here, we find that extra-regional links also have different impacts on innovative performance, depending on the region of the world to which Latin American cities are connected. In particular, we observe that links with western regions, Europe and North America, which historically play a central role in the Latin American research and innovation landscape, appear to be associated with higher patenting levels. However, connections with Asia are associated with poorer cities' innovation performance. This finding seems to indicate a kind of cumulative effect that knowledge exchanges could have on the patenting results of cities in the region.

In these models, we also obtain an interesting – and unexpected – finding when comparing the between-city and within-city effects: the results show opposite outcomes for these effects. In particular, we find that while maintaining a high number of links with European and North American cities is associated with having high patent levels, increasing the number of links with such regions reduces patenting levels in further periods. In the case of links with Asia, the exact opposite is true. Complementing the conjecture presented in the last paragraph, these results seem to indicate differences between the additional costs and benefits of establishing new extra-

Table 2. Negative binomial regressions: models 1–3.

	Model 1	Model 2	Model 3
Intercept	2.486*** (0.109)	2.488*** (0.097)	2.482*** (0.096)
<i>Between-city effects</i>			
Degree centrality	0.357 (0.255)	0.939*** (0.273)	0.927** (0.298)
Coordinator	−1.019*** (0.245)		−0.055 (0.374)
Gatekeeper		−1.758*** (0.317)	−1.693** (0.561)
Factor	1.597*** (0.278)	1.793*** (0.251)	1.794*** (0.251)
<i>Within-city effects</i>			
Degree centrality	0.035 (0.059)	0.089 (0.081)	0.130* (0.056)
Coordinator	0.073 (0.054)		0.056 (0.038)
Gatekeeper		−0.111 (0.069)	−0.091 (0.059)
Factor	−0.103 (0.056)	−0.049 (0.038)	−0.097** (0.034)
Pseudo- R^2 (fixed effects)	0.774	0.823	0.811
Pseudo- R^2 (total)	0.946	0.946	0.947
Akaike information criterion (AIC)	431.969	423.065	435.081
Bayesian information criterion (BIC)	451.113	442.209	458.480
Log-likelihood	−206.985	−202.532	−206.541
Number of observations	62	62	62
Number of groups: name	31	31	31
Variable: name (intercept)	0.263	0.187	0.212

Note: Standard errors are shown in parentheses; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; $p < 0.1$.

Source: Authors based on PatentsView data.

regional collaborations and the additional costs and benefits of having already consolidated extra-regional connections.

Finally, we obtain an analogous result regarding the role of coordinator: the negative and significant between-city effect is maintained (as in the rest of our models), while models 8 and 10 also report positive and significant results in the within-city effect of this brokerage role. This result slightly nuances our conclusion regarding our second hypothesis, indicating that although occupying coordinator positions is associated with registering on average lower levels of patenting, achieving improvements at the coordinator level can lead cities to subsequent increases in their patenting results.

DISCUSSION AND CONCLUSIONS

Research on innovation and regional development follows a fascinating path that often rather than offering conclusive answers, raises more questions. Knowledge networks have been widely studied from different approaches

which have made relevant contributions to the topic. In this sense, recent research on inter-city networks analysed the effects of knowledge networks on the performance of localities. This article contributes to this stream of research by shedding light on the trade-off effects that knowledge networks can have on cities performing brokerage roles.

We interpret the brokerage role played by some cities as a function that builds and sustains the infrastructure for knowledge channels (David & Foray, 1996). Based on some basic elements of the IS approach and recent contributions on clusters, firm innovation and open innovation studies, we examine the trade-offs of brokerage from a non-dichotomist perspective. In short, beyond considering the costs or benefits of brokerage, we seek to understand the complex non-linear effects on innovation processes that are carried out by heterogeneous agents from different geographical locations. Moreover, we exploit recent methodological advances from social network analysis to deepen this complex interaction, identifying intra- and inter-regional knowledge connections and distinguishing different brokerage roles.

Table 3. Negative binomial regressions: models 4–6.

	Model 4	Model 5	Model 6
Intercept	2.487*** (0.106)	2.488*** (0.097)	2.486*** (0.097)
<i>Between-city effects</i>			
Intra-regional links	0.463 (0.281)	0.203 (0.220)	0.138 (0.282)
Extra-regional links	0.075 (0.229)	0.771** (0.239)	0.877* (0.371)
Coordinator	−1.213*** (0.285)		0.219 (0.595)
Gatekeeper		−1.737*** (0.327)	−1.987** (0.760)
Factor	1.622*** (0.278)	1.760*** (0.257)	1.759*** (0.258)
<i>Within-city effects</i>			
Intra-regional links	−0.064 (0.069)	−0.059 (0.066)	−0.100 (0.079)
Extra-regional links	−0.025 (0.075)	−0.156 (0.167)	−0.153 (0.163)
Coordinator	0.058 (0.089)		0.080 (0.089)
Gatekeeper		0.084 (0.150)	0.133 (0.154)
Factor	−0.044 (0.065)	−0.010 (0.051)	−0.044 (0.062)
Pseudo- R^2 (fixed effects)	0.786	0.822	0.821
Pseudo- R^2 (total)	0.946	0.946	0.946
Akaike information criterion (AIC)	433.896	427.716	430.814
Bayesian information criterion (BIC)	457.294	451.114	458.467
Log-likelihood	−205.948	−202.858	−202.407
Number of observations	62	62	62
Number of groups: name	31	31	31
Variable: name (intercept)	0.245	0.189	0.192

Note: Standard errors are shown in parentheses; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; $p < 0.1$.

Source: Authors based on PatentsView data.

In this sense, the evidence reported here allows corroborating some structural characteristics of the Latin American IS, largely expressed in previous research. In particular, our networks reveal the extra-regional orientation of collaboration links, which is in line with a peripheral position of the region in global knowledge networks (Bianchi et al., 2021).

However, instead of describing the already known external dependencies and internal heterogeneities of the region, we analysed the role of cities as systemic agents. Regarding the Latin American IS, we corroborated the positive effects on patenting shown by the central nodes in inter-city networks (Yao et al., 2020). Yet, unlike these authors, we shed light on the trade-offs faced by broker cities in the region. These cities seem to face relatively higher costs than the benefits they obtain from knowledge networks. Although these conclusions are consistent with

the extensive research background on regional and national ISs in Latin America, to the best of our knowledge, the trade-off effects reported here have not been previously measured or estimated at the continental level.

In our latest set of models, we also find opposite results for the within-city and between-city effects of extra-regional links on innovation. It is worth discussing these findings from a dynamic perspective and in the light of firm-level innovation studies. Based on this approach, we can conjecture that links with cities located in advanced regions have a non-linear effect on the patent production of Latin American cities, an effect that varies according to time and the accumulation of local interactive capacity. For example, maintaining links with North America and/or Europe seems to positively affect innovation performance to a certain extent. From that point onwards, new collaborations may involve an investment

Table 4. Negative binomial regressions: models 7–10.

	Model 7	Model 8	Model 9	Model 10
Intercept	2.848*** (0.269)	2.482*** (0.097)	2.483*** (0.094)	2.481*** (0.094)
<i>Between-city effects</i>				
Intra-regional links	−0.235* (0.098)	0.073 (0.311)	0.025 (0.274)	−0.014 (0.303)
Links to Europe	0.043 (0.058)	0.101 (0.115)	0.235* (0.118)	0.256 (0.143)
Links to North America	0.074* (0.037)	0.227 (0.183)	0.572*** (0.173)	0.640* (0.297)
Links to East Asia	−1.059*** (0.306)	−0.402* (0.182)	−0.125 (0.212)	−0.097 (0.247)
Coordinator		−0.903** (0.291)		0.169 (0.676)
Gatekeeper			−1.463*** (0.403)	−1.676 (0.975)
Factor	1.589*** (0.292)	1.841*** (0.271)	1.856*** (0.261)	1.847*** (0.260)
<i>Within-city effects</i>				
Intra-regional links	−0.035 (0.044)	−0.140* (0.059)	−0.022 (0.051)	−0.120 (0.063)
Links to Europe	−0.036* (0.014)	−0.051 (0.028)	0.093 (0.087)	0.018 (0.092)
Links to North America	−0.069* (0.034)	−0.075 (0.098)	−0.099 (0.102)	−0.047 (0.104)
Links to East Asia	0.233* (0.113)	0.163* (0.073)	0.328** (0.114)	0.236* (0.119)
Coordinator		0.185** (0.058)		0.165** (0.063)
Gatekeeper			−0.336 (0.172)	−0.146 (0.186)
Factor	−0.100 (0.258)	−0.077* (0.036)	−0.022 (0.030)	−0.075* (0.036)
Pseudo- R^2 (fixed effects)	0.751	0.806	0.819	0.820
Pseudo- R^2 (total)	0.948	0.946	0.946	0.947
Akaike information criterion (AIC)	449.894	435.796	439.017	436.298
Bayesian information criterion (BIC)	477.547	467.703	470.924	472.460
Log-likelihood	−211.947	−202.898	−204.508	−201.149
Number of observations	62	62	62	62
Number of groups: name	31	31	31	31
Variable: name (intercept)	0.314	0.218	0.198	0.198

Note: Standard errors are shown in parentheses; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; $p < 0.1$.

Source: Authors based on PatentsView data.

and capacity allocation effort that disproportionately increases the cost of collaboration until the probability of obtaining patentable results in the following period is reduced. On the other hand, new collaborations established with emerging Asian countries appear to bring even more benefits than costs, as they are associated with improvements in patenting levels during the years following the collaboration.

In dialogue with the literature on the world-city network (Derudder & Taylor, 2016), our findings indicate that intermediating between global networks and regional networks seems to bring trade-offs to broker cities. In order to understand Latin American inter-city networks, in addition to these trade-offs, it would be worth considering the great heterogeneity not only among its cities but also within each of them, where highly competitive and

innovative sectors can coexist with large pockets of informality and poverty (Arocena & Sutz, 2010; Bianchi et al., 2021; Castellacci & Natera, 2016; Confraria & Vargas, 2019). Understanding dualism and heterogeneity in inter-city networks could be an interesting avenue for future research and, for this purpose, patent technology data can be exploited, which would allow analysing sectoral and technological specializations of Latin American cities and their connections to global networks.

Further research on inter-city networks from a regional IS approach is also essential, in particular, because, unlike networks at the national level, in continental regional systems, cities do not interact according to a single systemic coordinator – that is, according to a national state – as may be the case with cities in countries of continental size but with centrally planned development strategies (Fan et al., 2020; Wen et al., 2021; Yao et al., 2020). This type of research is especially relevant for the Latin American region in light of the great effort made by the regional governments to promote innovation and patenting during the last decades, in particular regarding the secular concern in the region for integrative continental projects that contribute to such national plans.

Thus, future research in this area may shed new light on innovation policy strategies addressing the specific challenges of openness related to the inherent uncertainty of cooperation and the unequal distribution of benefits and costs of open strategies.

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NOTES

1. For a detailed explanation about the process of data extraction and processing, see Bianchi et al. (2020).
2. Depending on where the interconnected cities are located, the links in our networks can be classified into

three broad categories: (1) intra-regional links, (2) links from Latin American cities to other parts of the world, and (3) links connecting pairs of cities outside of Latin America. While our data allow measuring adequately the first two types of links, in the third type (i.e., connections between non-Latin American cities) our data only measure a portion (presumably very small) of all the existing collaborative links. However, this is not a problem for our research since both our analytical approach and our methodology are focused on the first two types of links.

3. The approach we follow for the backbone extraction is the ‘agent-degree conditioned threshold’, which compares the observed number of co-patents with a null model that controls for the number of patents each innovator has (Neal, 2013).

4. Time windows are used in the literature since it is assumed that the actors involved in co-patents collaborate before and after the patent application date (e.g., Andersson et al., 2019; Breschi & Lenzi, 2015; Fleming et al., 2007).

5. Based on our data, a third type of broker role proposed by Gould and Fernández could also be calculated: the *itinerant* role (i.e., Latin American cities that mediate between cities located outside the region). However, such a position does not represent a brokerage role on a regional scale since it does not intermediate between any Latin American cities. Therefore, we decided not to include it in our analysis.

6. Our choice of using lagged variables is not just a mere econometric strategy. It is also based on our theoretical framework, where we argue that the city’s position in the network will facilitate access to knowledge and opportunities to innovate that will lead to the city generating more patents in the future. Therefore, according to Bellemare et al. (2017), the use of lagged explanatory variables is justified in our case since it has theoretical foundations. In the models we report in the paper we use a one-period lag, but our findings are robust to longer time lags (estimations are available from the authors upon request).

ORCID

Carlos Bianchi  <http://orcid.org/0000-0003-0547-3950>

Pablo Galaso  <http://orcid.org/0000-0002-7639-8225>

Segio Palomeque  <http://orcid.org/0000-0002-5396-3578>

REFERENCES

- Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly*, 45(3), 425–455. <https://doi.org/10.2307/2667105>
- Allison, P. (2009). *Fixed effects regression models*. SAGE. <https://doi.org/10.4135/9781412993869>.
- Andersson, D. E., Galaso, P., & Sáiz, P. (2019). Patent collaboration networks in Sweden and Spain during the Second Industrial Revolution. *Industry and Innovation*, 26(9), 1075–1102. <https://doi.org/10.1080/13662716.2019.1577720>
- Antonoli, D., Marzocchi, A., & Savona, M. (2017). Pain shared, pain halved? Cooperation as a coping strategy for innovation

- barriers. *The Journal of Technology Transfer*, 42(4), 841–864. <https://doi.org/10.1007/s10961-016-9545-9>
- Archibugi, D. (1992). Patenting as an indicator of technological innovation: A review. *Science and Public Policy*, 19(6), 357–368. <https://doi.org/10.1093/spp/19.6.357>
- Arocena, R., & Sutz, J. (2010). Weak knowledge demand in the South: Learning divides and innovation policies. *Science and Public Policy*, 37(8), 571–582. <https://doi.org/10.3152/030234210X12767691861137>
- Arora, A., Athreye, S., & Huang, C. (2016). The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. *Research Policy*, 45(7), 1352–1361. <https://doi.org/10.1016/j.respol.2016.03.019>
- Balland, P.-A., Jara-Figueroa, C., Petralia, S., Steijn, M. P. A., Rigby, D. L., & Hidalgo, C. A. (2020). Complex economic activities concentrate in large cities. *Nature Human Behaviour*, 4(3), 248–254. <https://doi.org/10.1038/s41562-019-0803-3>
- Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28(1), 31–56. <https://doi.org/10.1191/0309132504ph469oa>
- Bell, A., Fairbrother, M., & Jones, K. (2019). Fixed and random effects models: Making an informed choice. *Quality & Quantity*, 53(2), 1051–1074. <https://doi.org/10.1007/s11135-018-0802-x>
- Bellemare, M. F., Masaki, T., & Pepinsky, T. B. (2017). Lagged explanatory variables and the estimation of causal effect. *The Journal of Politics*, 79(3), 949–963. <https://doi.org/10.1086/690946>
- Belso-Martínez, J. A., Molina-Morales, F. X., & Martínez-Cháfer, L. (2015). Contributions of brokerage roles to firms' innovation in a confectionery cluster. *Technology Analysis & Strategic Management*, 27(9), 1014–1030. <https://doi.org/10.1080/09537325.2015.1045858>
- Bergquist, K., Fink, C., & Raffo, J. (2018). Identifying and ranking the world's largest science and technology clusters. In S. Dutta, B. Lanvin, & S. Wunsch-Vincent (Eds.), *The global innovation index 2018: Energizing the world with innovation* (11th ed., pp. 19). Cornell University, INSEAD, & World Intellectual Property Organization (WIPO).
- Bettencourt, L. M. A., Lobo, J., & Strumsky, D. (2007). Invention in the city: Increasing returns to patenting as a scaling function of metropolitan size. *Research Policy*, 36(1), 107–120. <https://doi.org/10.1016/j.respol.2006.09.026>
- Bianchi, C., Galaso, P., & Palomeque, S. (2020). *Invention and collaboration networks in Latin America: Evidence from patent data* (IECON Serie Documentos de Trabajo). Montevideo.
- Bianchi, C., Galaso, P., & Palomeque, S. (2021). Patent collaboration networks in Latin America: Extra-regional orientation and core-periphery structure. *Journal of Scientometric Research*, 10(1s), s59–s70. <https://doi.org/10.5530/jscires.10.1s.22>
- Bogers, M., Chesbrough, H., & Moedas, C. (2018). Open innovation: Research, practices, and policies. *California Management Review*, 60(2), 5–16. <https://doi.org/10.1177/0008125617745086>
- Borgatti, S. P. (2005). Centrality and network flow. *Social Networks*, 27(1), 55–71. <https://doi.org/10.1016/j.socnet.2004.11.008>
- Brache, J., & Felzensztein, C. (2019). Geographical co-location on Chilean SME's export performance. *Journal of Business Research*, 105, 310–321. <https://doi.org/10.1016/j.jbusres.2017.11.044>
- Breschi, S., & Lenzi, C. (2015). The role of external linkages and gatekeepers for the renewal and expansion of US cities' knowledge base, 1990–2004. *Regional Studies*, 49(5), 782–797. <https://doi.org/10.1080/00343404.2014.954534>
- Cao, Z., Derudder, B., Dai, L., & Peng, Z. (2021). 'Buzz-and-pipeline' dynamics in Chinese science: The impact of interurban collaboration linkages on cities' innovation capacity. *Regional Studies*. <https://doi.org/10.1080/00343404.2021.1906410>
- Castellacci, F., & Natera, J. M. (2016). Innovation, absorptive capacity and growth heterogeneity: Development paths in Latin America 1970–2010. *Structural Change and Economic Dynamics*, 37, 27–42. <https://doi.org/10.1016/j.strueco.2015.11.002>
- Confraria, H., & Vargas, F. (2019). Scientific systems in Latin America: Performance, networks, and collaborations with industry. *The Journal of Technology Transfer*, 44(3), 874–915. <https://doi.org/10.1007/s10961-017-9631-7>
- Cooke, P. (2001). Regional Innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, 10(4), 945–974. <https://doi.org/10.1093/icc/10.4.945>
- David, P. A., & Foray, D. (1996). Information distribution and the growth of economically valuable knowledge: A rationale for technological infrastructure policies. In M. Teubal, D. Foray, M. Justman, & E. Zuscovitch (Eds.), *Technological infrastructure policy. Economics of science, technology and innovation* (pp. 87–116). Springer Netherlands. https://doi.org/10.1007/978-94-015-8739-6_4
- de Araújo, I. F., Gonçalves, E., & Taveira, J. G. (2019). The role of patent co-inventorship networks in regional inventive performance. *International Regional Science Review*, 42(3–4), 235–280. <https://doi.org/10.1177/0160017618770717>
- de Jong, J. P. J., Kalvet, T., & Vanhaverbeke, W. (2010). Exploring a theoretical framework to structure the public policy implications of open innovation. *Technology Analysis & Strategic Management*, 22(8), 877–896. <https://doi.org/10.1080/09537325.2010.522771>
- De Noni, I., Ganzaroli, A., & Orsi, L. (2017). The impact of intra- and inter-regional knowledge collaboration and technological variety on the knowledge productivity of European regions. *Technological Forecasting and Social Change*, 117, 108–118. <https://doi.org/10.1016/j.techfore.2017.01.003>
- Delvenne, P., & Thoreau, F. (2017). Dancing without listening to the music: Learning from some failures of the 'national innovation systems' in Latin America. In S. Kuhlmann & G. Ordóñez-Matamoros (Eds.), *Research handbook on innovation governance for emerging economies: Towards better models* (pp. 37–58). Edward Elgar.
- Derudder, B., & Taylor, P. (2016). Change in the World City Network, 2000–2012. *The Professional Geographer*, 68(4), 624–637. <https://doi.org/10.1080/00330124.2016.1157500>
- Erbes, A., Robert, V., & Yoguel, G. (2010). Capacities, innovation and feedbacks in production networks in Argentina. *Economics of Innovation and New Technology*, 19(8), 719–741. <https://doi.org/10.1080/10438590903040807>
- Fan, F., Lian, H., & Wang, S. (2020). Can regional collaborative innovation improve efficiency? An empirical study of Chinese cities. *Growth and Change*, 51(1), 440–463. <https://doi.org/10.1111/grow.12346>
- Felzensztein, C., Deans, K. R., & Dana, L. (2019). Small firms in regional clusters: Local networks and internationalization in the southern hemisphere. *Journal of Small Business Management*, 57(2), 496–516. <https://doi.org/10.1111/jsbm.12388>
- Fischer, B. B., Queiroz, S., & Vonortas, N. S. (2018). On the location of knowledge-intensive entrepreneurship in developing countries: Lessons from São Paulo, Brazil. *Entrepreneurship & Regional Development*, 30(5–6), 612–638. <https://doi.org/10.1080/08985626.2018.1438523>
- Fleming, L., King, C., & Juda, A. I. (2007). Small worlds and regional innovation. *Organization Science*, 18(6), 938–954. <https://doi.org/10.1287/orsc.1070.0289>
- Florida, R., Adler, P., & Mellander, C. (2017). The city as innovation machine. *Regional Studies*, 51(1), 86–96. <https://doi.org/10.1080/00343404.2016.1255324>

- Foray, D. (2004). *The economics of knowledge book*. Massachusetts Institute of Technology.
- Freeman, C. (1991). Networks of innovators: A synthesis of research issues. *Research Policy*, 20(5), 499–514. [https://doi.org/10.1016/0048-7333\(91\)90072-X](https://doi.org/10.1016/0048-7333(91)90072-X)
- Galaso, P., & Kovářik, J. (2021). Collaboration networks, geography and innovation: Local and national embeddedness. *Papers in Regional Science*, pirs.12578. <https://doi.org/10.1111/pirs.12578>
- Galaso, P., & Rodríguez Miranda, A. (2020). The leading role of support organisations in cluster networks of developing countries. *Industry and Innovation*, 1–30. <https://doi.org/10.1080/13662716.2020.1856046>
- Galaso, P., Rodríguez Miranda, A., & Picasso, S. (2019). Inter-firm collaborations to make or to buy innovation. *Management Research: Journal of the Iberoamerican Academy of Management*, 17(4), 404–425. <https://doi.org/10.1108/MRJIAM-12-2018-0893>
- German-Soto, V., & Gutiérrez Flores, L. (2015). A standardized coefficients model to analyze the regional patents activity: Evidence from the Mexican states. *Journal of the Knowledge Economy*, 6(1), 72–89. <https://doi.org/10.1007/s13132-012-0101-z>
- Giuliani, E., & Bell, M. (2005). The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster. *Research Policy*, 34(1), 47–68. <https://doi.org/10.1016/j.respol.2004.10.008>
- Gould, R. V., & Fernandez, R. M. (1989). Structures of mediation: A formal approach to brokerage in transaction networks. *Sociological Methodology*, 19, 89. <https://doi.org/10.2307/270949>
- Griliches, Z. (1990). Patent statistics as Economic indicators: A survey. *Journal of Economic Literature*, 28(4), 1661–1707. <https://www.jstor.org/stable/2727442>
- Grimpe, C., & Kaiser, U. (2010). Balancing internal and external knowledge acquisition: The gains and pains from R&D outsourcing. *Journal of Management Studies*, 47(8), 1483–1509. <https://doi.org/10.1111/j.1467-6486.2010.00946.x>
- Guan, J., Zhang, J., & Yan, Y. (2015). The impact of multilevel networks on innovation. *Research Policy*, 44(3), 545–559. <https://doi.org/10.1016/j.respol.2014.12.007>
- Hill, A. D., Johnson, S. G., Greco, L. M., O'Boyle, E. H., & Walter, S. L. (2021). Endogeneity: A review and agenda for the methodology–practice divide affecting micro and macro research. *Journal of Management*, 47(1), 105–143. <https://doi.org/10.1177/0149206320960533>
- Innocenti, N., Capone, F., & Lazzeretti, L. (2020). Knowledge networks and industrial structure for regional innovation: An analysis of patents collaborations in Italy. *Papers in Regional Science*, 99(1), 55–72. <https://doi.org/10.1111/pirs.12478>
- Johnson, B. (2008). Cities, systems of innovation and economic development. *Innovation*, 10(2–3), 146–155. <https://doi.org/10.5172/impp.453.10.2-3.146>
- Johnson, B., Lorenz, E., & Lundvall, B. (2002). Why all this fuss about codified and tacit knowledge? *Industrial and Corporate Change*, 11(2), 245–262. <https://doi.org/10.1093/icc/11.2.245>
- Katz, J. S., & Ronda-Pupo, G. A. (2019). Cooperation, scale-invariance and complex innovation systems: A generalization. *Scientometrics*, 121(2), 1045–1065. <https://doi.org/10.1007/s11192-019-03215-8>
- Kauffeld-Monz, M., & Fritsch, M. (2013). Who are the knowledge brokers in regional systems of innovation? A multi-actor network analysis. *Regional Studies*, 47(5), 669–685. <https://doi.org/10.1080/00343401003713365>
- Khanna, T., Gulati, R., & Nohria, N. (1998). The dynamics of learning alliances: Competition, cooperation, and relative scope. *Strategic Management Journal*, 19(3), 193–210. [https://doi.org/10.1002/\(SICI\)1097-0266\(199803\)19:3<193::AID-SMJ949>3.0.CO;2-C](https://doi.org/10.1002/(SICI)1097-0266(199803)19:3<193::AID-SMJ949>3.0.CO;2-C)
- Koo, J. (2005). Knowledge-based industry clusters: Evidenced by geographical patterns of patents in manufacturing. *Urban Studies*, 42(9), 1487–1505. <https://doi.org/10.1080/00420980500185249>
- Laursen, K., & Salter, A. J. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, 43(5), 867–878. <https://doi.org/10.1016/j.respol.2013.10.004>
- Li, M. (2013). Social network and social capital in leadership and management research: A review of causal methods. *The Leadership Quarterly*, 24(5), 638–665. <https://doi.org/10.1016/j.leaqua.2013.04.005>
- Lobo, J., & Strumsky, D. (2008). Metropolitan patenting, inventor agglomeration and social networks: A tale of two effects. *Journal of Urban Economics*, 63(3), 871–884. <https://doi.org/10.1016/j.jue.2007.07.005>
- Maisonobe, M., Grossetti, M., Milard, B., Eckert, D., & Jégou, L. (2016). The global evolution of scientific collaboration networks between cities (1999–2014). *Revue Française de Sociologie*, 57(3), 417–441. <https://doi.org/10.3917/rfs.573.0417>
- Makkonen, T., Merisalo, M., & Inkinen, T. (2018). Containers, facilitators, innovators? The role of cities and city employees in innovation activities. *European Urban and Regional Studies*, 25(1), 106–118. <https://doi.org/10.1177/0969776417691565>
- Malerba, F., & Orsenigo, L. (2000). Knowledge, innovative activities and industrial evolution. *Industrial and Corporate Change*, 9(2), 289–314. <https://doi.org/10.1093/icc/9.2.289>
- Marshall, A. (1879). *The pure theory of domestic values*. London School of Economics and Political Science (LSE).
- Montaño, S. H., & González, E. D. (2007). La producción y el uso del conocimiento en México y su impacto en la innovación: análisis regional de las patentes solicitadas. *Análisis Económico*, 22(50), 185–217.
- Montobbio, F., & Sterzi, V. (2011). Inventing together: Exploring the nature of international knowledge spillovers in Latin America. *Journal of Evolutionary Economics*, 21(1), 53–89. <https://doi.org/10.1007/s00191-010-0181-5>
- Morales Valera, R. M., & Sifontes, D. A. (2014). Las patentes como resultado de la cooperación en I+D en américa latina: Hechos y desafíos. *Investigación y Desarrollo*, 22(1), 22–38. <https://doi.org/10.14482/index.22.1.3737>
- Neal, Z. P. (2012). *The connected city*. Routledge. <https://doi.org/10.4324/9780203101728>
- Neal, Z. P. (2013). Identifying statistically significant edges in one-mode projections. *Social Network Analysis and Mining*, 3(4), 915–924. <https://doi.org/10.1007/s13278-013-0107-y>
- Neal, Z. P. (2014). The backbone of bipartite projections: Inferring relationships from co-authorship, co-sponsorship, co-attendance and other co-behaviors. *Social Networks*, 39(1), 84–97. <https://doi.org/10.1016/j.socnet.2014.06.001>
- Niembro, A. (2020). Las disparidades entre los sistemas regionales de innovación en Argentina durante el periodo 2003–2013. *Economía Sociedad y Territorio*, 20(62), 781–816. <https://doi.org/10.22136/est20201381>
- Owen-Smith, J., & Powell, W. W. (2004). Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community. *Organization Science*, 15(1), 5–21. <https://doi.org/10.1287/orsc.1030.0054>
- Porter, M. E. (1990). *The competitive advantage of nations*. Free Press.
- Rantisi, N. M. (2002). The local innovation system as a source of 'variety': Openness and adaptability in New York City's garment district. *Regional Studies*, 36(6), 587–602. <https://doi.org/10.1080/00343400220146740>
- Rapini, M. S., da Motta e Albuquerque, E., Chave, C. V., Silva, L. A., de Souza, S. G. A., Righi, H. M., & da Cruz, W. M. S. (2009). University–industry interactions in an immature system

- of innovation: Evidence from Minas Gerais, Brazil. *Science and Public Policy*, 36(5), 373–386. <https://doi.org/10.3152/030234209X442016>
- Reis, R. C., Gonçalves, E., & Taveira, J. G. (2018). Determinants of inventive collaborations in Brazilian interregional and international networks. *Revista Brasileira de Inovação*, 17(2), 287–316. <https://doi.org/10.20396/rbi.v17i2.8649987>
- Saxenian, A. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Harvard University Press.
- Schilling, M. A., & Phelps, C. C. (2007). Interfirm collaboration networks: The impact of large-scale network structure on firm innovation. *Management Science*, 53(7), 1113–1126. <https://doi.org/10.1287/mnsc.1060.0624>
- Schuknecht, L., & Siegerink, V. (2020). The political economy of the G20 agenda on financial regulation. *European Journal of Political Economy*, 65, article 101941. <https://doi.org/10.1016/j.ejpoleco.2020.101941>
- Schulz, N. (2020). The politics of export restrictions: A panel data analysis of African commodity processing industries. *World Development*, 130, article 104904. <https://doi.org/10.1016/j.worlddev.2020.104904>
- Sigler, T. J., & Martinus, K. (2017). Extending beyond ‘world cities’ in World City Network (WCN) research: Urban positionality and economic linkages through the Australia-based corporate network. *Environment and Planning A: Economy and Space*, 49(12), 2916–2937. <https://doi.org/10.1177/0308518X16659478>
- Simmie, J., Sennett, J., Wood, P., & Hart, D. (2002). Innovation in Europe: A tale of networks, knowledge and trade in five cities. *Regional Studies*, 36(1), 47–64. <https://doi.org/10.1080/00343400120099852>
- van der Wouden, F., & Rigby, D. L. (2019). Co-inventor networks and knowledge production in specialized and diversified cities. *Papers in Regional Science*, 98(4), 1833–1853. <https://doi.org/10.1111/pirs.12432>
- Verginer, L., & Riccaboni, M. (2020). Cities and countries in the global scientist mobility network. *Applied Network Science*, 5(1), 38. <https://doi.org/10.1007/s41109-020-00276-0>
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol. 8). Cambridge University Press.
- Wen, H., Zhang, Q., Zhu, S., & Huang, Y. (2021). Inter- and intra-city networks: How networks are shaping China’s film industry. *Regional Studies*, 55(3), 533–545. <https://doi.org/10.1080/00343404.2020.1807492>
- Wolfe, D. A., & Gertler, M. S. (2004). Clusters from the inside and out: Local dynamics and global linkages. *Urban Studies*, 41(5–6), 1071–1093. <https://doi.org/10.1080/00420980410001675832>
- World Intellectual Property Organization (WIPO). (2018). *World Intellectual Property indicators 2018*. WIPO.
- Yao, L., Li, J., & Li, J. (2020). Urban innovation and intercity patent collaboration: A network analysis of China’s national innovation system. *Technological Forecasting and Social Change*, 160, article 120185. doi:10.1016/j.techfore.2020.120185