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When the rain comes, don't stay at home!
Regional innovation and trans-local investment in the aftermath of the Great Recession[*]

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Abstract

Global connectivity and knowledge circulation are necessary for innovation to thrive. However, in response to external shocks, economies tend to reduce their external exposure in order to minimize risk and focus their resources on internal markets. Uncoordinated and often competitive responses to economic shocks are in sharp contrast with the need for innovative solutions for recovery. This paper explores this paradox by looking at regional innovation in the USA in the aftermath of the Great Recession. The paper compares Foreign Direct Investment (FDI) with similar domestic, inter-state investment in order to assess whether a 'local innovation premium' is associated with global connectivity vis-à-vis purely domestic linkages. The results show that what matters for post-crisis innovation is active internationalization in the form of outward FDI. Truly global outward connectivity matters the most: investing abroad offers the highest short-term returns vis-à-vis domestic inter-regional investments. FDI connectivity with highly innovative frontier systems offers the highest returns when innovation is needed to respond to the crisis. However, low-innovation regions can still profit (in the short-run) from connectivity with other relatively less technologically advanced regions, benefitting from stronger congruence in terms of technological capabilities. These results send a warning message on the potentially adverse consequences of current policies in most advanced economies that seek to manage foreign activities of domestic companies in attempts to foster domestic security and recovery.

Keywords
Innovation; Foreign and Domestic Investment; Great Recession; Regions; USA.

JEL Codes
F21; O19; O3; O51; R12.

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1. Introduction

Globalization and innovation have been seen as two inseparable and self-reinforcing terms of the same economic growth equation. Economic and political integration are made possible by new technologies, while technological advancement needs global connectivity and knowledge circulation to thrive.

However, current geo-political tensions and recovery policies might split the two processes for the foreseeable future. On the one hand, virtually all countries are responding to economic challenges of recovery from COVID-19 by supporting domestic activities and offering (direct and indirect) incentives to promote the reshoring of foreign activities. In addition, growing geo-political tensions and conflicts are offering a new rationale for a more stringent scrutiny of foreign activities by domestic firms on 'national security', supply chain risk management, as well as economic nationalism grounds. On the other hand, innovation is a crucial factor in order to respond to global shocks and offer new products and processes to deal with their social and economic impacts and promote sustainable and inclusive recovery.

This paper offers a first attempt to revisit the globalization-innovation nexus in times of crisis by looking at the Great Recession in the United States of America (USA), and comparing domestic inter-regional investments – that tap into external knowledge but within national boundaries – with truly global foreign activities in the form of Foreign Direct Investment (FDI) in terms of regional innovativeness. This comparison will make it possible to identify the 'premium' (if any) associated with a truly global unconstrained process of knowledge search by local domestic companies in comparison with attempts to ring-fence national activities within national boundaries, limiting extra-local activities to inter-regional domestic connections.

This paper focuses on FDI as a channel allowing connections and knowledge flows among geographically distant territories. Specifically, it provides a comparative analysis between new, greenfield inward and outward US domestic, inter-state investments vs. 'global' FDI, and focuses on the innovative performance − defined in terms of new patents − of US Economic Areas (EA) in the aftermath of the Great Recession. Following Barba Navaretti and Venables (2004), US inter-state direct investments − i.e., those pursued by US-based companies in US states other than the headquarter − are classified as domestic. This makes the USA an ideal case study to analyze the spatial extent of extra-regional connectivity, as it allows one to compare the association with local innovation of investment projects which differ only in their national (i.e., intra-US) vs. global (i.e., extra-US) nature.

There is consensus in the economic geography literature that innovation is the result of a balanced combination of 'local buzz' (Storper and Venables, 2004) and 'global pipelines' (Bathelt et al., 2004). Global connectivity should be intended as a dynamic process based on the interaction between purely local, spatially-bounded conditions and extra-local factors (Canello, 2017) which allows territories to engage in innovation-driven economic growth processes promoted by increasing knowledge availability (Grossman and Helpman, 1991) within an integrated local-global framework (Bathelt et al., 2004).

Among the many channels through which regions can interact and exchange knowledge globally (e.g., trade, human capital, collaborative networks), FDI has received great attention by both scholars and policy makers. This is mainly due to the role played by multinational enterprises (MNEs) in shaping the geography − and shifting the organization − of production activities from the local to the global dimension (Iammarino and McCann, 2013), with consequences in terms of global connectivity among territories (Sturgeon et al., 2008; Crescenzi and Iammarino, 2017). The empirical evidence has highlighted the relevance of knowledge-based FDI-driven externalities, which shape innovative behaviors and promote innovation and innovative outputs (e.g., Crescenzi et al., 2015; Li et al., 2016; Crescenzi et al., 2022a).

Despite the large academic consensus on the importance of regional openness and global connectivity (e.g., through FDI) to promote innovation, competitiveness, economic development and growth of local systems, recent economic (e.g., the Great Recession), political (e.g., *Brexit*, the rise of economic nationalism in virtually all major economies, and the war in Ukraine) and global health (COVID-19) crises have called into question the benefits of the process of global economic integration and internationalization, with relevant implications for firms' cross-border activities and regional integration within global networks. This calls for further research into regional connectivity to uncover new patterns of association between extra-regional knowledge flows and the innovative behavior of regions. This, particularly, implies to disentangle a series of interrelated dimensions, including the spatial (national vs. global) extent of regional connections, the directionality of connectivity (passive internationalization based on inward investment vs. active internationalization based on outward flows), and the congruence between the regional systems being connected in terms of their technological capabilities.

This paper contributes to the debate on global connectivity by analyzing the role of trans-local 'pipelines' in driving the evolutionary dynamics of regions and productive clusters following a global shock (Bathelt et al., 2004; Sturgeon et al., 2008; Crescenzi and Iammarino, 2017). Indeed, the economic geography literature has underlined how global connections − e.g., through trade linkages (Silva and Leichenko, 2004; Rodríguez-Pose, 2012) − operate as a key factor influencing the evolutionary dynamics of regions by altering both the local-specific configuration and the cross-region distribution of economic activities, labor skills and knowledge assets. In fact, through the involvement of local firms in trade activities and global value chains/production networks, regions are likely to acquire novel resources which may help them to enter new growth and development paths driven by processes of knowledge acquisition (Eriksson, 2011), technological change (Rigby and Essletzbichler, 1997) and industrial re-configuration (Neffke et al., 2011).

In line with this conceptual framework, and considering the limitations related to data availability, this paper offers a threefold contribution to the existing literature. First, the paper explores regional innovation trajectories in response to the Great Recession, offering timely new input to current policy debates on the possible risks of global disconnect due to the push for a 're-nationalization' of the foreign activities of domestic firms. Second, the innovative dataset employed for the analysis makes it possible to match and compare greenfield US domestic, inter-state investments vs. 'purely' foreign investments in order to capture the 'value added' offered, ceteris paribus, by the foreign nature of the investment. Moreover, the interplay between US domestic, inter-state and foreign investments is analyzed considering the innovative congruence between destination and source economies, as well as comparing two different types of patents, namely more 'domestic' US patents granted under the United States Patent and Trademark Office (USPTO) vs. international Patent Cooperation Treaty (PCT) patents (as a proxy for truly new-to-the-world innovations). Third, the paper aims to capture a wider dimension of extra-regional connectivity by simultaneously accounting for both inward and outward investments, shedding new light on the directionality of global connectivity.[1]

The empirical findings offer three key additions to the existing literature. First, what matters for post-shock innovation is 'active' internationalization in the form of outward FDI. Outward investment makes it easier to tap into selected pools of external knowledge in the short-run response to a crisis. Second, truly global connectivity matters the most for post-crisis innovation: investing abroad offers the highest short-term returns vis-à-vis domestic inter-regional investments. Third, it is 'active' FDI connectivity with highly innovative territories that matters when innovation is needed to respond to a crisis. However, low-innovation regions can still profit from connectivity with other relatively less advanced regions due to higher

[1] It is worth mentioning, even at this stage, that the empirical analysis carried out has a descriptive nature and, thus, that the empirical evidence presented has to be interpreted as a simple, though robust, correlation among variables.

technological congruence.

The rest of the paper is organized as follows. Section 2 presents the conceptual framework and derives the research hypotheses. Section 3 discusses the dynamics of innovation and trans-local investments in the USA. Section 4 describes the data and the empirical methodology. Section 5 presents and discusses the results. Section 6 concludes with some reflections on the lessons learned from the Great Recession for innovation in the post-COVID-19 economic landscape.

2. Connectivity, knowledge flows and regional innovation after a shock

Four decades of unprecedented advancements in transportation and communication technologies have persuaded some commentators of a decreasing importance of physical distance in economic activity. Technological development and dramatic reductions in transport and communication costs seemed capable of underpinning a self-reinforcing process of economic integration, allowing new economic actors (e.g., from emerging economies) to compete successfully in the global economy with large efficiency gains in advanced economies. All this came to a halt first with the Great Recession in 2008 and, a decade later, with the COVID-19 crisis (Baldwin and Weder di Mauro, 2020a, 2020b; IMF, 2020), the growing geo-political tensions, and the war in Ukraine.

The Great Recession, the COVID-19 crisis, and the Ukraine war have all increased – in different ways – the cost of economic transactions across distance and national borders, disrupted supply chains, and triggered a process of 're-nationalization' and reshoring of economic activities 'back' to their home countries (IMF, 2020). The COVID-19 has precipitated these changes to a much larger extent than the Great Recession due to the pandemic' simultaneous impact on both supply and demand in a much broader set of sectors and geographies, whereas the loci of the Great Recession were the financial sectors of a limited number of countries. US President Donald Trump has notoriously embedded this goal into his economic policy objectives by incentivizing US firms to 'bring jobs back to America' (Nicholas, 2020). The COVID-19 crisis has further reinforced this call for a global reshoring of previously internationalized activities in the US and across the globe (Bloom, 2020). The 'recovery plans' in both the US and the European Union place a strong emphasis on (and make incentives available for) re-shoring of domestic activities back to their domestic jurisdictions as a means to boost domestic employment and increase domestic security and self-sufficiency in essential and strategic sectors (from food to micro-processors).

As a consequence of these dramatic (and highly spatially asymmetric) changes in international competition, local production systems have to redefine their competitive strategies in order to 'bounce back' after the shock, or, alternatively, identify new and more suitable development paths (Martin et al., 2016; Crescenzi and Iammarino, 2017; Xiao et al., 2018). In this respect, economic actors – and the local systems within which they are located and operate – are required to intensify or initiate innovation processes to both sustain and foster productivity and efficiency (through process innovation) and differentiate their portfolios of goods and services (through product innovation) in order to compete successfully (Castellani and Zanfei, 2007; Cassiman et al., 2010; Antonietti and Cainelli, 2011) and develop new resilience patterns (Archibugi and Filippetti, 2011).

The short-run local capacity to innovate in response to external shocks is therefore central to the economic destiny of regions and beyond. However, innovation does not happen in isolation. Globalization has allowed firms and regions to connect globally, giving them the possibility to discover and acquire knowledge generated in distant places, and which can be adapted to, and integrated with, preexisting local knowledge (Canello, 2017). Thus, global connectivity represents a fundamental way for firms and regions to develop new competitive advantages through an innovation-driven process based on the combination of 'local buzz'

(Storper and Venables, 2004) and ‘global pipelines’ (Bathelt et al., 2004).

The importance of regional connectivity has been highlighted by various contributions on regional innovation systems and industrial clusters. This literature has moved from the idea of innovation driven by knowledge spillovers occurring among geographically proximate actors within spatially-bounded local production systems (e.g., Porter, 1990; Jaffe et al., 1993; Audretsch and Feldman, 1996; Cooke et al., 1997) to the idea of innovation resulting from trans-local interactions and externalities (e.g., Bathelt et al., 2004; Turkina et al., 2016).

The argument supporting the need for regions to establish trans-local ‘pipelines’ relies on the risk of localism which could arise as a consequence of too little connectivity (Boschma, 2005; Boschma and Frenken, 2010). In fact, although knowledge flows and spillovers among economic actors are facilitated by geographic proximity within spatially-bounded systems (Jacobs, 1969; Glaeser et al., 1992), excessive proximity and closure can make regions static, and prevent them from undertaking innovation-driven processes of transformation towards new competitive trajectories (Crescenzi and Iammarino, 2017).

Extra-regional connectivity can help regions avoid – or at least limit − lock-in effects by allowing them to access new, non-locally available knowledge, as regions differ in their knowledge profiles (Chung and Yeaple, 2008). Then, a region can “reinvent itself” (Mudambi et al., 2017, p. 20) by defining a new knowledge profile based on the combination of old, new, local and external knowledge through which novel and improved innovation processes promote economic development (Boschma and Iammarino, 2009; Benneworth and Dassen, 2011) and, ultimately, resistance to shocks and resilience.

This idea has been stressed by the most recent literature on regional innovation systems, clusters and industrial districts, which has used the concepts of ‘open innovation’ and ‘open networks’ to explain successful stories of local systems which have relied on international networks to renew and improve innovation-based strategies in the face of increased global competition (Fitjar and Rodríguez-Pose, 2011, 2013; Mudambi et al., 2017). In this respect, internationalization through FDI seems to represent the most important channel for regions to develop, amplify and leverage global connections, with MNEs fulfilling a central role in this process (Iammarino and McCann, 2013). MNEs operate by decomposing the different phases/functions of the value chain and reallocating them across a variety of locations worldwide through FDIs. MNEs act as key nodes within global production networks, as they organize and manage globally dispersed activities in order to maximize value-added creation by exploiting diverse, local-specific competitive advantages (Dicken, 2003; Gereffi, 2005; Hess and Yeung, 2006; Dicken, 2007). In this way, MNEs are able to capture new knowledge generated in very different and geographically distant regional systems, and recombine it with that they already possess internally (Coe et al., 2008; Cusmano et al., 2010; Kedron and Bagchi-Sen, 2012).

In addition, the activities of global MNEs within global value chains produce positive externalities affecting the actors and the local production systems connected along the global networks (Ernst and Kim, 2002; Coe et al., 2004; Yeung, 2009).

This leads to the formulation of our first hypothesis:

Hypothesis #1: *Trans-local connectivity through 'foreign' direct investment stimulates regional innovation in the aftermath of a global shock vis-à-vis equivalent 'domestic' inter-regional connectivity.*

Knowledge flows exchanged through FDI are bi-directional: they involve both the host regions where MNE subsidiaries are located, and the home regions where MNEs are headquartered. FDI-mediated knowledge flows in the host region may arise from different channels which include, in particular, intra-industry demonstration, competition and labor market effects, which drive innovativeness, efficiency and productivity of domestic firms mainly indirectly (Fosfuri et al., 2001; Castellani and Zanfei, 2003; Görg and Greenaway, 2004), and inter-industry backward and forward linkages, through which knowledge flows directly among foreign-owned and domestic firms (Ernst and Kim, 2002; Javorcik, 2004; Javorcik and Spatareanu, 2008). All in all, the presence of foreign-owned firms is likely to promote innovative behaviors in the host region through knowledge exchange and technological improvement, thus pushing the regional system towards increases in efficiency and productivity (Barba Navaretti and Venables, 2004). Conversely, FDI-related effects in the home region depend both on the ability of the MNE to manage reverse knowledge transfers, i.e., its capacity to transfer the acquired knowledge from the foreign subsidiaries to the headquarter, as well as on the possibility of knowledge exchange between the MNE and the local firms within the home regional system, for example through forward and backward linkages, imitation and competition processes, or labor mobility (Griffith et al., 2006; Castellani and Pieri, 2013; Rabbiosi and Santangelo, 2013).

In this sense, FDI acts as a 'bridge' through which knowledge may spread among different geographies worldwide. Thus, it represents a channel for regions to expand trans-local connections to a global extent (Iammarino and McCann, 2013). This idea finds confirmation in several empirical studies analyzing the innovative returns of both inward (Antonietti et al., 2015; Crescenzi et al., 2015; Crescenzi and Jaax, 2017) and outward (Criscuolo et al., 2005; Criscuolo, 2009; Li et al., 2016) FDI-related externalities.

The discussion on FDI and MNE-centered global networks highlights the second dimension characterizing regional connectivity: its directionality. Knowledge acquisition through extra-regional networks is the result of a dynamic and complex process which is bi-directional in nature. In fact, regions can enlarge their internally-generated knowledge set with novel, external knowledge both by exploiting new inputs brought into the region by non-local economic actors (e.g., by subsidiaries of foreign MNEs), and by actively looking for new knowledge sets available outside the regional system (e.g., through foreign subsidiaries of domestic MNEs). This means that knowledge acquisition through trans-local 'pipelines' is the result of a combination of a 'passive' injection of inputs and an 'active' search of *ad hoc* resources. This dynamic process characterizes not only knowledge flows based on FDI (inward and outward investments), but also extra-regional connections through trade, sub-contracting and human capital mobility. When regions have to quickly adapt existing local knowledge to a new competitive environment in response to a shock, they need to be highly selective and effective. Local actors need to effectively tap into external pools of knowledge without the barrier of the strategic behavior of foreign firms hosted in the regional economy that might actively try to minimize local knowledge spillovers, particularly in times of crisis (Alcacer and Chung, 2007; Crescenzi et al., 2022a). In a time of crisis, active outward connectivity of local domestic firms might offer the most effective means to access new non-redundant knowledge set, by-passing strategic barriers imposed by inward investors active in the local economy.

This leads to the second hypothesis:

Hypothesis #2: *Active outward connectivity offers the highest short-term innovation returns to respond to a global shock.*

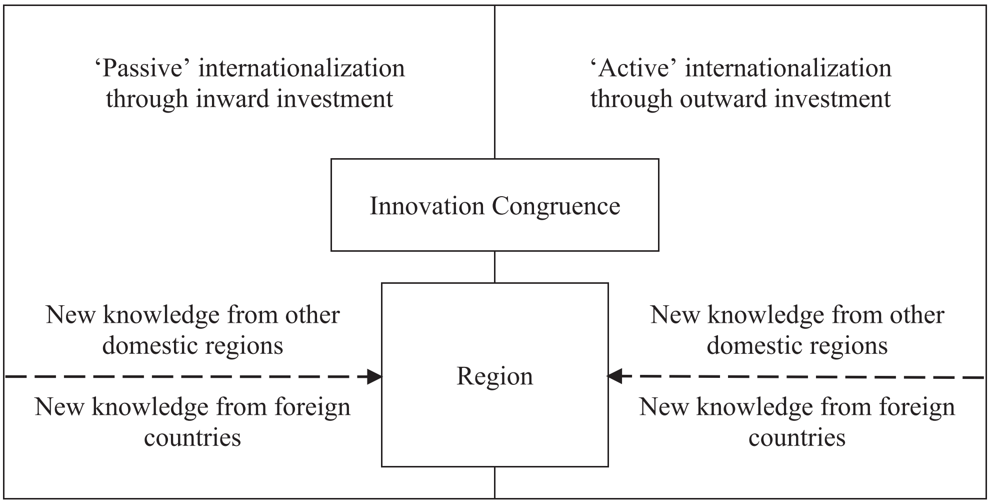
A third dimension characterizing regional knowledge connectivity concerns the technological congruence among the regional systems being connected (Boschma, 2005). With specific reference to innovation, technological proximity and congruence in innovative capability between interconnected regional systems are likely to play a crucial role for knowledge to flow and externalities to materialize (Castellani and Zanfei, 2003), particularly in the aftermath of a global shock. For example, little innovative congruence between the sourcing and receiving regions may prevent – and certainly slow-down – the identification, acquisition, transfer and, finally, use of new knowledge urgently needed to respond to shocks and the corresponding changed competitive landscape. This can happen if two local systems, although connected, occupy distant relative positions in the territorial distribution of innovative capability, independent of the spatial extent of the connection and the direction of the flow. Thus, technological and innovative congruence among interconnected regional systems may facilitate and speed-up the process of adaptation, integration and recombination of the different knowledge sets acquired through trans-local 'pipelines' (Boschma and Iammarino, 2009).

This leads to the third hypothesis:

Hypothesis #3: *Higher congruence between inter-connected regions/countries facilitates (short-run) innovation in the aftermath of a global shock.*

By combining the three dimensions characterizing regional connectivity, a broad framework emerges to identify successful regional profiles. Regions may develop new, innovation-driven competitive strategies by exploiting knowledge generated outside the regional boundaries. This new knowledge can be sourced from a variety of places, at both national and global level. In particular, FDI represents a key channel for knowledge to flow, as it connects regional systems globally and allows for bi-directional knowledge sourcing resulting from both a 'passive' acquisition (through inward flows) and an 'active' search (through outward flows). In addition, the process of extra-regional knowledge acquisition may also depend on the level of technological congruence among the interconnected regions. Thus, a region can enter trans-local 'pipelines' selectively in order to acquire novel knowledge which maximizes the configuration of its new knowledge profile, and, consequently, allows for the identification of an optimal new innovation-driven competitive trajectory. Figure 1 summarizes this conceptual framework.

Figure 1: Conceptual framework.



Notes: Authors’ elaboration.

3. Trans-local investment and innovation in the USA

The USA represents a suitable environment to analyze regional patterns of (global) connectivity. As stated in the introductory section to this paper, direct investments realized by US-based companies in US states other than the headquarter are identified as domestic (Barba Navaretti and Venables, 2004). Empirically, this allows one to investigate the spatial extent of trans-local connections characterizing US regions by comparing (inward and outward) flows of investments occurring domestically (i.e., across US regions) and globally (i.e., among US regions and foreign countries). In addition, the USA is both highly innovative and deeply involved in global networks managed by MNEs.

The USA is the country most heavily involved in international cross-border activities, in particular in terms of FDI (UNCTAD, 2017). As Appendix Figure A1 shows, the recent dynamics of US foreign investments has been characterized by a positive trend, and FDI has recovered quite rapidly after the negative peaks reached during both the 2001 stock market crash and the 2007 financial crisis. This positive FDI dynamics also characterizes the USA’s world primacy: indeed, the US was classified as both the largest recipient of FDI and the most outward-investing economy during the last decade (see Appendix Table A1).

Besides contributing to the USA's primacy in global ranks, both inward and outward FDI seem to play a significant role in supporting the US economy (Kornecki, 2014). For example, Goss et al. (2007) estimate that foreign-owned capital accounted for 16% of the overall US productivity growth during the 1990s, while Payne and Yu (2011) underline the contribution of foreign-owned firms to employment, job creation and high wages in the USA. Similarly, Slaughter (2010) and Jackson (2017) suggest that outward FDI contributes to the US economy in terms of employment, output, capital investment, exports and R&D activity through increases in the performance of US parent companies which are driven by their foreign affiliates.

In particular, the evidence of a strict relationship between FDI and R&D activity is presented in Appendix Figure A2, which shows the dynamics of business R&D expenditure in the USA in the aftermath of the Great Recession. For example, 16% of the R&D activity performed by US businesses in 2012 can be ascribed to subsidiaries of foreign MNEs, while 77% can be ascribed to US parent companies, for which foreign affiliates' R&D activity amounted to approximately US$ 45 billion (NSB, 2016).

R&D represents one of the main drivers of the innovative capacity of firms, regions and countries, and this holds true in particular for the USA. Jaffe (1989), Acs et al. (1992), Acs et al. (2002) and Crescenzi and Rodríguez-Pose (2013), among others, underline both the importance of R&D as an input for the production of innovation in the USA, as well as how R&D differentials help to explain differences in innovativeness across US localities, at both state and sub-state level.

In this respect, the literature also provides evidence on the existence of a strong spatial heterogeneity in terms of innovation − mainly captured by patent measures − within the USA (Carlino et al., 2007; Crescenzi et al., 2007; Usai, 2011). This is evidenced in Appendix Figure

A3, which maps the spatial distribution of PCT patents over the 2004-2013 period, clearly highlighting a phenomenon of spatial concentration in terms of innovative performance.

For example, Crescenzi and Rodríguez-Pose (2013) show that the 35% of all US patenting over the 1994-2007 period was concentrated in the top five innovative EAs. Using a similar measure of patenting and the same geographic level of aggregation, a very similar result emerges considering the subsequent 2007-2013 period: the top five most innovative EAs concentrated 40.1% of all PCT patents ascribable to the USA.[2]

In addition, there is evidence of a strong spatial concentration also in terms of inward and outward FDI. The top ten innovative EAs, identified over the 2010-2013 period, concentrated over the previous 2007-2009 period a share of inward greenfield FDI ranging from 31% to 42%, and a share of outward greenfield FDI ranging from 56% to 60%. Greenfield investment projects realized over the 2007-2009 period by US-based companies across US EAs are also characterized by high levels of concentration: the share of inward US domestic investments concentrated in the top ten innovative EAs ranges from 18% to 19%, while the share of outward US investments ranges from 30% to 46% (see Appendix Table A2).[3]

This evidence suggests a clear pattern characterizing regional connectivity of US EAs and their innovative performance. Specifically, the best performing regions in terms of innovative behavior have also been highly connected with other domestic and foreign territories. In other words, regions with good innovative capacity are also highly involved in trans-local 'pipelines' at both national and global level.

Finally, a more in-depth look at the 'dimensions' of US regional connectivity through greenfield direct investments over the 2007-2009 period shows that 38% of inward investment

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[2] A similar figure emerges when considering USPTO patents. In this case, the top five EAs concentrated 40.3% of all USPTO patents ascribable to the USA. In addition, four of the top five innovative EAs are included in both the USPTO and PCT figures.

[3] Data on brand new greenfield investments drawn from the *fDi Markets* database (Financial Times) are used due to the absence of official statistics available at the EA level.

projects are of foreign origin, while foreign investments represent 69% of outward investment projects. Indeed, 105 of the 179 US EAs have been involved in both domestic and foreign inward and outward investments, while only three EAs reported zero investments. Focusing on the 176 EAs which have shown some kind of extra-regional connections, a variegated picture emerges: 82 regions recorded more inward US domestic investments than any other type, 39 regions recorded more outward US domestic investments, 13 regions recorded more inward foreign investments, and 42 regions recorded more outward foreign investments. Overall, this preliminary evidence suggests that US EAs have shown very different patterns of regional connectivity, both in terms of spatial extent and direction of the extra-regional 'pipelines'.

4. Empirical framework

4.1. Data

The data used in the empirical analysis are drawn from several sources. Regional patent data are drawn from the *PatentsView* database and the *REGPAT* database provided by the USPTO and the OECD, respectively. While USPTO patents present a more domestic nature, PCT patents can be considered as 'worldwide patent applications' (OECD, 2009). Thus, the use of both types of patent data allows one to provide a more comprehensive analysis of the national vs. global extent of extra-regional connections by comparing the more 'domestic' vs. 'international' innovative returns of investments.

Data on inward and outward investments are drawn from the Financial Times' *fDi Markets* database, which provides information on brand new greenfield investment projects in terms of set up year, source and destination region, industrial sector at the two-digit level of the

North American Industry Classification System (NAICS) and business activity.[4] The *fDi Markets* database presents two main limitations: first, it only collects information on greenfield investments, excluding data on other types of investments; second, it collects information on planned future investments, although regular updates of the database mitigate this second issue because investment projects which have not been completed are deleted from the database. However, it presents significant advantages, at least for the purposes of this paper. The data collected for the US economy includes both purely foreign investments, i.e., investment projects realized by US companies outside the USA and realized by non-US companies in the US territory, and intra-US domestic investments, i.e., investment projects realized by US companies across US states. In addition, the geographic information on the source and destination territory of the investments are available at the county level: this allows one to identify US domestic investments realized across different EAs.[5]

Data on private firms' R&D expenditure, sales and geographic location are drawn from the North American firm-level *COMPUSTAT* database provided by Standard and Poor's Corporation.[6] Data on regional human capital are drawn from the *American Community Survey*, and are elaborated by the US Census Bureau's Population Estimates Program. Population data are drawn from the *American Community Survey*, while data on personal income and sectoral employment are provided by the US Bureau of Economic Analysis (BEA). Due to data restrictions, the empirical exercise focuses on the 2007-2013 short-run period.

[4] The *fDi Markets* database classifies business activities as follows: business services; construction; customer contact center; design, development and testing; education and training; electricity; extraction; headquarters; ICT and Internet infrastructure; logistics, distribution and transportation; maintenance and servicing; manufacturing; recycling; research and development; retail; sales, marketing and support; shared services center; technical support center. See Appendix Tables A3 and A4 for the distribution of investment projects by two-digit NAICS sector and business activity, respectively.

[5] Moreover, the reliability of the database is supported by the large number of empirical works which have used it (e.g., Crescenzi et al., 2014; Castellani and Pieri, 2016; Crescenzi et al., 2022b).

[6] The use of R&D firm-level data is due to the absence of official R&D regional statistics for the US. Although private firms' R&D expenditure represents only a proxy for a region's R&D endowment, similar measures have been employed in the analysis of sub-national innovative dynamics in the US (e.g., Feldman, 1994; Crescenzi and Rodríguez-Pose, 2013).

4.2. Empirical modeling

The empirical analysis is based on the knowledge production function (KPF) framework originally proposed by Griliches (1979) in the context of firm-level studies, and subsequently largely employed to analyze the innovation-FDI nexus at the regional level. The aim of the analysis is to provide a descriptive comparison between inward and outward US domestic, inter-state investments vs. FDI, and to assess whether a potential statistical association exists between regional connectivity − here proxied by inward and outward investments − and the innovative performance of US EAs in order to test our three hypotheses.

As a preliminary exercise, a cross-sectional augmented regional KPF-type equation is specified to evaluate regional profiles of connectivity. Specifically, US EAs are split into five categories according to the monetary value of the investments received and realized over the 2007-2009 period. The first category includes regions which neither received nor realized investments, either domestically or abroad; the second category includes regions which recorded the greatest value of investments associated with inward domestic projects; the third category includes regions which recorded the greatest value of investments associated with outward domestic projects; the fourth category includes regions which recorded the greatest value of investments associated with inward foreign projects; finally, the fifth category includes regions which recorded the greatest value of investments associated with outward foreign projects. Thus, the following empirical equation is specified:

$$\log\left(Patent_{r,t}\right) = \alpha + \beta Investment\ Profile_{r,t-1} + \sum_{d=1}^{D} \gamma_d Controls_{r,t-1}^{d} + \boldsymbol{\zeta}_s + \varepsilon_{r,t} \quad (1)$$

where the dependent variable ($Patent_{r,t}$) denotes the fractional number of patents − either granted under the USPTO or filled under the PCT, and regionalized by inventors' residence −

per 100,000 inhabitants in EA $r = 1, \ldots, 179$ over the 2010-2013 period. The term $Investment\ Profile_{r,t-1}$ refers to the categorical variable defined before, which classifies EAs into five different profiles of extra-regional connectivity. The baseline category for the Ordinary Least Squares (OLS) estimation of Equation (1) corresponds to the regional profile 'neither domestic nor foreign, neither inward nor outward' investments. The vector $Controls^{d}_{r,t-1}$ includes: a measure of R&D, defined as percentage of R&D expenditure over sales performed by US private firms in EA r over the 2007-2009 period; a measure of human capital, defined as the percentage of US population aged 18 or more with at least a bachelor degree in EA r in year 2009; a variable capturing the number of (either USPTO or PCT) patents per 100,000 inhabitants in EA r over the 2007-2009 period; three sectoral controls defined for the year 2009, namely a Herfindahl-Hirschman Index (HHI) defined at the two-digit level of the NAICS, the share of manufacturing employees over total employment, and the share of services employees over total employment.[7] The terms ζ_s denotes a vector of state dummy variables, while ε_{rt} is the error term.[8]

The second step of the empirical analysis aims at providing a more comprehensive description of patterns of association between regional connectivity and innovation. To this aim, Equation (1) is modified by replacing the EA-level investment profile variable ($Investment\ Profile_{r,t-1}$) with the vector $Investments^{c}_{r,t-1}$, which includes four variables capturing inward and outward new greenfield US domestic direct investments and FDI defined in percentage terms as monetary value of the investments over personal income in EA r over the 2007-2009 period. Therefore, Equation (2) is specified as follows:

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[7] Data on human capital at the county level to be aggregated at the EA level are available starting from the year 2009.

[8] Appendix Table A5 presents preliminary estimates of a baseline KPF equation used to identify the R&D input. As the variable for human capital is available only for the year 2009, the KPF has been estimated using the R&D variable defined for the year 2009 and the 2007-2009 period alternatively. The results obtained with respect to both USPTO and PCT patents suggest a negligible coefficient of the 2009 R&D variable, but a positive and statistically significant coefficient of the R&D variable defined over the 2007-2009 period. This exercise has guided the choice to include the 2007-2009 R&D variable in the main empirical analysis.

$$\log\left(Patent_{r,t}\right) = \alpha + \sum_{c=1}^{C} \beta_c Investments_{r,t-1}^{c} + \sum_{d=1}^{D} \gamma_d Controls_{r,t-1}^{d} + \boldsymbol{\zeta}_s + \varepsilon_{r,t} \quad (2)$$

and is estimated via OLS.[9]

As the empirical exercise aims at providing a comparison, although descriptive in nature, between US domestic, inter-state investments vs. FDI, the four EA-specific variables entering the vector $Investments_{r,t-1}^{c}$ in Equation (2) have been constructed also considering sub-sets of US domestic vs. foreign individual investment projects with the same 'structural' characteristics, besides the true population of investments. To this aim, a preliminary one-to-one, exact matching procedure with random sampling has been performed on the sets of individual inward (outward) US domestic and foreign investment projects at the US level, i.e., before aggregating them at the EA level. Thus, the matching strategy is adopted in order to derive exactly the same profile of inward (outward) US domestic and foreign investments that have been set up in the USA (abroad) over the 2007-2009 period. In this respect, two matching criteria have been adopted: the first one considers 'structural' characteristics of individual investments in terms of two-digit NAICS sector and business activity; the second one considers a third dimension, namely the low or high level of innovativeness of the source (destination) territory of the inward (outward) investment. Specifically, inward (outward) US domestic investments are defined as low- or high-innovative according to the level of innovativeness of the EAs setting up (receiving) the investments, and the level of innovativeness of an EA is defined by considering its share of PCT patents filed over the 2000-2009 period with respect to the US total. Similarly, inward (outward) foreign investments are defined as low- or high-innovative according to the level of innovativeness of the countries setting up (receiving) the

[9] Appendix Table A6 presents the correlation coefficients between the USPTO and PCT dependent variables and the set of explanatory variables. Appendix Table A7 presents some descriptive statistics of the variables entering Equations (1) and (2), while Appendix Table A8 reports the correlation matrix of the explanatory variables.

FDI, and the level of innovativeness of a country is defined by considering its share of PCT patents filed over the 2000-2009 period with respect to the world total excluding the USA.[10]

The one-to-one, exact matching procedure with random sampling has been performed separately for inward and outward investment projects as follows. First, individual inward (outward) US domestic investments have been matched with individual inward (outward) foreign investments in the same two-digit NAICS sector and business activity pair. Second, a random sampling procedure has been performed in order to pick one-to-one matched pairs of inward (outward) US domestic and foreign investments. Finally, individual randomly-sampled matched investments have been aggregated at the EA level in order to construct the four variables entering the vector $Investments^{c}_{r,t-1}$ in Equation (2). The same procedure has been performed considering as matching criterion the triplet defined by two-digit NAICS sector, business activity, and low vs. high level of innovativeness of source – for inward – and destination – for outward – territory.

Appendix Table A9 presents the distribution of greenfield direct investments recorded over the 2007-2009 period by domestic vs. foreign nature, and by direction. Although the one-to-one matching approaches cause a substantial drop in the number of investment projects, it allows one to identify sets of investments which are identical in terms of economic sector, business activity, and innovativeness of the source/destination territory, thus allowing for a clearer analysis of the spatial (national vs. global) extent of extra-regional connections.[11]

[10] The choice of using only PCT patents to classify EAs and extra-regional connected territories (i.e., the EAs and the countries sourcing and receiving investments) is motivated by the international nature of PCT patents and the standardized procedure used to evaluate applications (Khan and Dernis, 2005). This facilitates the comparison among geographically different territories.

[11] It is worth underline that the two matching procedures not only lead to the identification of highly homogenous profiles of inward (outward) US domestic vs. foreign investments, but also reduce differences between the sets of inward (outward) US domestic and foreign investments in terms of monetary value. Indeed, as shown in Appendix Table A10, the mean difference in monetary value between the sets of inward (outward) US domestic and foreign investments becomes statistically negligible when considering the sub-sets of matched investment projects.

5. Empirical results

5.1. Preliminary evidence: regional profiles of connectivity

Table 1 synthesizes the key results of the OLS estimation of Equation (1). Specifically, it reports the estimated coefficients referring to the regional investment profiles captured by the variable $Investment\ Profile_{r,t-1}$, and the base category refers to EAs which recorded zero investments over the 2007-2009 period. The comparison of the results obtained with respect to USPTO and PCT patents offers two relevant preliminary insights. First, when considering the most valuable and radically innovative PCT patents, it is foreign connectivity that matters the most vs. domestic connections of all types, offering initial support for Hypothesis #1. Second it is 'active' – rather than 'passive' – internationalization that matters the most in the short-run, offering initial support for Hypothesis #2. Exploitation of trans-local 'pipelines' through outward investments is associated with a relatively higher level of patenting. Interestingly, more domestic USPTO patenting is positively associated with both US domestic and foreign investments, while international PCT patenting is positively associated with foreign outward investments only.

This preliminary evidence helps to shed light on the patterns of association between regional connectivity and innovation. In particular, it highlights how different regional strategies of trans-local connections are associated with different innovative behaviors in the aftermath of a global shock.

Table 1: Regional profiles of connectivity.

Spatial Extent of Investments	Patent Office			
	USPTO		PCT	
	Direction of Investments		Direction of Investments	
	Inward	Outward	Inward	Outward
US domestic	0.5012	0.8034**	0.5866	0.8574
	(0.3165)	(0.3562)	(0.5148)	(0.5422)
Foreign	0.4962	1.0640***	0.6103	1.2185**
	(0.3293)	(0.3770)	(0.5394)	(0.5559)

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. Robust standard errors in parentheses. Coefficients refer to four possible categories of regional connectivity, and the base category for the OLS estimations (run separately for USPTO and PCT patents) is 'neither domestic nor foreign, neither inward nor outward'. The other categories are: 'more domestic than foreign, more inward than outward'; 'more domestic than foreign, more outward than inward'; 'more foreign than domestic, more inward than outward'; 'more foreign than domestic, more outward than inward'. Both specifications include EA-specific innovation inputs and control variables, as well as State dummies. The R^2 equals 0.87 for the USPTO regression and 0.89 for the PCT regression.

5.2. Regional connectivity and innovation

Table 2 synthesizes the results of the OLS estimation of Equation (2), and reports the estimated elasticities of the variables for inward and outward US domestic and foreign investments. Specifically, the true population of investments is used to construct the EA-specific investment variables considered in specifications (1) and (2); the sub-sets of matched investments defined with respect to the two-digit NAICS sector-business activity pair criterion are used to construct the EA-specific investment variables considered in specifications (3) and (4); finally, the sub-sets of matched investments defined with respect to the triplet made by two-digit NAICS sector, business activity, and innovativeness of source/destination territory are used to construct the EA-specific investment variables considered in specifications (5) and (6).

The results confirm the previous descriptive findings. In the aftermath of the Great Recession, regions are better off when they 'actively search' for new knowledge sources outside their regional boundaries (i.e., through outward investments). In particular, a positive and statistically significant association emerges between outward investments and patenting independently of the spatial extent of connections, confirming Hypothesis #2.

However, it should be noted that the estimated elasticity referring to truly global 'pipelines' (i.e., outward FDI) is both larger in magnitude and more significant than the elasticity referring to national ‘pipelines’ (i.e., US domestic investment) in four out of six specifications, independently of the type of patent and the set of investment projects considered, thus providing overall support for Hypothesis #1.

Therefore, it clearly emerges how trans-local connections matter for regions to identify new knowledge sets to be exploited in order to move towards new innovation-driven competitive strategies. However, the results also suggest that only the proactive search of *ad hoc* inputs outside regional boundaries matters, and that this process of knowledge acquisition tends to be magnified by the global extent of connections.

Table 2: Spatial extent and directionality of regional connectivity.

Dependent Variable	$\log(\text{Patent}_{r,t})$					
Preliminary Matching on Individual Investments						
NAICS Sector and Business Activity	No		Yes		Yes	
Innovative Congruence of Source/Destination Region	No		No		Yes	
Patent Office	USPTO	PCT	USPTO	PCT	USPTO	PCT
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Inward US Investments}_{r,t-1}$	0.0038	-0.0040	0.0054	0.0072	0.0006	0.0011
	(0.0095)	(0.0145)	(0.0040)	(0.0043)	(0.0030)	(0.0050)
$\text{Outward US Investments}_{r,t-1}$	0.0222***	0.0193*	0.0179*	0.0216*	0.0453***	0.0358*
	(0.0075)	(0.0101)	(0.0096)	(0.0121)	(0.0139)	(0.0207)
$\text{Inward FDI}_{r,t-1}$	-0.0010	-0.0030	-0.0017	-0.0022	-0.0027	-0.0037
	(0.0056)	(0.0076)	(0.0036)	(0.0060)	(0.0035)	(0.0053)
$\text{Outward FDI}_{r,t-1}$	0.0294****	0.0334****	0.0305****	0.0319****	0.0217****	0.0248****
	(0.0072)	(0.0080)	(0.0069)	(0.0077)	(0.0054)	(0.0069)
Innovation Inputs	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
State Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of EAs	179	179	179	179	179	179
R^2	0.893	0.896	0.893	0.899	0.903	0.898
H_0: Homoskedasticity (p-value)	0.094	0.078	0.040	0.021	0.017	0.015

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. Robust standard errors in parentheses.

The evidence presented until this point has exclusively considered two of the three dimensions of regional connectivity previously discussed, i.e., the spatial extent and the direction of connectivity. However, the third dimension concerning the congruence between the interconnected territories is likely to play a key role in understanding the association between regional connectivity and innovation. In fact, in order for knowledge to flow along trans-local ‘pipelines’ and, more importantly, contribute to a region’s renewal process in the aftermath of a global shock, it is required that the source and destination territories of the flow present some form of congruence in terms of technological capabilities to facilitate timely knowledge acquisition, transformation and use.

To this aim, and in order to test Hypothesis #3, each of the four variables capturing inward and outward US domestic and foreign investment is split into two variables capturing the level of innovativeness of the source/destination territories of the inward/outward investments. Following the same operationalization approach presented before in the context of matching, inward (outward) US domestic investments are grouped at the EA level according to the level of innovativeness of the EA setting up (receiving) the investments, and, similarly, inward (outward) foreign investments are grouped at the EA level according to the level of innovativeness of the countries setting up (receiving) the FDI. Moreover, in order to investigate the role played by innovative congruence between source and destination EAs and countries, the regression equation is augmented by a series of interaction terms between a dummy variable capturing the low- or high-innovative status of an EA and each of the eight EA-specific investment variables.

Table 3 reports the elasticities obtained from the OLS estimation of the modified version of Equation (2). Specifically, the true population of investments is used to construct the EA-specific investment variables considered in specifications (1) to (4), while the sub-sets of matched investments defined with respect to the triplet made by two-digit NAICS sector, business activity, and innovativeness of source/destination territory are used to construct the EA-specific investment variables considered in specifications (5) and (8).

Table 3: Spatial extent and direction of regional connectivity: innovativeness of source/destination regions/countries and EA patenting heterogeneity.

Dependent Variable	$\log(\text{Patent}_{r,t})$							
Preliminary Matching on Individual Investments								
NAICS Sector and Business Activity	No				Yes			
Innovative Congruence of Source/Destination Region	No				Yes			
Patent Office	USPTO		PCT		USPTO		PCT	
Innovativeness	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inward US $\text{Investments}_{r,t-1}$ – HIEA	-0.0004	0.0129	-0.0162	0.0200**	-0.0049	0.0004	-0.0266	0.0030
	(0.0170)	(0.0082)	(0.0211)	(0.0099)	(0.0161)	(0.0025)	(0.0335)	(0.0033)
Outward US $\text{Investments}_{r,t-1}$ – HIEA	0.0235**	0.0342***	0.0118	0.0284*	0.0294	0.0323**	-0.0055	0.0246*
	(0.0099)	(0.0113)	(0.0146)	(0.0153)	(0.0394)	(0.0130)	(0.0572)	(0.0146)
Inward US $\text{Investments}_{r,t-1}$ – LIEA	0.0038	0.0007	-0.0020	-0.0039	0.0020	-0.0020	0.0017	-0.0018
	(0.0030)	(0.0068)	(0.0057)	(0.0092)	(0.0044)	(0.0033)	(0.0029)	(0.0028)
Outward US $\text{Investments}_{r,t-1}$ – LIEA	-0.0014	-0.0004	0.0058	0.0017	0.0091	0.0024	0.0067	0.0027
	(0.0038)	(0.0071)	(0.0053)	(0.0078)	(0.0109)	(0.0028)	(0.0101)	(0.0027)
Inward $\text{FDI}_{r,t-1}$ – HIC	-0.0002	-0.0188	-0.0023	-0.0152	-0.0018	-0.0221	-0.0026	-0.0240
	(0.0060)	(0.0189)	(0.0081)	(0.0219)	(0.0045)	(0.0219)	(0.0065)	(0.0308)
Outward $\text{FDI}_{r,t-1}$ – HIC	0.0160	0.0160*	0.0238	0.0219**	0.0362	0.0185**	0.0336	0.0218**
	(0.0420)	(0.0096)	(0.0385)	(0.0098)	(0.0221)	(0.0089)	(0.0227)	(0.0109)
Inward $\text{FDI}_{r,t-1}$ – LIC	-0.0024	0.0018	0.0010	0.0021	-0.0013	0.0012	0.0010	0.0013
	(0.0016)	(0.0016)	(0.0027)	(0.0020)	(0.0011)	(0.0013)	(0.0018)	(0.0014)
Outward $\text{FDI}_{r,t-1}$ – LIC	0.0140	0.0023	0.0165**	0.0021	-0.0041	0.0013*	0.0098	0.0011
	(0.0084)	(0.0021)	(0.0079)	(0.0027)	(0.0387)	(0.0007)	(0.0219)	(0.0009)
Innovation Inputs	Yes		Yes		Yes		Yes	
Control Variables	Yes		Yes		Yes		Yes	
State Dummies	Yes		Yes		Yes		Yes	
Number of EAs	179		179		179		179	
R^2	0.915		0.918		0.914		0.914	
H_0: Homoskedasticity (p-value)	0.011		0.024		0.004		0.004	

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. Robust standard errors in parentheses. Low and high levels of EA patenting are defined around the median value of the distribution of the EAs' share of PCT patents filled over the 2000-2009 period with respect to the US total. The median value is chosen as the skewness test rejects the null hypothesis of normality with p-value equal to 0.000. The dummy variable for EA patenting takes value 1 if an EA has a value above the median, while it takes value 0 if an EA has a value below or equal to the median. There are 90 (89) EAs with low (high) value of patenting. The dummy variable for EA patenting is interacted with all investment variables. HIEA stands for high-innovative EA; LIEA stands for low-innovative EA; HIC stands for high-innovative country; LIC stands for low-innovative country. Source/destination regions/countries are defined as high- or low-innovative with respect the distribution of their share of PCT patents filled over the 2000-2009 period. The total value for EAs reflects the US total. The total value for countries is the world total excluding the US.

The results suggest that, first, inward regional connectivity seems to remain negligible as a channel for regions to access new knowledge, with the only exception being inward US domestic investments originating from highly innovative EAs and realized in highly innovative EAs. However, the estimated elasticity turns out to be statistically significant with respect to the most advanced and innovative PCT patents. Second, US domestic investments to highly innovative EAs seem to matter only for high-innovative sourcing EAs. Third, the role of a proactive search of new knowledge is further reinforced looking at outward FDI to high-innovative countries, that seem to matter only for high-innovative sourcing EAs.

The results presented in Table 3 confirm Hypothesis #2, while do not confirm Hypothesis #1. Moreover, Hypothesis #3 is only partially confirmed: in fact, it seems that innovative congruence matters, but only between high-innovative source and destination regions/countries. On the contrary, trans-local connectivity through either domestic or foreign direct investments does not seem to be associated with the innovativeness of low-innovation EAs in the aftermath of a global shock, independently from the low- or high-innovative level of the source – for inward – and destination – for outward – territory.

6. Conclusion and discussion

The economic literature has widely emphasized the benefits arising from international openness and economic integration. However, recent events – ranging from the COVID-19 pandemic to the war in Ukraine – are undermining the future of these processes. This affects the possibility of regions and local productive systems exploiting the global dimension of trans-local 'pipelines' to access new and valuable inputs not available locally in order to identify and explore new competitive strategies and development trajectories in response to the same shocks.

This paper contributes to the debate on the responses to globalization shocks by exploring the role of regional connectivity in shaping the response to the Great Recession. Specifically, it provides an innovative comparative − although descriptive − analysis of inward and outward US domestic direct investments vs. FDI and the innovative performance of US EAs over the short-run, post-crisis period. The paper aims to provide some preliminary evidence on how the different dimensions characterizing regional connectivity − namely, the spatial (national vs. global) extent of connectivity, the directionality (inward vs. outward) of connectivity, and the innovative congruence among the connected territories − interact with the innovative behavior of regions in the aftermath of a major shock.

Three key results emerge as lessons from the Great Recession. First, truly global connectivity is key to 'innovate out' of any crisis. Domestic inter-regional connections are no substitute for global connectivity. Second, a proactive search for new knowledge through outward investments is associated with more innovative regions in the post-shock period. This is the case, in particular, for the production of international PCT patents that capture most radical innovation new to the world. Third, the innovative congruence among connected territories matters for regions to successfully exploit extra-regional connections. This means that it is not the establishment of trans-local 'pipelines' per se that matters for a region, but the identification of appropriate knowledge-generating places to connect with.

The empirical results presented in this paper have to be taken with caution and, particularly, should not be interpreted as causality effects. In fact, the paper aims at detecting patterns of association between regional connectivity and short-term innovative behavior in order to highlight the complexity of trans-local connections and, by no means, seeks to quantify the effect of domestic or foreign investments on regional innovation outcomes. In addition, the empirical exercise is limited by the unavailability of detailed data to capture the different modes of regional connectivity. Greenfield FDI represents only one possible channel for regions to connect, and it operates jointly with several other forms of networking, such as trade, human capital migration, sub-contracting, joint ventures, mergers and acquisitions. Therefore, the contribution of this paper should be read as purely descriptive of some of the dynamics characterizing trans-local 'pipelines' in the context of US regions. The possibility to address the main limitations of this paper remains in the agenda for future research.

Having acknowledged these relevant caveats, our results should stimulate a wider reflection on the future challenges to local innovation systems in the recovery phase following the COVID-19 pandemic. Regional innovation systems where local actors can leverage global outward connectivity are in a strong position to reinvent themselves in the new economic order. However, the reconfiguration of geo-political equilibria and the corresponding internationalization (or re-nationalization/reshoring) policies can ultimately jeopardize this possibility with adverse overall consequences on technological development. In the 'dark hour' of the pandemic, we desperately sought more ventilators for our hospitals. The EU and US innovation systems responded to the challenge almost immediately. The unprecedented rapidity of vaccine development across multiple competing research centers in both Continents is another testimony of the response capabilities of many national and regional innovation systems. For these systems to function effectively, a vaccine against isolation and global disconnect seems the most urgent input 'recovery' policies should deliver. Sadly, there seems to be limited appetite for this option in policy debates given growing geo-political tensions and conflicts, making compelling evidence from the recent past more relevant than ever before.

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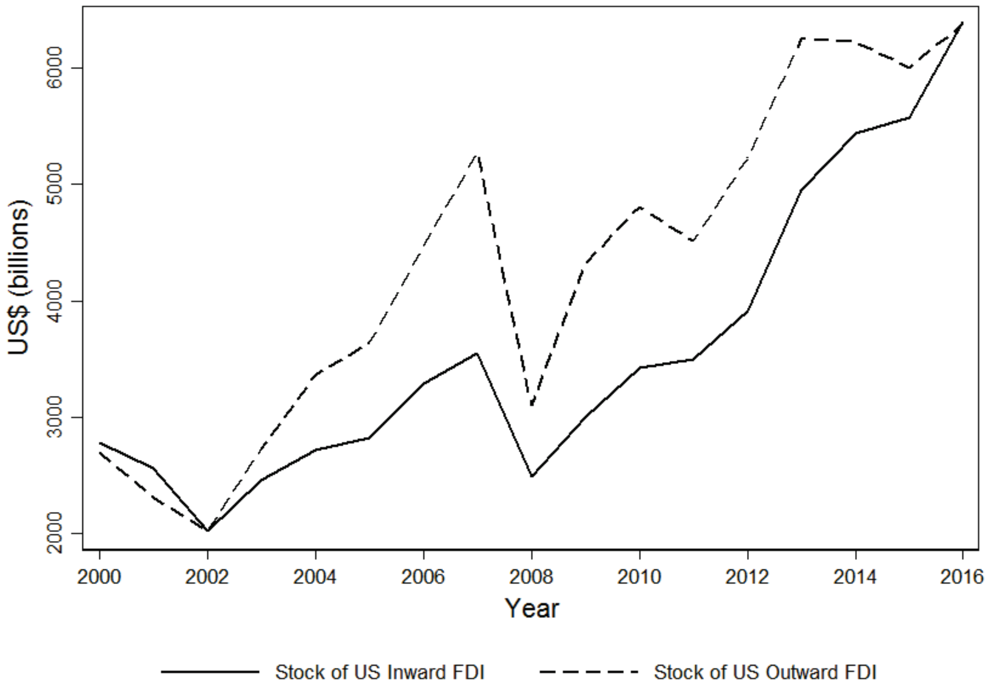
APPENDIX

Figure A1: Inward and outward FDI in the USA, 2000-2016.



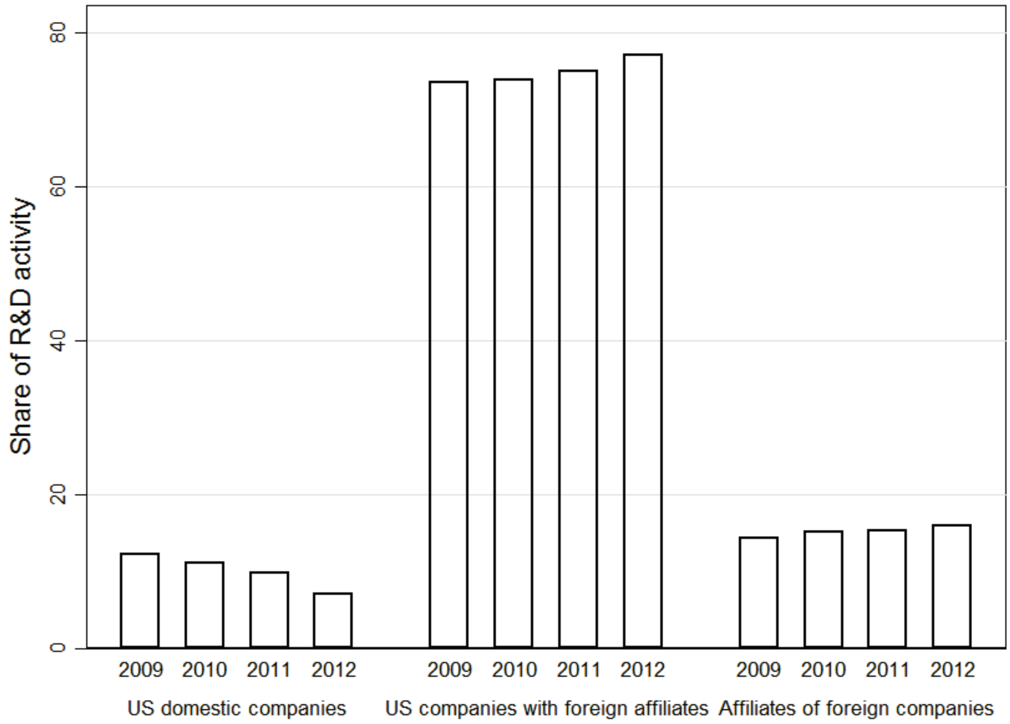
Notes: Authors' elaboration on UNCTAD data.

Table A1: FDI top performing countries.

Inward FDI Stock		Outward FDI Stock	
2006	2016	2006	2016
USA (23.37)	USA (23.91)	USA (29.79)	USA (24.40)
United Kingdom (7.35)	People's Republic of China (11.02)	United Kingdom (9.75)	People's Republic of China (10.74)
Germany (5.67)	United Kingdom (4.48)	Germany (6.57)	United Kingdom (5.52)

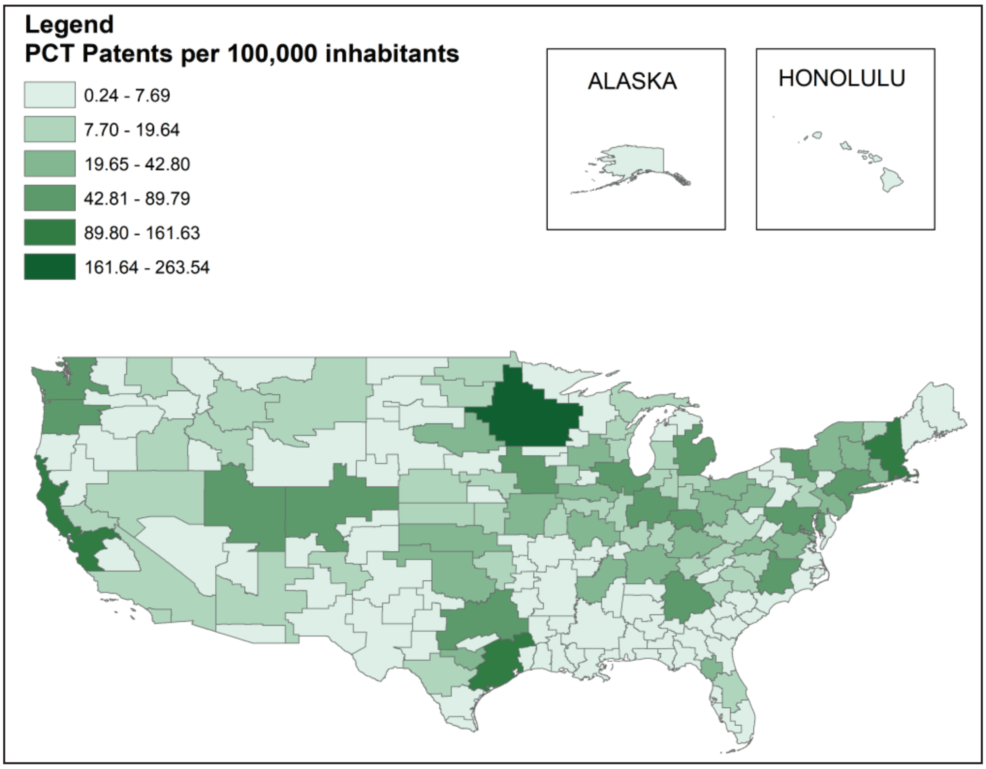
Notes: People's Republic of China includes Hong Kong. Percentages on world's total in parentheses. Authors' elaboration on UNCTAD data.

Figure A2: Dynamics of R&D activity in the USA by type of business.



Notes: Authors' elaboration on data collected by the National Science Board (NSB 2016). A firm is defined as a foreign affiliate if more than 50% of its capital is owned by a parent company.

Figure A3: Geographic distribution of PCT patens in US EAs, 2004-2013.



Notes: Authors' elaboration on data provided by the Organization for Economic Cooperation and Development (OECD) and the US Bureau of Economic Analysis (BEA). Average values over the 2004-2013 period.

Table A2: Top ten innovative EAs and spatial concentration of greenfield investment projects.

Dimensions	Top 10 Innovative EAs (2010-2013)	
	USPTO	PCT
Patents (number, 2010-2013)	55.44	58.25
Patents (number, 2007-2009)	53.64	57.45
Inward FDI (US$, 2007-2009)	42.17	31.18
Outward FDI (US$, 2007-2009)	59.87	55.92
Inward US Investments (US$, 2007-2009)	19.31	18.24
Outward US Investments (US$, 2007-2009)	30.47	46.40
Personal Income (US$, 2009)	39.06	36.54
Population (number, 2009)	32.45	33.46

Notes: Percentage values on US totals. Inward (outward) FDI refers to greenfield investment projects realised by foreign companies (US companies) in US EAs (other countries). Inward (outward) US investments are greenfield investment projects realised by US-based companies across US EAs. Authors' elaboration on patent data drawn from the *PatentsView* database (USPTO) and *REGPAT* database (OECD); on greenfield investment data drawn from the *fDi Markets* database (Financial Times); and on US BEA data.

Table A3: Distribution of investment projects by two-digit NAICS sector.

Two-Digit NAICS Sector	US Domestic Investments		FDI			
			Inward		Outward	
	No.	%	No.	%	No.	%
11 – Agriculture, Forestry, Fishing, Hunting	2	0.05	3	0.13	9	0.11
21 – Mining, Quarrying, Oil and Gas Extraction	20	0.54	14	0.63	92	1.13
22 – Utilities	139	3.75	56	2.52	147	1.80
23 – Construction	75	2.03	14	0.63	168	2.06
31 – Manufacturing	109	2.94	77	3.46	296	3.63
32 – Manufacturing	300	8.10	225	10.12	646	7.92
33 – Manufacturing	532	14.37	670	30.13	1,794	22.00
42 – Wholesale Trade	4	0.11	0	0.00	1	0.01
44 – Retail Trade	47	1.27	185	8.32	437	5.36
45 – Retail Trade	27	0.73	4	0.18	39	0.48
48 – Transportation, Warehousing	52	1.40	19	0.85	53	0.65
49 – Transportation, Warehousing	167	4.51	49	2.20	210	2.57
51 – Information	429	11.59	342	15.38	1,673	20.51
52 – Finance, Insurance	728	19.67	186	8.36	676	8.29
53 – Real Estate, Rental, Leasing	66	1.78	63	2.83	123	1.51
54 – Professional, Scientific, Technical Services	604	16.32	207	9.31	1,027	12.59
56 – Administrative and Support and Waste Management and Remediation Services	174	4.70	48	2.16	302	3.70
61 – Educational Services	42	1.13	9	0.40	78	0.96
62 – Health Care and Social Assistance	122	3.30	20	0.90	34	0.42
71 – Arts, Entertainment, Recreation	6	0.16	11	0.49	48	0.59
72 – Accommodation and Food Services	57	1.54	22	0.99	303	3.72
Total	3,702	100.00	2,224	100.00	8,156	100.00

Notes: Percentage values on column totals. Sector 31 includes: food manufacturing; beverage and tobacco product manufacturing; textile mills; textile product mills; apparel manufacturing; leather and allied product manufacturing. Sector 32 includes: wood product manufacturing; paper manufacturing; printing and related support activities; petroleum and coal products manufacturing; chemical manufacturing; plastics and rubber products manufacturing; non-metallic mineral product manufacturing. Sector 33 includes: primary metal manufacturing; fabricated metal product manufacturing; machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance and component manufacturing; transportation equipment manufacturing; furniture and related product manufacturing; miscellaneous manufacturing. Sector 44 includes: motor vehicle and parts dealers; furniture and home furnishings stores; electronics and appliance stores; building material and garden equipment and supplies dealers; food and beverage stores; health and personal care stores; gasoline stations; clothing and clothing accessories stores. Sector 45 includes: sporting goods, hobby, musical instrument, and book stores; general merchandise stores; miscellaneous store retailers; non-store retailers. Sector 48 includes: air transportation; rail transportation; water transportation; truck transportation; transit and ground passenger transportation; pipeline transportation; scenic and sightseeing transportation; support activities for transportation. Sector 49 includes: postal service; couriers and messengers; warehousing and storage.

Table A4: Distribution of investment projects by business activity.

Business Activity	US Domestic Investments		FDI			
			Inward		Outward	
	No.	%	No.	%	No.	%
Business Services	1,410	38.09	395	17.76	1,448	17.75
Construction	132	3.57	39	1.75	411	5.04
Customer Contact Centre	98	2.65	23	1.03	123	1.51
Design, Development, Testing	96	2.59	73	3.28	523	6.41
Education and Training	47	1.27	18	0.81	143	1.75
Electricity	45	1.22	24	1.08	54	0.66
Extraction	10	0.27	3	0.13	68	0.83
Headquarters	145	3.92	244	10.97	476	5.84
ICT and Internet Infrastructure	107	2.89	28	1.26	169	2.07
Logistics, Distribution, Transportation	385	10.40	113	5.08	297	3.64
Maintenance and Servicing	46	1.24	22	0.99	70	0.86
Manufacturing	517	13.97	335	15.06	971	11.91
Recycling	26	0.70	10	0.45	17	0.21
Research and Development	37	1.00	37	1.66	190	2.33
Retail	0	0.00	253	11.38	765	9.38
Sales, Marketing, Support	561	15.15	598	26.89	2,295	28.14
Shared Services Centre	15	0.41	4	0.18	57	0.70
Technical Support Centre	25	0.68	5	0.22	79	0.97
Total	3,702	100.00	2,224	100.00	8,156	100.00

Notes: Percentage values on column totals.

Table A5: Baseline regional knowledge production function.

Dependent Variable	$\log(\text{Patent}_{r,t})$			
Patent Office	USPTO		PCT	
	(1)	(2)	(3)	(4)
$\text{Human Capital}_{r,2009}$	0.1154***	0.0937**	0.1222***	0.0972**
	(0.0397)	(0.0399)	(0.0409)	(0.0410)
$\text{R\&D}_{r,2009}$	0.0627	…	0.0751	…
	(0.0617)		(0.0636)	
$\text{R\&D}_{r,t-1}$	…	0.2256**	…	0.2631***
		(0.0977)		(0.1002)
State Dummies	Yes	Yes	Yes	Yes
Number of EAs	179	179	179	179
R^2	0.495	0.515	0.514	0.539
H_0: Homoskedasticity (p-value)	0.850	0.578	0.567	0.786

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. Standard errors in parentheses.

Table A6: Correlation coefficients of patents with innovation inputs and investment variables.

Dependent Variable	$\log(\mathrm{Patent}_{r,t})$			
Patent Office	USPTO		PCT	
	ρ	p-value	ρ	p-value
$\log(\mathrm{Patent}_{r,t-1})$	0.8420	0.0000	0.8445	0.0000
$\mathrm{Human\ Capital}_{r,2009}$	0.3479	0.0000	0.3585	0.0000
$\mathrm{R\&D}_{r,2009}$	0.1724	0.0210	0.1688	0.0239
$\mathrm{R\&D}_{r,t-1}$	0.2780	0.0002	0.2898	0.0001
$\mathrm{Inward\ US\ Investments}_{r,t-1}$	0.0033	0.9651	-0.0128	0.8651
$\mathrm{Outward\ US\ Investments}_{r,t-1}$	0.0613	0.4147	0.0754	0.3157
$\mathrm{Inward\ FDI}_{r,t-1}$	-0.1014	0.1767	-0.1118	0.1364
$\mathrm{Outward\ FDI}_{r,t-1}$	0.2039	0.0062	0.2616	0.0004

Table A7: Descriptive statistics of the dependent and explanatory variables.

	Mean	Std. Dev.	Min.	Max.
$\log(\text{Patent}_{r,t})$– USPTO	5.2949	1.2608	1.6191	8.7563
$\log(\text{Patent}_{r,t})$–PCT	4.2752	1.3257	0.9037	7.8741
Inward US $\text{Investments}_{r,t-1}$	0.0007	0.0012	0.0000	0.0103
Outward US $\text{Investments}_{r,t-1}$	0.0003	0.0011	0.0000	0.0133
Inward $\text{FDI}_{r,t-1}$	0.0004	0.0012	0.0000	0.0132
Outward $\text{FDI}_{r,t-1}$	0.0005	0.0014	0.0000	0.0162
Human $\text{Capital}_{r,2009}$	18.7932	4.3628	11.7778	34.0000
$\text{R\&D}_{r,t-1}$	0.6231	1.2233	0.0000	8.5551
$\log(\text{Patent}_{r,t-1})$– USPTO	2.9432	0.9230	0.2881	5.6270
$\log(\text{Patent}_{r,t-1})$–PCT	2.2481	0.9965	0.0576	4.7668
Sectoral $\text{Concentration}_{r,2009}$	0.0037	0.0069	0.0000	0.0614
Manufacturing $\text{Share}_{r,2009}$	0.1022	0.0452	0.0213	0.2600
Services $\text{Share}_{r,2009}$	0.7571	0.0640	0.5910	0.8894

Table A8: Correlation matrix of explanatory variables.

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Inward US $\text{Investments}_{r,t-1}$	[1]	1										
Outward US $\text{Investments}_{r,t-1}$	[2]	-0.03	1									
Inward $\text{FDI}_{r,t-1}$	[3]	0.00	-0.03	1								
Outward $\text{FDI}_{r,t-1}$	[4]	-0.06	0.05	-0.05	1							
Human $\text{Capital}_{r,2009}$	[5]	-0.04	-0.02	-0.03	0.13	1						
$\text{R\&D}_{r,t-1}$	[6]	-0.04	0.00	0.13	0.04	0.30	1					
$\log(\text{Patent}_{r,t-1})$ – USPTO	[7]	-0.07	-0.01	-0.10	0.19	0.53	0.41	1				
$\log(\text{Patent}_{r,t-1})$ – PCT	[8]	-0.02	0.01	-0.08	0.23	0.53	0.43	0.87	1			
Sectoral $\text{Concentration}_{r,2009}$	[9]	0.11	-0.01	0.01	-0.12	-0.14	-0.12	-0.33	-0.36	1		
Manufacturing $\text{Share}_{r,2009}$	[10]	-0.06	0.06	-0.03	0.03	-0.33	0.01	0.07	0.04	-0.01	1	
Services $\text{Share}_{r,2009}$	[11]	-0.18	-0.02	-0.01	0.13	0.47	0.16	0.40	0.43	-0.55	-0.57	1

Table A9: Inward and outward US domestic and foreign investments.

Spatial Extent / Direction	True Sample		Matched Sample [(a)]		Matched Sample [(b)]	
	Inward	Outward	Inward	Outward	Inward	Outward
US Domestic Investments	3,702	3,702	1,290	2,665	1,283	2,561
FDI	2,224	8,156	1,290	2,665	1,283	2,561

Notes: Number of investment projects. (a) One-to-one exact matching with random sampling of matched investments based on two-digit NAICS sector and business activity of individual investment projects (b) One-to-one exact matching with random sampling of matched investments based on two-digit NAICS sector, business activity, and innovative congruence of source (inward) / destination (outward) region of individual investment projects. Regions (i.e., EAs for domestic investments, and countries for FDI) are defined as either low- or high-innovative with respect to the distribution of PCT patents filled over the 2000-2009 period. The total value for EAs reflects the US total. The total value for countries is the world total excluding the US.

Table A10: Difference in mean monetary value of investments: pre- and post-matching procedure.

Spatial Extent / Direction	Inward					
	True Sample		Matched Sample (a)		Matched Sample (b)	
	Mean Value	Difference [p-value]	Mean Value	Difference [p-value]	Mean Value	Difference [p-value]
US Domestic Investments	31.77	-4.27 [0.089]	52.33	7.40 [0.519]	41.57	-0.60 [0.936]
FDI	36.04		44.93		42.17	
Spatial Extent / Direction	**Outward**					
	True Sample		Matched Sample (a)		Matched Sample (b)	
	Mean Value	Difference [p-value]	Mean Value	Difference [p-value]	Mean Value	Difference [p-value]
US Domestic Investments	31.77	-13.85 [0.000]	48.12	-9.07 [0.168]	49.21	-4.67 [0.494]
FDI	45.62		57.19		53.88	

Notes: Mean monetary value of investment projects (in US million dollar). (a) One-to-one exact matching with random sampling of matched investments based on two-digit NAICS sector and business activity of individual investment projects (b) One-to-one exact matching with random sampling of matched investments based on two-digit NAICS sector, business activity, and innovative congruence of source (inward) / destination (outward) region of individual investment projects. Regions (i.e., EAs for domestic investments, and countries for FDI) are defined as either low- or high-innovative with respect to the distribution of PCT patents filled over the 2000-2009 period. The total value for EAs reflects the US total. The total value for countries is the world total excluding the US.