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External relations, regional productivity, and exogenous shocks: lessons from the Italian experience

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Abstract
This study provides novel insights into the debate concerning the external drivers of productivity at local (NUTS-3) level. In particular, it explores the role played by global production networks, measured through ownership ties among multinational firms and their subsidiaries abroad, in shaping patterns of productivity growth of local economies. Focusing on the Italian experience and using spatial econometrics techniques, the article demonstrates that external relations play a crucial role in sustaining the productivity of Italian provinces, even during periods of severe economic downturns, like the Great Recession. In detail, productivity growth is positively correlated with the Intensity of the networks established by multinational firms and their geographical dispersion.

Keywords Production networks · Productivity growth · Spillovers

JEL Classification D62 · O18 · R11

1 Introduction

Today more than ever before, world trade, investment and production are organised around global value Chains (GVCs), which include all the activities firms perform in order to launch a product on the market: from design, production, logistics and distribution to after-care services (Fuller & Phelps, 2018). GVCs are more and more often governed by Multinational Enterprises (MNEs), through their foreign activities. Indeed, MNEs set up affiliates abroad to access specific assets, such as natural resources, cheap labour force, technology and specialised knowledge, not available in places of origin (Alcacer et al., 2016; Inomata, 2017). This geographical

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fragmentation of the production process has generated new and more complex forms of foreign investments, usually called Global Production Networks (GPNs) or networked FDI, in which countries or regions hosting MNEs' activities become nodes of a global network shaped by complex inter-firm relationships (Baldwin and Okumbo, 2014; Bettarelli and Resmini, 2022).[1]

While details regarding why and how firms participate in GPNs have been extensively explored, both at theoretical and empirical levels (Antras and Chor, 2021; Ter Wal and Boschma, 2011; Alcacer, 2006; Goerzen et al., 2013; Amador and Cabral, 2016; Yeung, 2021), the economic advantages accruing to regions belonging to international production networks have not yet been fully understood by the literature (Ascani et al., 2020; Pain et al., 2016). A number of interesting questions, in fact, still need to be thoroughly answered: is there evidence of a positive correlation between GPNs and regional economic performance? Are the potential benefits, if existing, homogeneous across sectors and over space? Is this type of external relations a pathway out of economic downturns?

This article aims at providing an answer to these questions through an empirical analysis of the link between participation in global production networks and productivity of Italian NUTS-3 regions, over the period 2007–2018. To achieve our research objective, we use a novel comprehensive dataset on the external networks of the 107 Italian NUTS-3 regions, across different economic sectors. By linking network data with information on the socio-economic characteristics of Italian provinces, we can establish a more nuanced empirical relation between external connectedness and productivity at local level. Afterwards, we divide the time period under analysis into two sub-periods (i.e., pre- and after-crisis) to understand if benefits accruing to networked provinces vanish during a period characterized by a severe economic downturn.

The paper is organized as follows. Section 2 emphasizes the key contributions of this article with respect to existing literature, Sect. 3 describes how we operationalize the concept of GPNs. Section 4 explains the empirical model employed in the analysis. Section 5 discusses some empirical stylized facts concerning Italian regions participation in GPNs, as well as the main results of our econometric analysis, while Sect. 6 provides concluding remarks and outlines the implications of our findings for further research.

2 Literature review

Traditionally, the spatial behavior of MNEs has been explained as a mix between agglomeration advantages and proximity to foreign markets (Brainard, 1997; Blomstrom & Kokko, 1998; Meyer and Sinani, 2009; Kugler, 2006; Haskel et al.,

[1] GPNs are a type of global value chain encompassing at least a headquarters and many foreign affiliates controlled by the same corporation and repeatedly interacting with each other since they carry out complementary tasks and functions. Therefore, GPNs are hierarchically organised and characterized by relation-specific investments. Not all GVCs respond to these characteristics. Indeed, they may also include independent firms operating at different stages of the production chain, which develop arms-length relationships. For more details, see, e.g., Baldwin and Okumbo (2014) and Coe and Yeung (2015).

2007; Gorg and Strobl, 2001; Gorg and Greenaway, 2004; Girma, 2005; Driffield, 2006).

However, recent advances in two connecting technologies (Baldwin, 2012), i.e. transportation and communication technologies, have questioned this approach to the location of MNEs, which tends to overemphasize the role of geographical proximity in patterns of FDI-induced knowledge flows and to underestimate the role of networks.

By slicing up production activities and placing them in efficient locations around the world, MNEs create new opportunities of growth for firms involved in the network and, ultimately, for their locations (Coe et al., 2008; Crescenzi & Iammarino, 2017; Alcacer et al., 2016). Therefore, the network has to become the unit of analysis when dealing with the impact of FDIs on regional development (Bathelt et al., 2004; Turkina and van Assche, 2018).

As noted by the literature, participation in global production networks promotes the diversification of assets, gives access to different assets not available locally and to new markets (Van Meeteren et al., 2016; Iammarino and McCann, 2013; Rodriguez-Pose and Fitjar, 2012). Moreover, the geographical fragmentation of networks allows connected local systems to reduce losses from asymmetric shocks and to avoid situations of entropic death or cognitive lock-in, thus ensuring an improved efficiency to the entire economic system (Bathelt et al., 2004; Boschma, 2005; Camagni, 1991; Frenken et al., 2007; Neal, 2011; Pain et al., 2016; Ter Wal & Boschma, 2011; Ter Wal and Boschma, 2011; Bettarelli et al., 2024). In other words, being part of a global network helps regions to develop and prosper.

While connectivity and openness are widely acknowledged as key factors for local economic performance at theoretical level (Crescenzi & Iammarino, 2017), there is no sound empirical evidence that regions embedded in GPNs enjoy a better economic performance than not-networked ones. To our knowledge, only a handful of studies has empirically tested this hypothesis at both national and international level, with mixed results. In particular, Neal (2011) demonstrated that connectivity, measured as airline linkages, positively affects employment in US networked cities. Pain et al. (2016), instead, tested the relationship between network connectivity—proxied with different indicators, including the links generated by the office command and control functions of global firms—and economic performance between 2000 and 2008 for a sample of large European and US cities. They found that "in all specifications, connectivity measures never impact significantly on the economic growth of the cities in both Europe and the US" (Pain et al., 2016, p. 10). David et al. (2013) obtained similar results in a smaller sample of European cities. In contrast, recent contributions by Cortinovis and Van Oort (2019) and Ascani et al. (2020), found that external relations based on commercial or productive networks may positively affect the performance of regions involved in the networks, with potential different features concerning the nature and the intrinsic characteristics of the external networks.

This study follows this recent strand of literature by examining the role of external relations in shaping local productivity trajectories of Italian regions. In contrast with previous empirical literature, we focus on external relations created by Italian MNEs operating in different economic sectors and their foreign subsidiaries and examine several salient characteristics of these networks as potential channels of transmission of productivity spillovers. Furthermore, we investigate whether these external networks reduce or exacerbate potential negative effects generated by external shocks, like the global financial crisis of 2008. The issue is not trivial: global shocks propagate over space more quickly the more an economic system is integrated into the global economy (Bernard et al., 2019; Boehm et al., 2019; Todo et al., 2015). Since external networks increase the interdependence among countries and regions, one may expect that GPNs may contribute to spreading over space the effects of shocks occurring within the network, thus amplifying business cycle's fluctuations with severe implications for the well-being of networked territories.

This study makes the following key contributions to the current debate on the topic. First, we show that GPNs are positively correlated with the productivity of networked local economic systems. More interestingly, we find that this positive effect survives to economic downturns, allowing networked regions to overcome the negative impact of the financial crisis. This result depends on the degree of geographical dispersion of the network, as geographic diversification ensures the so-called "portfolio effect" (Boschman and Iammarino, 2009): the more geographically dispersed is the network, the lower the probability that business cycles in networked territories are synchronized. Furthermore, we demonstrate that the positive effect that external connections may exert on economic performance is not restricted to advanced services or professional jobs, as implicitly assumed by previous literature on world city networks (Derudder et al., 2010; Rosenblat, 2010; Taylor, 2001), but occurs in different economic sectors, thus enlarging the set of potential policy actions devoted to increasing international connectivity of local economies.

3 Network metric

In order to explore the potential relationship between external relations and productivity at the regional level, we first collected data on Italian MNEs and their foreign subsidiaries, by using the Amadeus dataset issued by Bureau van Dijk. It contains quantitative and qualitative information on active firms operating in Europe and their ownership structure.[2] We use the latter to identify the nationality of the company. More in detail, we included in the sample each independent Italian company at the top of the corporate ownership structure and their foreign subsidiaries.[3] We did this in two periods, i.e., 2007 and 2012. Then, we aggregated these firms by Italian NUTS-3 regions and, within regions, by five economic macro-sectors, i.e., primary activities, construction and public utilities, manufacturing activities,

[2] Amadeus is a database of comparable financial and business information on around 21 million companies across 43 European countries. The database provides update standardised annual accounts (consolidated and unconsolidated), and financial ratios, with up to ten years of time series, as well as sectoral activities and ownership data. As for Italy, Amadeus has information on all Italian companies required to file their accounts, approximately 1 million companies.

[3] To trace these intra-firm links, we considered ownership shares equal or larger than 25.01% and used two different released of the Amadeus dataset.

Table 1 Italian provinces' external connections, 2007 and 2012 (percentages)

	2007	2012
Destinations outside Italy		
Europe	60.92	58.95
North America	14.23	11.58
South-Centre America	9.21	8.39
Africa	5.07	6.05
Oceania	1.05	0.54
Middle East	1.28	1.36
Far East	8.23	13.13
Origin within Italy (NUTS1)		
North East	26.2	29.4
North West	39.8	43.1
Centre	28.2	20.5
South	2.2	2.8
Islands	3.6	4.2
Sector of activity (HQs)		
Agriculture	5.18	4.49
Public utilities	5.78	3.95
Knowledge Intensive Sectors	20.02	30.09
Other services sectors	41.93	41.05
Manufacturing	27.90	20.44

Source: author's computation based on firm-level data from Amadeus dataset

knowledge-intensive services sectors and other service.[4] Eventually, we ended up with 535 observations (107 Italian provinces, by 5 economic sectors).

In order to control the geographical scope and the organizational structure of GPNs, (Ascani et al., 2020; Bettarelli & Resmini, 2022), we emphasized two specific characteristics, i.e. the intensity of the network and the degree of geographical dispersion. We measured the intensity of the external network of each Italian province *i,* in macro-sector *s,* by counting the number of firms participating in it. This implies to consider both the firms that create networks, namely the headquarters located in Italy, and their subsidiaries abroad, each of which performs different tasks within the network. In particular, subsidiaries give access to tangible and intangible resources specific to foreign locations, while the headquarters collect, reuse, and diffuse these resources at home and along the network. Eventually the effect that external networks may exert on regional performance is the result of the joint action of these two types of firms (Ascani et al., 2020; Bettarelli and Resmini, 2022).[5]

[4] See Table A1 in the Appendix for a detailed description of each macro-sector.

[5] This consideration does not imply that all foreign affiliates may have access to the same set of local resources. Some affiliates may be sales offices or distributors, with limited to no resource (tangible or intangible) flowing back to home economies. We are not able to consider the specific tasks of all foreign

Another noteworthy aspect related to global connections is the spatial dimension of the network. As suggested by the literature, MNEs geographically fragment the production chain to exploit advantages of different locations and become more competitive in the global market. However, there exists a significant debate regarding the appropriate level of geographic diversification (Qian et al., 2010). Geographical proximate networks allows MNEs to minimize coordination costs and take advantage of institutional proximity, a better knowledge of markets, and entry modes (Peng et al., 2010; Qian et al., 2010; Rugman & Verbeke, 2004), while geographically dispersed networks allow MNEs to access a variety of knowledge sources that are not available in their own region (Nachum et al., 2008), and to diversify risks, since distant countries' business cycles are less likely correlated with respect to those of proximate countries (Hitt et al., 1997). These considerations can be applied to the performance of territorial units hosting networked firms. Regions gain by being embedded into global networks, though benefits that accrue to local territories vary with the degree of geographical dispersion of the external connections created by MNEs. Geographically concentrated networks allow territories to take advantage of the potential benefits that can be drawn from spatial proximities, while geographically dispersed networks allow territories to accumulate more generalized knowledge that can be drawn from internationalization. Moreover, more geographically dispersed networks reduce the risks of cognitive lock-in and protect from demand shocks. To operationalize these ideas, we first split the world into seven geographical continental macro-regions.[6] Then, we compute a Theil entropy index, decomposed in two components, measuring the first the degree of dispersion of Italian MNEs' foreign subsidiaries within each continental macro-region, and the other measuring how subsidiaries controlled by Italian firms are dispersed among continental macro-regions.[7]

Footnote 5 (continued)
affiliates, due to data limitations. However, this issue may at worst underestimate the effect of external connectivity on regional productivity.

[6] Macro-regions are: Europe, North America, South America, Far East, Middle East, Africa, and Oceania.

[7] The two components of the Theil entropy index are as follows:

$$Inter-reg.dispersion = \sum_{r=1}^{m} P_i^r \ln \frac{1}{P_i^r},$$

where r refers to macro-regions, whose total number is m (with $m=1, \dots 7$), and P_i^r is the proportion of the r-th region to the province i total number of connected firms in all regions. The higher the index, the more dispersed across the world is the network of province i in sector s.

$$Intra-reg.dispersion = \sum_{r=1}^{m} P_{rm}^m \times Intra_m$$

with:

$$intra_m = \sum_{c \in r} P_{cr}^r \ln \frac{1}{P_{cr}^r}$$

P_{cr}^r is the share of firms in the c-th country to the total number of firms of the r-th macro-region. The higher the index, the more dispersed the firms are within the same macro-region.

4 Methodology and data

This section presents the estimation strategy and the data we use to reach our research goals. In light of our very granular territorial analysis, we expect to find spatial dependence in our data sample, at least for two reasons. First, the productivity growth rate of province i may not be independent from that of neighbouring provinces, because of physical and human capital externalities and technological interdependence between regions (e.g. Ertur & Koch, 2007). Figure 1 below seem to confirm that productivity growth patterns are spatially dependent, both when we consider the entire period and the two sub-periods.

Secondly, latent unobservable influences, like culture, infrastructure, or regional endowments of physical capital can affect the dependent variable, though they do not appear as explanatory variables in the model. Spatial diagnostics reported in Table 7 in Appendix, confirm the existence of these conjectures. As a result, we estimate our regression equation through a SAR model with spatially autocorrelated errors (Elhorst, 2014):

$$\mathrm{y}_{\mathrm{ist}} = \alpha + \rho \mathrm{W}\mathbf{y}_{ist} + \mathbf{N}_{ist-1}\beta + \boldsymbol{X}_{ist-1}\gamma + \delta_i + \theta_s + v_{is} \quad (1)$$

$$v_{is} = \lambda \mathrm{W} v_{is} + \varepsilon_{is}$$

where ρ and λ indicate the spatial autoregressive parameter and the coefficient of the spatially lagged autoregressive errors respectively, and W the spatial weighting matrix. We opt for a simple inverse distance function, as we expect that processes channelling knwoledge spillovers across space may decay as distance among areas increases (Dettori et al., 2012).[8] Subscripts i and s stand for province and economic sector, respectively. **N** is a vector of variables related to province i global connections, while **X** is the vector of controls; δ and θ are province and sector fixed effects, and v is the error term, clustered by province.[9] The dependent variable (y) represents the productivity growth rate, in percentage terms, between years 2008–2018. Productivity in each sector is defined as gross value added over total employment. In a different specification, aimed at disentangling the effect of network externalities on productivity growth during and after economic shocks, we split the sample into two sub-periods, i.e., 2008–2012 and 2013–2018, and compute the dependent variable accordingly.[10]

[8] This does not mean that other a-spatial links among territorial units may play a separate role (Marrocu et al., 2013; Bettarelli and Resmini, 2022). However, our objective is not to estimate the overall knowledge multiplier. More simply, we are controlling for spatial dependent patterns in regional development trajectories.

[9] In specifications in which we control for variables that do not vary across economic sectors, we substitute province fixed effects with NUTS-2 region fixed effects; in so doing, we avoid sector-invariant controls being omitted due to collinearity.

[10] We recall the readers that external connectivity has been measured in 2007 and 2012. Thus, in this exercise, we first estimate the effect of external connectivity in 2007 on regional productivity growth between 2008 and 2012; then, the effect of external connectivity in 2012 on regional productivity growth between 2013 and 2018. Note that we identify 2012 as cut-off year separating pre- and post-crisis periods, based on Italian GDP data. We acknowledge that this may be not the case in other countries.

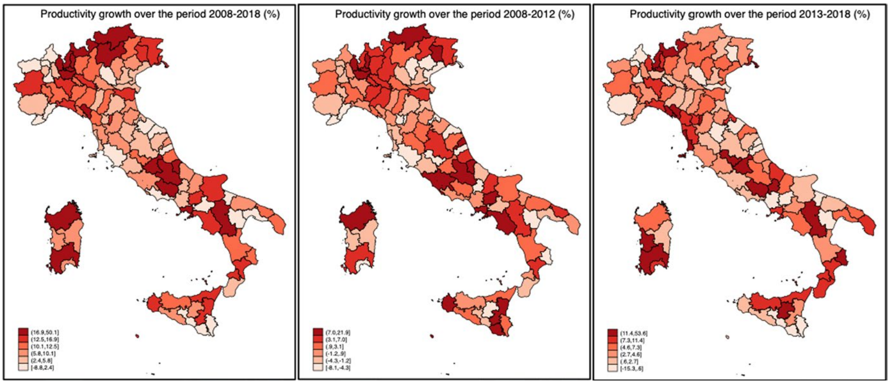

Fig. 1 Regional productivity growth by nuts3 regions and over time

As robustness checks, we consider alternative empirical models. First, we use a first-order contiguity matrix, instead of the inverse of distance. Second, we consider different spatial econometric approaches: a Spatial Durbin Error Model (SDEM), where we also include the spatial lag of the network variable, and a Spatial Error Model (SEM). Then, we estimate Eq. (1) without using a spatial approach. In this case, we use a standard OLS model. In fact, the maximum likelihood estimator, used in the SAR model, implies that residuals must be normally distributed, conditional on the covariates, to obtain valid standard errors. Linear models are less restrictive on this assumption. The structure of our data does not allow us to construct a "true" panel setting, as there is few time-variation in network variables. However, we are able to account for sector-time-invariant regional-level characteristics, that may affect the productivity growth and/or the degree of external connectivity of regions, through region and sector fixed effects.

The vector **N** includes first the intensity of the network as a whole and then separately of its two components, i.e., headquarters and foreign subsidiaries. Theoretically, we expect that the two entities, jointly composing the external network of a province/sector, may have a different impact on regional productivity, according to their role within the network. We expect to find a positive association between the intensity of the networks and regions' performance. The magnitude of the coefficients related to the two sub-components will help us to understand which one is more relevant to channel the benefits of being connected internationally into local factors conducive for productivity growth. In contrast, we have no prior for the potential relationship between regions' productivity and geographical dispersion. A positive sign would indicate that benefits overcome the costs related to the management of the networks and both types of networks generate positive externalities which may enhance regional productivity. However, benefits from intra-regional networks reflect the advantages of a better knowledge of proximate markets, while benefits from inter-regional networks depend on the minimization of the risk. This effect, if present, is called portfolio effect (Boschma and Iammarino, 2009). Whether geographically concentrated networks generate more (or less) productivity spillovers than geographically dispersed networks of external relations is an empirical issue that we will try to solve later in this study.

In order to explain productivity patterns, besides the characteristics of the network previously discussed, we rely on a number of controls that are commonly used in the relevant literature (Tsvetkova et al., 2020). In particular, we include a proxy of regional technological capabilities, measured by the number of patent applications to the European patent office aggregated at Nuts-2 level (*Innovation*). It is generally expected that technology and R&D activity may offer a positive contribution to productivity growth, both directly, because of their positive effects on innovation, and indirectly, since they increase the absorptive capacity of economic agents, allowing them to benefit also from innovative activities of other economic actors (e.g., Aghion, 2006; Veugelers, 2021). Human capital available regionally is another intensively studied explanation of regional economic performance. As before, greater levels of human capital may affect productivity directly, as a more educated labour force is expected to produce more, and indirectly, since the quality of human capital is crucial for technological progress (Marrocu et al., 2013). We measure it as the percentage of population in each region with a tertiary education (*Human capital*). Productivity may also be affected by the industrial structure of the region (Tsvetkova et al., 2020). Technological-intensive sectors are expected to be on average more productive than other sectors, and their expansion may enhance productivity growth. Moreover, the industrial structure usually reflects regional competitive and regulatory regimes, as many policies and regulations are sector specific. We measure the industrial structure of each Italian province (*Industry_Structure*) by using the traditional location quotients computed on value added.[11] The literature also recognizes the existence of a positive link between the productivity of regions and the benefits of diverse agglomeration economies (e.g., Combes et al., 2012; Duranton and Puga, 2004; Puga, 2010); thus, we include in the regression equation the population density (*Popdens*) of each province. Institutions at both national and regional levels, also contribute to shape productivity growth trajectories (e.g., Easterly & Levine, 2001; Garcilazo et al., 2015), since they are responsible of the provision of public services and of the implementation of laws and regulations established at national level. We proxy the quality of local institutions (*Quality of institutions*) through the European quality of Government index, a multi-dimensional concept of institutional quality developed by the Quality of Government Institute of Gothenburg University (Charron et al., 2014). Lastly, the vector of controls includes the initial level of the labour productivity of each province/sector, to control for the presence of potential conditional convergence patterns. Tables 5 and 6 in the Appendix report descriptive statistics of dependent and independent variables as well as the corresponding correlation matrix. The latter signals high correlation among some of the network

[11] The location quotient (LQ) quantifies how concentrated an industry is in a region compared to the national average. It is calculated by comparing the industry's share of regional employment (or value added) with its share of national employment (value added). Industrial LQ and its dynamic over time reveal how important is each industry in the region's economy and what makes a particular region unique in comparison to the national average. Indeed, a high-LQ industry with a small number of employees signals an export-oriented industry, not vital to the region's economy, while a large, high-LQ industry with declining LQ over time may endangering the regional economy.

variables, i.e. total intensity with number of HQs and number of affiliates. This is due to the way variables have been built, given that total intensity equals the sum of its components. As a result, we never include the three variables simultaneously in our regressions.

Independent variables are collected for the year before the beginning of the period we use to compute the dependent variable, to alleviate issues of reverse causality, i.e. 2007 and 2012. In all specifications, we use standardised scores for the independent variables (z-values with average zero and standard deviation of one) in order to make the impact of explanatory variables directly comparable (Frenken et al., 2007).

5 Empirical results

5.1 Stylised facts

Before discussing regression results, we present some descriptive statistics related to external connections of Italian provinces, measured in 2007 and 2012. We do not weight these raw data by, e.g., the economic size of regions, as they are intended to describe networks of Italian MNEs as they are. Note that regions' economic size patterns do not drive our empirical analysis, as we use region and sector fixed effects.

The upper section of Table 1 pools the international distribution of outward linkages originating from Italian provinces. Even though data show that connections were truly global, since all the seven macro-regions previously described were linked to Italy, they were strongly unbalanced towards Europe and, to a lesser extent, North America.

It is however worth noticing that in 2012 the size of both European and American networks has reduced with respect to the previous period, in favour of other macro-regions, and mainly Africa and the Far East. This may be an indirect effect of the Great Recession, which may have pushed Italian MNEs to re-orient their production networks towards the geographical areas less hit by the economic downturn (Galar, 2015). The central panel of Table 1 presents the distribution of Italian MNEs across the national territory. On average, over 70% of Italian MNEs concentrates in the Northern part of the country. Quite surprisingly, the aggregate Islands (that includes only two NUTS-2 regions) outperforms the South aggregate, because of Sicily, which alone contributes for the 2.8% and 3.4% of Italian external networks in the two sub-periods, respectively. In terms of economic sectors, the bottom part of Table 1 indicates that services account for about 60% of networked Italian MNEs with subsidiaries abroad, followed by manufacturing MNEs, which represent about 28% of Italian firms with production networks abroad. Agriculture, construction, and public utilities host together a little bit more than 10% of global networks of Italian provinces.

In sum, we found three regularities that are related to our research questions. First, external relations are somewhat geographically concentrated within Italy. Indeed, most of Italian MNEs are in the Northern part of the country. Secondly, Italian provinces' external networks develop mainly within Europe, even though this trend has been slowing down after Great Recession. Thirdly, external relations are driven by Italian MNEs operating in the services sectors, where we observe an intensification of the phenomenon in knowledge-intensive sectors over time. Next sections explore whether and to what extent these characteristics condition Italian provinces' productivity growth.

5.2 Baseline estimates

Table 2 summarizes the outcomes of the regression analysis over the entire period, i.e., 2008–2018. We start by considering the impact on region/sector productivity of our key variable, i.e., the intensity of the external network (column 1); then, we consider separately its main components, i.e., parent-houses and subsidiaries (column 2), and lastly we add other controls (column 3). Overall, we find that the effect of the intensity of the network is strong and has the expected positive sign. On average, a one standard deviation increase in the intensity of the network is linked to a productivity premium of about 2.3%. Thus, external connections contribute to enhancing Italian provinces' productivity growth. Both MNEs and their foreign subsidiaries contribute to this positive effect, as shown by the sign and significance of the coefficients reported in column 2. This supports our hypothesis that is the complete network rather than outward foreign investments, to generate benefits to networked regions and sectors, an idea not yet consolidated in the literature. In particular, it is the number of MNEs that mostly contribute to regional productivity, as they represent the "knowledge gatekeepers" that distribute external resources at home (Ascani et. al., 2020; Bettarelli and Resmini, 2022).[12]

As for geographical dispersion, both intra- and inter-regional external relation variables have a positive sign, but only inter-regionally dispersed networks seem to be able to significantly affect regional productivity growth (column 3). Thus, we can conclude that geographically diversified external relations bring to networked regions more benefits that geographically concentrated networks.

The positive impact of external networks is robust to the inclusion of other controls, as indicated by column (4). The signs of all parameter estimates are as expected, though the production structure variable does not seem to influence the productivity rate in any significant way. In particular, we find that the productivity growth rate responds positively to the presence of skilled workers, high-quality institutions, high innovation capabilities, and diversified agglomeration externalities. Lastly, the initial level of productivity enters with a negative and significant sign, suggesting that processes of convergence are at work. The insignificance of the production structure variable may be explained by the way variables we use are conceptually related one to each other. Indeed, *Production_Structure* reflects the relative importance of each macro-sector in the regional economy. Thus, if knowledge

[12] Note that specification in column 2 allows us to evaluate the impact of foreign affiliates on regional productivity, net of the number of MNEs. In fact, our data do not allow us to directly compute regional productivity, net of firms with international networks. This is a limitation of our study, since regional productivity may also be affected directly by the presence of (large) company with the international networks. Through specification in column (2), we partially control for this issue.

Table 2 Baseline regressions' results

Productivity	08–18 (1)	08–18 (2)	08–18 (3)	08–18 (4)
Intensity_tot	2.101***		1.812**	3.046**
	(0.636)		(0.811)	(1.241)
Intensity_sub		0.839*		
		(0.478)		
Intensity_HQs		1.562**		
		(0.583)		
Intra-regional networks			0.515	
			(0.941)	
Inter-regional networks			1.293**	
			(0.516)	
Production_structure				2.704
				(2.204)
Population density				3.206***
				(0.998)
Innovation				1.798**
				(0.707)
Human capital				2.268***
				(0.861)
Inst_quality				1.691**
				(0.798)
Initial productivity level	−0.858***	−861***	−0.860***	−0.885***
	(0.177)	(0.180)	(0.178)	(0.170)
Rho (ρ)	0.637***	0.627***	0.612***	0.518***
	(0.207)	(0.217)	(0.220)	(0.201)
Lambda (λ)	0.487**	0.463*	0.444*	0.412*
	(0.242)	(0.274)	(0.268)	(0.232)
Observations	535	535	535	535
R-squared	0.417	0.421	0.455	0.451
Nuts-3 dummies	Yes	Yes	Yes	No
Nuts-2 dummies	No	No	No	Yes
Sectoral dummies	Yes	Yes	Yes	Yes

Standard errors in parentheses, clustered by region. ρ indicates the spatial lag term, λ the spatial correlated error term. Models have been estimated using the Stata command *xsmle* (Belotti et al., 2017)

*0.1; ** 0.05; *** 0.01

intensive sectors are dominant in a specific region, this may suggest that this region is also well-endowed with well-educated labour force and has already developed high-technological capabilities. Furthermore, our variable also reflects the relative specialization of each province, a concept that explains the level of productivity but not necessarily its growth rates.

As noted above, we test the robustness of our baseline results to alternative empirical approaches. In detail, we re-estimate our baseline regression, as in column 1 of Table 2, using different spatial models (SDEM and SEM), weighting matrix (contiguity instead of (inverse of) distance), and OLS with region and sector fixed effects. Results, reported in Table 8 in the Appendix, are qualitatively similar to those reported in Table 2, reassuring us on the validity of our analysis.

5.3 The role of the global financial crisis

One may argue that the considered period is not ideal to provide accurate estimates of the impact that global connectivity may exert on regions' productivity growth, since it includes the global financial shock starting in 2008. Given the potential distortive effects of this event on productivity growth rate, and on the structure of global production networks (Galar, 2015), we decide to split the sample into two sub-periods, i.e., 2008–2012 and 2013–2018. The former aims at capturing the effect of external connections during the economic downturn, while the latter focuses on the post-crisis period. This strategy allows us first to understand whether and to what extent external relations helped Italian regions to counteract the negative effects of the crisis; secondly, to avoid the confounding effect of this disruptive event.

Table 3 shows the outcomes. Columns (1)–(4) refer to the period from 2008 to 2012, while columns (5)–(8) focus on the post-crisis period (2013–2018). As noted above, independent variables are collected in the year preceding the start of the period we consider to build dependent variables, i.e. 2007 and 2012, respectively. As before, we first consider our main regressors, i.e., the intensity of the external network and its two main components, and the geographical dispersion of the external networks, and then include the other controls.

What emerges with strength from Table 3 is that the impact of the intensity of the global network (*Intensity_tot*) remains positive and statistically significant in both sub-periods (column 5). Thus, we can conclude that our baseline result is robust to exogenous shocks, and secondly, that external relations have sustained Italian regions' productivity during the economic downturn.

In columns (2) and (6), we consider the impact that HQs and subsidiaries, separately. A comparison between coefficients associated with *Intensity_sub* and *Intensity_hq*, confirms that the impact of HQs and subsidiaries diverge quite substantially, not only between them, but also between periods. *Intensity_hq* shows larger coefficients than *Intensity_sub*, both during and after the crisis, thus highlighting the importance of local MNEs in collecting and diffusing external tangible and intangible resources at home. However, when we consider the years of the crisis (column 3), we cannot reject the hypothesis that the effect of *Intensity_hq* is equal to zero. In contrast, *Intensity_sub* keeps sustaining productivity growth during crisis, too. This implies that, keeping constant the number of MNEs, a large number of subsidiaries allows a local economy to diversify sources of external assets, which proves to be crucial during asymmetric shocks.

As far as the geographical dispersion of networks is concerned, our findings confirm the role played by inter-regional dispersed networks in enhancing Italian provinces' productivity. Indeed, the variable *Inter-regional network* is always positive, statistically significant, and large in magnitude. Not surprisingly, its impact on regional productivity is particularly strong during the crisis (Column 3), with a one standard deviation increase in *Inter-regional network* that affects regional productivity growth of about 2%, all else equal. On the other side, we can never reject the null hypothesis that coefficients associated with *Intra-reg. network,* i.e., the distribution of subsidiaries within macro-regions, is equal to zero. These results are consistent with the portfolio hypothesis: what matters most in terms of external relations are externalities related to diversification, rather than to similarities and proximity.

As for the other controls, they keep their expected signs, while their magnitude and significance weaken during the crisis period, except for the industrial structure variable, which becomes statistically significant in the post-crisis period (column 8). Thus, specialization per se is not able to protect local economies from exogenous shocks, while it ensures a more rapid recovery.

Overall, this set of results indicates that productivity growth is heavily correlated with the capacity of a province/sector to establish productive networks with foreign locations, via outward investments of local MNEs. Second, external connectivity represents a crucial driver of productivity growth even during a period of deep recession, thus improving the resilience capacity of a province/sector. Third, external networks are effective when they involve GUOs and subsidiaries spread throughout the world. This indicates that what matters in terms of network externalities is not only how much a province-sector is connected to the world, but also how.

6 Concluding remarks

The aim of this paper has been to investigate the effects that GPNs created by multinational firms by fragmenting vertically and geographically the production process exert on productivity growth at local level. Our study demonstrated that the role of these networks as catalysts for regional development should be revalued. As a matter of fact, they positively associated with regional productivity growth, even during periods of severe downturns.

More in details, we uncovered that GPNs' potential benefits vary along different dimensions. As suggested by the traditional literature on network externalities, intensity matters. However, while previous studies used to measure the intensity of external networks by looking at the numerousness of foreign affiliates only, we adopt a truly network approach and consider both the headquarters and the foreign affiliates. These two entities play a different role within the network and exert their positive effect under different circumstances. In particular, we find that regions with a large number of foreign subsidiaries have enjoyed higher productivity growth rates during the crisis period, all else equal.

Geographical dispersion proved to be another important feature. We considered both a measure of inter-regional dispersion, associated with portfolio and risk diversification effects, and a measure of intra-regional dispersion, associated with scale economies in processes of learning and accumulation of knowledge. We found that only inter-regional geographical dispersion is able to exert a positive and significant

Table 3 Effects over time

Productivity	08–12	08–12	08–12	08–12	13–18	13–18	13–18	13–18
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intensity_tot	1.072*		.918*	1.095*	1.134**		1.087**	1.498***
	(0.472)		(0.412)	(0.677)	(0.477)		(0.399)	(0.269)
Intensity_sub		0.907**				0.401**		
		(0.399)				(0.253)		
Intensity_hq		1.405				0.889***		
		(1.213)				(0.348)		
Intra-reg. network			0.624				0.479	
			(0.(0.611)				(1.016)	
Inter-reg. network			1.812**				1.119*	
			(0.806)				(0.643)	
Production_structure				1.237				0.755*
				(2.204)				(0.410)
Population density				1.373*				1.855***
				(0.721)				(0.596)
Innovation				1.365*				0.907**
				(0.661)				(0.358)
Human capital				1.438*				1.514**
				(0.715)				(0.678)
Inst_quality				1.063**				0.912*
				(0.386)				(0.399)
Initial productivity level	−0.438***	−0.441***	−0.438***	−0.439***	−0.521***	−0.533***	−0.527***	−0.529***
	(0.121)	(0.181)	(0.134)	(0.102)	(0.107)	(0.111)	(0.109)	(0.109)
Rho (ρ)	0.590***	0.578***	0.562***	0.514***	0.529***	0.557***	0.559***	0.519***
	(0.061)	(0.059)	(0.056)	(0.051)	(0.188)	(0.192)	(0.191)	(0.199)

Table 3 (continued)

Productivity	08–12	08–12	08–12	08–12	13–18	13–18	13–18	13–18
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lambda (λ)	0.431**	0.411*	0.401*	0.389*	0.249*	0.218*	0.273*	0.256*
	(0.201)	(0.299)	(0.291)	(0.234)	(0.155)	(0.099)	(0.159)	(0.128)
Observations	535	535	535	535	535	535	535	535
R-squared	0.391	0.396	0.401	0.398	0.411	0.419	.412	0.401
N3 dummies	Yes	Yes	Yes	No	Yes	Yes	Yes	No
N2 dummies	No	No	No	Yes	No	No	No	Yes
Sectoral dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses, clustered by region. ρ indicates the spatial lag term, λ the spatial correlated error term. Models have been estimated using the Stata command *xsmle* (Belotti et al., 2017)

*0.1; ** 0.05; *** 0.01

effect on regions' productivity. Once again, this effect is particularly relevant during the economic downturns. Thus, we can conclude that Italian multinationals create geographically dispersed networks to protect themselves, and the regions they belong to, from production shocks. In so doing, they exploit external sources of knowledge, which allow them to enlarge the local existing knowledge base.

As any research, this study has some limitations that open new avenues for further research. First, networks are identified according to ownership ties; therefore, it provided evidence on the potential role played by hierarchical networks in shaping regional development trajectories, though not by arms-length ties. This implies that all network dimensions entering our regression equations are imperfect proxies of the true size of extra-regional ties. Furthermore, we have no elements to comment on the differential impact of networks with a different organizational structure (Gereffi et al., 2005). Secondly, it would be worth to improve the granularity of our analysis in many aspects. From a geographical perspective, we considered the external relationships of Italian provinces. A finer geographical disaggregation of external linkages would allow to understand whether, and to what extent, the production networks encompassing Italian regions are global or more regionally oriented. Instead, from a sectoral perspective, more disaggregated data would allow us to gain deeper insights on those sectors and firm-level factors that drive the formation of networks; this, in turn, would also allow us to inspect their contribution to the structural characteristics of the networks. Thirdly, this study has not properly accounted for the dynamic nature of GPNs (Coe et al., 2008). We considered only two periods and provided some evidence on the several different effects that network characteristics have on the performance of Italian provinces along the business cycle. More research is needed to study how robust they are and how, and to what extent, the evolution of GPNs over time affects local development trajectories and vice-versa. Fourthly, it would be interesting to consider other potential weighting variables— such as trade and capital flows—in the analysis of network externalities, i.e., the impact of external connectivity of region *i* on other regions. Finally, regional productivity may also be affected directly by the presence of (large) company with the international networks. More detailed productivity data, differentiating for different types of firms (e.g., MNEs), would allow to control for this issue.

Despite these limitations, the following two policy messages can be derived from our findings. First, the formation of GPNs by local firms should be promoted, given that outward foreign direct investments do not deteriorate the competitiveness of local economies by offshoring strategic assets and competences abroad. Secondly, the geographic dispersion of GPNs puts the development opportunities of each region in relation to those of other regions, often quite distant in space. Thus, soft and hard infrastructures able to reduce transaction costs between nodes become crucial to ensure that networked regions may develop GPNs of the "right Intensity" to gain from their potential advantages.

Appendix

See Tables4,5,6,7,8.

Table 4 Sectoral classification

Nace macro-category	2-digit sectors
Agriculture, fishing, mining	Crop and animal production, hunting, and related service activities; forestry and logging; fishing and aquaculture; mining and coal and lignite; extraction of crude petroleum and natural gas; mining of metal ores; other mining and quarrying; mining support service activities
Construction and public utilities	Electricity, gas, steam, and air conditioning supply; water collection, treatment, and supply; sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities and other waste management services; construction buildings; civil engineering; specialised construction activities
Knowledge intensive services	Water transport; air transport; publishing activities; motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities; telecommunications; computer programming; information service activities; scientific research and development; legal and accounting activities; activities of head offices; management consultancy activities; architectural and engineering activities; technical testing and analysis; advertising and market research; other professional, scientific and technical activities; employment activities; security and investigation activities; financial service activities, except insurance and pension funding; insurance, reinsurance and pension funding, except compulsory social security; activities auxiliary to financial services and insurance activities; veterinary activities; public administration and defence; compulsory social security; education; human health activities; residential care activities; social work activities without accommodation; creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities; sports activities and amusement and recreation activities
Other services	Wholesale and retail trade and repair of motor vehicles and motorcycles; wholesale trade, except of motor vehicles and motorcycles; retail trade, except of motor vehicles and motorcycles; land transport and transport via pipelines; warehousing and support activities for transportation; postal and courier activities; accommodation; food and beverage service activities; real estate activities; rental and leasing activities; travel agency, tour operator reservation service and related activities; services to buildings and landscape activities; office administrative, office support and other business support activities; activities of membership organisations; repair of computers and personal and household goods; other personal service activities; activities of households as employers of domestic personnel; undifferentiated goods and services producing activities of private households for own use; activities of extraterritorial organisations and bodies

Table 4 (continued)

Nace macro-category	2-digit sectors
Manufacturing	Manufacture and food products; manufacture of beverages; manufacture of tobacco products; manufacture of textile; manufacture of wearing apparel; manufacture of leather and related products; manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials; manufacture of paper and paper products; printing and reproduction of recorded media; manufacture of coke and refined petroleum products; manufacture of chemicals and chemical products; manufacture of basic pharmaceutical products and pharmaceutical preparations; manufacture of rubber and plastic products; manufacture of other non-metallic minerals products; manufacture of basic metals; manufacture of fabricated metal products, except machinery and equipment; manufacture of computer, electronic and optical products; manufacture of electrical equipment; manufacture of machineryand equipment; manufacture of motor vehicles, trailers and semi-trailers; manufacture of other transport equipment; manufacture of furniture; repair and installation of machinery and equipment

Table 5 Dependent and independent variables: descriptive statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Prod. Growth rate (08–18)	535	10.423	20.686	−68.516	198.376
Prod. Growth rate (12–18)	535	1.572	14.148	−37.314	95.638
Prod. Growth rate (13–18)	535	6.439	19.521	−62.973	259.976
Intensity_tot (2007)	535	15.404	76.931	0	977
Intensity_sub (2007)	535	1.552	4.186	0	53
Intensity_HQs (2007)	535	13.852	74.177	0	929
Geo_disp (2007)	535	0.366	0.703	0	2.94
Productivity level (2007)	535	51.935	14.887	10.098	175
Human capital (2007)	535	17.2	4.597	10.11	33.718
Production_structure (2007)	535	1.08	0.541	0.114	4.215
Population density (2007)	535	268.308	370.181	38.6	2631.5
Inst. quality (2007)	535	52.121	4.811	37.91	64.211
Intensity_tot (2012)	535	3.797	17.147	0	250
Intensity_sub (2012)	535	2.722	13.355	0	192
Intensity_hqs (2012)	535	1.075	3.937	0	58
Geo_disp (2012)	535	0.361	0.77	0	3.229
Productivity level (2012)	535	51.967	13.536	10.282	109.7
Human capital (2012)	535	16.973	4.481	10.243	31.952
Production_structure (2012)	535	1.089	0.589	0.079	4.94
Population density (2012)	535	268.31	370.181	38.6	2631.5
Inst quality (2012)	535	50.333	4.707	37.02	62.812

Table 6 Independent variables: correlation matrix

Variables 2007	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Intensity_tot	1.000								
(2) Intensity_sub	0.873	1.000							
(3) Intensity_HQs	0.899	0.842	1.000						
(4) Geo_disp	0.505	0.432	0.488	1.000					
(5) Initial_prodty	0.214	0.261	0.207	0.295	1.000				
(6) Human capital	0.218	0.176	0.217	0.133	−0.011	1.000			
(7) Production_ structure	0.007	0.029	0.006	0.003	−0.297	−0.092	1.000		
(8) Population density	0.237	0.366	0.225	0.198	0.061	0.177	−0.134	1.000	
(9) Inst_quality	−0.099	−0.111	−0.096	−0.146	−0.095	−0.129	0.077	−0.061	1.000
Variables 2012	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Intensity_tot	1.000								
(2) Intensity_sub	0.898	1.000							
(3) Intensity_HQs	0.872	0.853	1.000						
(4) Geo_disp	0.398	0.381	0.441	1.000					
(5) Productivity level	0.217	0.207	0.241	0.318	1.000				
(6) Human capital	0.142	0.135	0.163	0.118	−0.018	1.000			
(7) Production structure	−0.011	−0.010	−0.014	0.010	−0.291	−0.082	1.000		
(8) Population density	0.355	0.349	0.363	0.199	0.109	0.165	−0.129	1.000	
(9) Inst. quality	−0.088	−0.081	−0.110	−0.139	−0.061	−0.123	0.079	−0.061	1.000

Table 7 Spatial model diagnostics

Test	Statistics	*p*-value
Moran's I	8.412	0.000
Spatial error:		
LM	4.987	0.021
Robust LM	7.812	0.091
Spatial lag:		
LM	18.121	0.000
Robust LM	12.671	0.000

Diagnostics refer to a cross-section dataset, with NUTS-3 regions as unit of analysis

Table 8 Robustness checks

Productivity	08–18	08–18	08–18	08–18
	(1)	(2)	(3)	(4)
Intensity_tot	2.342**	2.384**	2.459**	2.197***
	(1.094)	(1.113)	(1.054)	(0.523)
Production_structure	−0.482	−0.454	−0.531	−1.763
	(1.075)	(1.159)	(1.061)	(1.562)
Initial productivity level	−0.896***	−0.905***	−0.889***	−0.858***
	(0.081)	(0.083)	(0.079)	(0.135)
Rho (ρ)	0.842***		0.861***	
	(0.080)		(0.066)	
Lambda (λ)	0.746***	0.927***	0.450***	
	(0.122)	(0.030)	(0.068)	
Network (spatially lagged)	−2.025			
	(2.322)			
Observations	535	535	535	535
NURS-3 dummies	Yes	Yes	Yes	Yes
Sectoral dummies	Yes	Yes	Yes	Yes
Spatial weighting matrix	Inverse Distance	Inverse Distance	Contiguity	
Model	SDEM	SEM	SAR	OLS

Standard errors in parentheses, clustered by region. ρ indicates the spatial lag term, λ the spatial correlated error term. Models have been estimated using the Stata command *xsmle* (Belotti et al., 2017)

*0.1; ** 0.05; *** 0.01

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