Regions on course for the Fourth Industrial Revolution: the role of a strong indigenous T-KIBS sector

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Abstract: From the perspective that a region's industrial development mostly builds upon existing local capability endowments to form a trajectory of related diversifications, we argue that regions with a strong technology-based knowledge-intensive business service (T-KIBS) sector potentially have resource-based relatedness in their 'knowledge space' allowing their local manufacturing sector to diversify production more easily towards Industry 4.0. The study assays whether the internal configuration of the local KIBS sector contributes to the economic outcome of local industry by implementing spatial econometrics models on a regionalized database for 24 European Union countries.

Keywords: Knowledge-intensive business service (KIBS) sector; technology-based knowledge-intensive business service (T-KIBS); related diversification; territorial servitization; fourth industrial revolution

JEL codes: L26, O14, R58

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1. Introduction

The study presented in this paper analyses how the heterogeneous innovation orientation of knowledge-intensive business service (KIBS) firms influences the economic contribution of industrial firms to the local economy, in terms of gross value added per worker. Consequently, in a context of the fourth industrial revolution, we explore whether the internal disruptive configuration of the local KIBS sector contributes to the creation of new industrial paths leading to improved economic trajectories of local industry.

Firms - and by extension regions - need to continually extend their digital and technological knowledge and skills if they want to remain competitive within the current fourth industrial revolution (Whittle & Kogler, 2020). To avoid stagnation and remain resilient, industrial regions must embark in technological expansion (Boschma, 2015). In such a context, resilience reflects the processes through which regional economies restructure their industrial and service-augmented technological base (Whittle & Kogler, 2020). Such diversification of the regional industrial base, by virtue of reconfiguring the underlying capabilities of a regional economy, can forge radical changes in its techno-economic structure (Weitzman, 1998). This can transform their underlying capabilities and avoid technological lock-ins (Saviotti & Frenken, 2008) and develop new growth paths (Martin & Sunley, 2007) that are more compatible with the local adoption of industry 4.0.

However, for many incumbent industrial regions, the knowledge and skill set required to produce and compete in the context of the fourth industrial revolution translates in radical change from existing capabilities. The radical reconfiguration of the underlying capabilities of a regional economy is often needed to adapt its techno-economic structure to industry 4.0. Yet, it has been repeatedly found that the success rate of regions diversifying into unrelated knowledge-space is extremely low (Bocshma et al., 2012; Pinheiro et al., 2018).

The guiding principles behind both the resource-based view (Penrose, 1959) and the evolutionary theory (Nelson & Winter, 1982) have highlighted that industry develops skills, routines and specializations overtime that determine the possibilities of future diversification (Boschma, Balland, & Kogler, 2014; Neffke, Henning, & Boschma, 2011). Industrial regions therefore diversify their production in ways related to an existing set of knowledge and skill (Hidalgo et al., 2007), suggesting that capabilities should be built at a regional level to enable the development of new capabilities. Consequently, the accumulation and production of knowledge is embedded in region-specific patterns which have been developed over time (Rigby & Essletzbichler, 1997). Therefore, local industry is more likely to adopt industry 4.0 processes if these are cognitively proximate to their existing skill-set (Whittle & Kogler, 2020).

Whilst regions strive to adapt their innovation systems to the trends of Industry 4.0, their existing knowledge base strongly conditions the ability of regions to successfully transform and adapt to the new conditions required to perform within the fourth industrial revolution (Kogler et al., 2017). In such innovation ecosystems, the role of KIBS has been found to be crucial for the resilience of local industry (Arnold et al., 2015; Den Hertog, 2000; Eraydin & Koroglu, 2007; Horváth & Rabetino, 2019; Macpherson, 2008; Martinez-Fernandez, 2010; Shearmur & Doloreux, 2013; Zhang, 2016). The self-reinforcing symbiotic relation between KIBS and local industry that has been observed by territorial servitization scholars to improve the performance of local industry in knowledge-driven economies (Lafuente et al., 2017; De Propris & Storai, 2019; Horváth & Rabetino, 2019; Wyrwich, 2019). Consequently, value-adding industrial transformation and performance in an era of industry 4.0 is likely to vary according to the functions and local knowledge dissemination readily accessible locally as a result of KIBS (Lafuente et al., 2019a).

Nevertheless, it is now well accepted that not all knowledge is equal (Whittle, 2019; Whittle & Kogler, 2020) and that, in their role of knowledge conduits, the heterogeneous nature of KIBS sectors may condition their contribution to local industrial performance in the context of the fourth industrial revolution (Corrocher et al., 2009) that embrace the adoption of smart manufacturing technologies such as artificial intelligence, real-time monitoring, robotics, 3D, mobile tech, space technology and drones (De Propris & Bailey, 2020).

KIBS sectors have been categorized into two main groups, technology-based KIBS (T-KIBS) and professional-based KIBS (P-KIBS) (Doloreux & Shearmur, 2010; 2011). T-KIBS, which include provision of digital and smart manufacturing technologies, bear higher innovation investments and depend to a great extent on the creation, absorption and distribution of knowledge (Strambach, 2008; Wyrwich, 2019). Thus, T-KIBS arguably play a more active role in the operational processes of manufacturing businesses and their transition through the fourth industrial revolution. P-KIBS, on the other hand, are based on professional services and support activities that depend more on expertise (Amara et al., 2016).

In this sense, building off the related diversification trajectory of a region's industry, based on the existing local knowledge space and capability set (Whittle & Kogler, 2020), regions with a strong indigenous T-KIBS sector are more likely to develop the territorial servitization processes compatible with the fourth industrial revolution (De Propris & Storai, 2019; Lafuente et al., 2019a).

Therefore, the research objective of the study is to identify whether the positive effect of KIBS on the local economic contribution of industrial firms, in terms of gross value added per worker, is stronger in regions where the configuration of the KIBS sector is skewed in favor of T-KIBS, as compared to P-KIBS.

To reach this objective, we employ spatial econometrics models on a database built from two separate sources (Regional Entrepreneurship & Development Index and Eurostat) that includes information for the years 2012-2014 for 121 European Union (EU) regions from 24 countries. The results suggest that disruptive territorial servitization processes are taking place in many EU regions (Lafuente et al., 2017). However, when separating T-KIBS and P-KIBS, the regional benefits in terms of GVA per worker are only found to be significant in regions with a strong T-KIBS sector. Therefore, in the context of the fourth industrial revolution the increased presence of disruptive T-KIBS firms pays-off for industrial firms and the local economy.

We differentiate from previous literature by suggesting and empirically assessing through an EU-wide analysis using spatial econometric methods that in regions with a strong indigenous T-KIBS industry (rather than P-KIBS) manufacturing firms are better equipped to implement possible industry 4.0 technologies that stimulate the competitiveness of local industry.

2. KIBS and regional industry

Most industrial policy today makes use of a variety of incentives and support schemes to facilitate the adaptation to industry 4.0 through innovation-driven business investments, considered sources of high-value employment, know-how and local industry competitiveness (Mudambi, 2008). Such policy is often used as an instigator and stimulus towards the fourth industrial revolution within local industries so as to promote local competitiveness and economic performance (Araya, 2019; Corrocher & Cusmano, 2014; Macpherson, 1997; 2008; Martinez-Fernandez, 2010). However, a wide body of empirical literature casts doubts on the positive contribution of such incentives if focused in isolation of the existing local value chains and its endogenous capability endowments (Ascani et al., 2016; Lafuente et al., 2017; Rocha & Sternberg, 2005). Innovation stimulus, when not embedded in the local economic fabric, tends to develop limited local linkages and pursue industrial functions with little to no disruptive value-adding spillovers (Hood & Young, 2000; Phelps, 2008). The benefits of Industry 4.0 stimulus "*...can only be delivered with parallel indigenous innovation efforts… and conducive innovation systems*" (Fu et al., 2011, p. 1210).

Disruptive innovation increasingly happens through collaboration (Crescenzi et al., 2016). Collaboration within a territorial system has become an increasingly important element in innovative activity, whether between firms, universities, public agencies and research teams

(Boschma, 2005; Boschma & Frenken, 2010; Johnston & Huggins, 2017). Much has been studied of the horizontal Marshallian additive collaborations found amongst members of the same sector allied as part of clusters (Porter, 2000) or industrial districts (Becattini et al., 2003). However, as public administrations seek to develop innovative ecosystems that favor the fourth industrial revolution, there has been a lack of understanding of the importance of vertical exchanges of territorial servitization among players up and down the local value chains. Vertical proximity, especially with advance business service providers is essential for knowledge-based transfers and collaborations, leading to capability development and disruptive local industrial innovativeness and competitiveness (Acs et al., 2013).

As opposed to the efficiency-based economies of the past century, the knowledge economy guiding the competitiveness of most industries today are much more reliant upon intangible resources and know-how as sources of sustainable strategic advantage (OECD, 2006; Rodríguez-Pose, 2013). In such a scenario, new ‘functional’ economies where the value-chain complementarities and collective competence along the local value chains are more important than pure industry specialization for agglomeration economies to take hold (Crescenzi et al., 2016). “*The key… does not come from economic territorial specialization or from the pure quantitative agglomeration of firms in a particular region, but rather from the inter-connections and complementarities that link these together*” (Lafuente et al., 2019a, p. 314).

For territorial economies, the proper configuration of local value chains has been found to stimulate knowledge flow and disruptive innovative capabilities leading to local product-service innovation systems that are compatible with industry 4.0 (Lin et al., 2014). The renaissance of local industry and its trend towards automation and data exchange in manufacturing technologies and processes have been linked to the synergetic process called territorial servitization (Lafuente et al., 2017), where local innovative capabilities develop from resilient incumbent manufacturers that attract knowledge-intensive business service firms (KIBS), that in-turn help to spur a renewed growth of innovative new manufacturing start-ups (Lafuente et al., 2019a). “*Territorial servitization is the symbiotic relation between knowledge-intensive service (KIBS) sectors and manufacturing firms as an engine for enhanced territorial resilience, manufacturing renaissance and competitiveness, as well as regional development*” (Lafuente et al., 2017, p. 20). From a territorial perspective, product-service innovation systems are rarely completely internalized by manufacturers. The decision to outsource access to required knowledge-intensive service capabilities is more often than not the norm rather than the exception in industrial regions where internal service provision frequently falls outside the capability frontier of local manufacturers (Buztinsa et al., 2019).

Götz & Jankowska (2017) observed that digital transformation in a region with tight interfirm collaboration may be advantaged by the local knowledge base. But they stressed that only local value chains equipped with adequate expert knowledge provision in the field of IT solutions and the technologies crucial to Industry 4.0 are able to gain a competitive foothold in the new industrial system. KIBS therefore play a decisive role in the fourth industrial revolution, where industrial firms interacting with KIBS are found to be more innovative (Muller & Zenker, 2001) and productive (Arnold et al., 2016) and generally better apt to compete in the context of the fourth industrial revolution (De Propris & Bailey, 2020).

As a result, local value chains composed of a diverse set of complementary product and service providers might be more adequate for developing the disruptive territorial servitization processes facilitating industry 4.0 than a service deficient local industrial specialization. In such an innovation ecosystem, the role of indigenous knowledge-intensive service provision is key where KIBS have been found to be crucial for the renaissance of local industry (Horváth & Rabetino, 2019). KIBS are both creators and transmitters of knowledge across the actors within a local innovation ecosystem (Shearmur & Doloreux, 2019; Vaillant et al., 2012). They are especially important to compensate the liability of smallness that often hampers the innovation quest of manufacturing SMEs that lack the internal resources and capabilities required for internal advance service development (Lafuente et al., 2019a). In a context of industry 4.0 where servitizing the production process is key for competitiveness, most manufacturers are faced with an inherent incapacity to generate the necessary internal service capabilities (Horváth & Rabetino, 2019). KIBS therefore 'inject' servitization across new and incumbent manufacturers of a given territory (Corrocher & Cusmano, 2014). As such, the presence of KIBS in a territory may act as a stimulus to greater industrial value-added in terms of the productivity of local industry. It is therefore hypothesized that:

Hypothesis 1: At the regional level, KIBS businesses have a positive impact on the economic performance of the local manufacturing industry, in terms of gross value added per worker.

However, the ability to develop value-adding industrial innovation is likely to vary according to the functions of the value chain that are readily accessible locally. Service provision is crucially important for the disruptive innovation capabilities of the local manufacturing industry in the most knowledge-intensive stages of the value chain (Bustinza et al., 2013). But not all knowledge-intensive service provision plays the same role within the territorial servitization process of the local product-service innovation system (Doloreux & Shearmur, 2011; Vaillant et al., 2012). As such, KIBS have been categorized into two main groups, technology-based KIBS (T-KIBS) and professional-based KIBS (P-KIBS) (Doloreux & Shearmur, 2010).

Many distinctions have been reported in the service literature, in terms of knowledge intensity and innovation among services, that lead to believe that KIBS are not necessarily uniform in the way they contribute to the gross value-added of the transformation of local industry (Snyder et al., 2016; Witell et al., 2016). Related literature and research have long categorized service innovation in ways that separate, for example, radical and incremental service innovations (Gallouj & Weinstein, 1997), as well as product and process service innovations (Vaux Halliday & Trott, 2010). More recent categorizations have been developed that propose that service innovation differs according to the customers' character and function (Michel et al., 2008), level of digitalization (Dotzel et al., 2013), and business model specificities (Chiu et al., 2013). Gallouj and Savona (2009) argue that because of the immaterial aspects of the contributions of services to innovation, underestimations of the service industry's local economic impact and performance are often made. This inaccurate measurement is not only in terms of intensity, but also in its variety (Gallouj & Savona, 2009). The nature of knowledge-intensive services and service innovation will have distinct impacts that will likely reverberate throughout local industry. Crucially, distinctions are expected to be especially pronounced in the way KIBS firms, depending on the type of services supplied, impact the strategic and financial performance of their industrial clients (Shearmur & Doloreux, 2015; 2019; Wyrwich, 2019).

Therefore, when considering the resilience potential of local manufacturing in a context of industry 4.0, and the capacity of local industrial innovation system to adapt to the current industrial revolution, the role and importance played by KIBS may differ depending on the nature of the knowledge-intensive service supplied. As such, T-KIBS and P-KIBS may influence the performance of local industry in different ways. T-KIBS and P-KIBS are both business services that predominantly depend on high human capital injections, intangible resources and knowledge intensity (Doloreux & Shearmur, 2011). However, these two generic types of KIBS are fundamentally different (Doloreux & Shearmur, 2010). The characteristics as well as the positioning of T-KIBS within the value chain of their clients are likely more connected to manufacturers' operations and, ultimately, to their economic outputs (Lafuente et al., 2017). On contrary, the characteristics of support services provided by P-KIBS are not always linked to business operations, which may imply that these services are less intensively used within their customers' value chain (Amara et al., 2016).

T-KIBS tend to use complex technologies, bear higher innovation investments and depend to a great extent on the creation, absorption and distribution of knowledge. The business model of T-

KIBS is more tightly connected to co-creating and commercially exploiting advanced knowledge through service transactions and provision. These sophisticated digital and technology-based services, which include provision of smart manufacturing technologies, are found to be conducive to greater disruptive innovation-driven and value-adding activity (Amara et al., 2016).

P-KIBS, on the other hand, are grounded on professional-based services and support activities that depend more on expertise. The exclusivity of such expertise is often the source of P-KIBS' competitiveness, and therefore these firms tend to be less prone to transfer their knowledge to other local firms (Doloreux et al., 2010). P-KIBS have also been found to be less engaged in innovation and co-creation activities (Shearmur & Doloreux, 2009). The advanced services supplied by P-KIBS may be of importance for local industry, but they are unlikely to stimulate the necessary flows of knowledge across a local value chain that can drive the territorial servitization process, and consequently local industrial performance (Amara et al., 2016). On the other hand, the greater involvement of T-KIBS in manufacturing operations is likely more conducive to a data-enhanced industrial transition leading to innovation-driven improvements in industries' value chain that are compatible with industry 4.0 implementation and have the potential to translate into superior economic performance. Doloreux et al. (2010) report that the main differentiating factor between the two types of KIBS that explains the different roles each play as knowledge providers and innovation propagators within a local economy come from their distinct levels of commitment to cooperation and networking with external organizations. As compared to P-KIBS, T-KIBS have a much higher propensity to exchange resources and knowledge within localized value-chain networks, making the entire regional industrial innovation system better equipped to confront the fourth industrial revolution (Doloreux et al., 2010; Hervas et al., 2019).

The geographical distribution of both types of KIBS often coincides (Corrocher et al., 2009) (as the correlation matrix found in Table A2 in the Appendix indicates). However, and regardless the size of KIBS sectors in the region, it is the internal configuration of the KIBS sector that plays a role of influence (Doloreux & Shearmur, 2011). New activities are never completely removed from the regions existing knowledge base (Boschma, 2017). Kogler and Whittle (2018) demonstrate for Irish NUTS-3 regions how technological diversification is strongly biased towards related areas of the knowledge space. It is therefore key to understand how local industries are cognitively predisposed to diversify and adopt activities characteristic of the fourth industrial revolution (Whittle & Kogler, 2020). Regions with T-KIBS have a potential resource-based relatedness in its 'knowledge space' allowing its local manufacturing sector to more easily diversify production towards industry 4.0.

From the arguments exposed above, the positive effect of KIBS on the local value-adding performance of industry can therefore be deduced to be stronger in regions with a greater regional rate of T-KIBS, as compared to P-KIBS. Therefore:

Hypothesis 2: The positive impact of KIBS on the economic performance of manufacturing sectors (gross value added per worker) is stronger in regions with greater T-KIBS to P-KIBS firms.

3. Data, variable definition and method

3.1 Data and regions

To reach the objective of this study data from two separate sources was used. First, this study employs secondary data on regional economic and industrial performance throughout Europe obtained from Eurostat databases. For all variables, values are averages between 2012 and 2014. Second, data coming from the Regional Entrepreneurship and Development Index (REDI) for the years 2012-2014 was used.

In this study the unit of analysis is the region, and both of these databases have been developed using standardized uniform data gathering and surveying methods across all the analyzed territories in our study, making the data suitable for territorial comparisons. The data does not permit internal analysis such as the properties of interfirm relationships nor the knowledge-intensive service utilization of specific manufacturers, which goes beyond the purpose of this study's regional-based model.

The time-frame covered by the data used in the study coincides with the trough of the economic and financial crisis in most of the EU. Nevertheless, although the economic downturn had important conjunctural effects on industrial productivity, this effect was quite heterogeneous across regions and countries. As such, the use of EU wide data dampens any biases that single market analysis would be likely to offer.

The final sample used in this study includes information for 24 countries totaling 121 EU regions. Due to information availability some NUTS 2 have been added to NUTS 1, resulting in a total of 121 observations (of which 54 NUTS-2 regions). This joint regional analysis approach is similar to that used by several recent studies looking into regional industrial development in Europe (e.g., Content et al., 2019; Horváth & Rabetino, 2019). Note that territories in Bulgaria, Cyprus, Luxembourg and Malta were not included due to unavailability of data. These countries only represent 1.75% of the EU-28 population, and less than 0.8% of its GDP.

3.2 Variable definition

Dependent variable. The dependent variable is, for each region, the average gross value added (GVA) per employee generated by manufacturing firms. The GVA measures the value of goods and services produced by the studied industry, thus representing a good proxy variable of the contribution of manufacturing businesses to the regional economy. Previous studies have applied this measure as the indicator of regional productivity (Esteban, 2000) and economic performance (Audretsch & Keilbach, 2004; Szerb et al., 2019). Because proximity is a key aspect of the influence of KIBS on the local economy, GVA is a preferred measure of the output of entities smaller than the economy as a whole (Dunell, 2009). GVA, in the context of the local economic impact of KIBS, becomes a better reflection of the productivity of local producers as it excludes the indirect transfers and taxes which could distort production processes (Munday & Roberts, 2006). Traditional output measures such as GDP can record sharp increases just on the account of increased tax collection due to better compliance and not necessarily due to increased output (Burgess, 2011). GVA therefore provides a better measure of local economic activity (Burgess, 2011; Dunnell, 2009; Szerb et al., 2019).

Regional rate of KIBS firms and proportion of KIBS. Following the classification of knowledge-intensive services proposed by the European Commission (2016), the main independent variable is the regional rate of KIBS, defined as the proportion of KIBS in the region's total number of business. Additionally, following the European Commission's (2016) classification as well as the prior studies on KIBS firms (Horváth & Rabetino, 2019; Wyrwich, 2019), we split KIBS firms according to whether they are more technology- (T-KIBS) or professional-oriented (P-KIBS) businesses. We consider T-KIBS as businesses operating in the fields of programming and broadcasting activities (NACE Rev-2: 60), telecommunications (NACE Rev-2: 61), computer programming, consultancy and related services (NACE Rev-2: 62), information service activities (NACE Rev-2: 63) and scientific research and development (NACE Rev-2: 72). The group of P-KIBS includes businesses whose main activity falls into the following categories: water transport (NACE Rev-2: 50), air transport (NACE Rev-2: 51), legal and accounting activities (NACE Rev-2: 69), activities of head offices; management consultancy activities (NACE Rev-2: 70), architectural and engineering activities; technical testing and analysis (NACE Rev-2: 71), advertising and market research (NACE Rev-2: 73), other professional, scientific and technical activities (NACE Rev-2: 74), employment activities (NACE Rev-2: 78), and security and investigation activities (NACE Rev-2: 80).

For the empirical analysis, multiple variables linked to KIBS firms are employed. First, we use the regional rate of KIBS, defined as the number of KIBS firms divided by the total number of firms. Second, two variables account for the internal configuration of the KIBS sector in the region: number of T-KIBS divided by total number of KIBS, and number of P-KIBS divided by the total number of KIBS. Descriptive statistics in Table 1 reveal that, among the analyzed EU regions, KIBS businesses are primarily oriented to professional activities (P-KIBS). Finally, note that the proportion of T-KIBS is introduced in all regression models (the reference group is P-KIBS).

----- Insert Table 1 about here -----

Control variables. We control for the quality of the regions' entrepreneurial ecosystem, the size of manufacturing firms, agglomeration economies (population density and capital city), GDP per capita, and location in the different model specifications.

First, the quality of the entrepreneurial ecosystem is measured via the REDI score. The Regional Entrepreneurship and Development Index (REDI), originally developed by Szerb et al. (2014), is an index number that seeks to measure the quality of the entrepreneurial ecosystem. As Acs et al. (2015) argue, regions may benefit from entrepreneurial processes that contribute to better allocate resources to the local economy, enhance disruptive innovativeness and, subsequently, the economic performance of industry. This process is likely influenced by the local entrepreneurial ecosystem (Szerb et al., 2019). The REDI index results from the combination of a number of variables obtained from multiple sources, including the Adult Population Survey (APS) of the Global Entrepreneurship Monitor (GEM), Eurostat, World Bank, World Economic Forum, and the Heritage Foundation (Szerb et al., 2014). The REDI index—which constitutes a reliable index number to measure the quality of the regional entrepreneurial ecosystem—offers a rich diversity of individual, micro and regional information related to entrepreneurial activity across Europe. The REDI scores—which are computed at regional level thus ensuring its compatibility with the rest of the data used in this study—have been used in prior studies dealing with the quality of regional entrepreneurial ecosystems (Acs et al., 2015; Audretsch & Belitski, 2017; Lafuente et al., 2019b; Szerb et al., 2019).

Second, average size of manufacturers (employees) is used as a relevant indicator that helps to measure if industrial firms can develop economies of scale and have more access to resources. Following prior work (e.g., Swamidass & Kotha, 1998; Szerb et al., 2019), we expect that larger businesses also have better performance, in terms of GVA per worker.

Third, additional regional characteristics are controlled for. On the one hand, agglomerations are considered, as they are deemed conducive to performance because they offer the opportunity to businesses for exploiting an increased local demand, greater access to cheaper production factors

(Bottazzi & Gragnolati, 2015; Smith & Florida, 1994) and knowledge spillovers (Glaeser et al., 1992). Additionally, location in large or densely populated cities may prove itself critical to access skilled labor resources (Meliciani & Savona, 2015). Therefore, in our study we follow the practice of Meliciani and Savona (2015) and Szerb et al. (2019) and assess the role of urbanization by introducing regional population density and a dummy for regions with a capital city. Finally, we include a set of country dummy variables to rule out potential country-specific effects that may explain differences in GVA per worker across regions.

3.3 Method

In this study a spatial econometrics approach is used to test for the presence and reveal the nature of spatial interactions among the study regions, and evaluate the proposed hypotheses empirically. For this purpose, we follow the methodological plan for cross-section data described in Anselin and Rey (2014). As a point of departure, the non-spatial linear (OLS) regression model takes the following form:

$$\mathbf{Y}_i = \beta_0 + \beta\mathbf{Z}_i + \delta\mathbf{X}_i + \varepsilon_i \quad (1)$$

In equation (1), the dependent variable (**Y**) is the average manufacturing GVA per worker, whereas **Z** denotes the vector of the key independent variables connected to the KIBS industry: rate of KIBS in the region and the configuration of the local KIBS sector (proportion of T-KIBS, and the proportion of P-KIBS is the reference group). The vector **X** includes the control variables: the REDI index as a proxy of the entrepreneurial ecosystem, average size of manufacturing firms, population density, capital city dummy, GDP per capita, and the set of country dummy variables. Note that we logged the REDI index, the average employment in manufacturing firms, population density and GDP per capita in order to reduce skewness.

In the presence of spatial dependence between the study regions, OLS models are not applicable because a correlation exists between the geographic observations (Anselin, 1988; L'Horty & Sari, 2019). Therefore, two spatial models are considered, namely a spatial autoregressive model and a spatial error model. The spatial autoregressive model (SAR) suggests that the spatial dependence between neighboring regions lies in the similarity (or dissimilarity) of their dependent variables (i.e., in our case, the productivity level of their regional manufacturing sector).

$$\mathbf{Y}_i = \rho W\mathbf{Y}_i + \beta_0 + \beta\mathbf{Z}_i + \delta\mathbf{X}_i + \varepsilon_i \quad (2)$$

In equation (2), W is the spatial weight matrix that describes the spatial connections between regions and ρ is the regression parameter of the spatially lagged dependent variable.

In the spatial error model (SEM) the spatial dependence emerges in the error terms and takes the following form:

$$\mathbf{Y}_i = \beta_0 + \beta\mathbf{Z}_i + \delta\mathbf{X}_i + \varepsilon_i \quad (\varepsilon_i = \lambda W\varepsilon_i + \mu_i) \tag{3}$$

In SEM models (equation (3)) the error term of unit *i* (ε_i) depends on the error terms of neighboring regions (with λ parameter) determined by the spatial weights matrix (W) and an idiosyncratic component (μ_i). The spatial autocorrelation modeled in equation (3) (SEM model) can be consequence of either omitted variable problems or spatial data aggregation.

Based on Anselin and Rey (2014), we use Lagrange Multiplier (LM) and robust LM tests to verify the most appropriate model. After testing the OLS models against the proposed spatial configurations (SAR and SEM) with four spatial weight matrices—namely, queen contiguity, binary distance, inverse distance and inverse distance squared matrices—the results of the LM and robust LM tests indicate the use of the spatial models. For both model specifications—first, with only the rate of KIBS and second, adding the proportion of T-KIBS—the LM and robust LM tests point to a stronger spatial dependence with the use of the binary weight matrix. Therefore, and similar to Fritsch and Slavtchev (2011) and L'Horty and Sari (2019), we employ the SEM model (equation (3)) in our analysis and estimate the regression parameters using the maximum likelihood (ML) method (Greene, 2003). Table A3 in the Appendix displays the detailed results of the spatial diagnostic tests while, for comparative purposes, Table A4 presents the OLS results.

In terms of the study hypotheses, we expect that $\beta > 0$ for the variable measuring the rate of KIBS in the local economy to corroborate that KIBS businesses have a positive impact on economic performance of local manufacturing industry, in terms of the gross value added per worker (**H1**). Additionally, a positive result for the coefficient linked to the variable measuring the configuration of the KIBS sector ($\beta > 0$ for the proportion of T-KIBS) would corroborate that the positive effect of KIBS on the economic performance of local manufacturing industry is stronger in regions with a greater proportion of T-KIBS than P-KIBS (**H2**).

4. Results

This section presents the results of the spatial regression models (SEM: equation (3)) relating KIBS rates and the economic contribution of industrial businesses, in terms of GVA per worker. Prior to reporting the empirical findings, note that we computed the VIF values for all models in order to evaluate the potential threat of collinearity. Results in Table 2 indicate that, for all model specifications, the average VIF as well as the maximum VIFs are below the commonly used cut-off threshold of ten (Greene, 2003). The results of this diagnostic test therefore do not raise collinearity concerns.

Concerning the key findings of the study, regression results in model 1 (Table 2) indicate that the mere presence of more KIBS businesses (regional rate of KIBS) is not enough to generate value-adding interactions between productive industries and KIBS firms that will arguably materialize in greater economic outcomes. Therefore, hypothesis 1 (**H1**) that proposes a positive relationship between the regional rate of KIBS and GVA per worker for that region is not confirmed.

The positive effects of a strong KIBS sector might be conditional on the organizational and operational heterogeneity of KIBS businesses (Wyrwich, 2019). Looking at the coefficients in model 2 (Table 2), it is plausible to argue that not all KIBS are active knowledge brokers with the capacity to trigger industrial productivity. Although prior results suggest that territorial servitization processes are taking place in many European regions (Bellandi & Santini, 2019; De Propris & Storai, 2019; Lafuente et al., 2017), the positive benefits of the territorial presence of an active hybrid value chain composed of a mixture of industry and KIBS firms only materialize in greater manufacturing economic performance in the case of greater proportion of T-KIBS in the region. Therefore, the local presence of T-KIBS firms pays-off for industrial firms and the territorial product-service innovation system.

The results in model 2 of Table 2 indicate that, regardless the overall regional rate of KIBS firms, industrial sectors in a region will produce more economic output (GVA per worker) if the focal region enjoys a KIBS industry with a local configuration skewed towards T-KIBS firms. The change in the relative proportionality of T-KIBS in a region positively changes the local manufacturing labor productivity. Therefore, hypothesis two (**H2**), that proposes that the positive relationship between KIBS and manufacturing GVA per worker is stronger in regions with a greater proportion of T-KIBS, is confirmed.

----- Insert Table 2 about here -----

The results in Table 2 indicate that the coefficient for the proxy control variable used to measure the quality of the entrepreneurial ecosystem (REDI) positively impacts GVA per worker and that this effect is consistent throughout the different model specifications. This result is similar to prior work emphasizing that a healthy entrepreneurial ecosystem is likely to generate innovative disruptions that are conducive to territorial outcomes (e.g., Horváth & Rabetino, 2019; Lafuente et al., 2019b; Szerb et al., 2019).

Taken together, notwithstanding endogenic-based distortions, the relations between the model's independent variables the empirical findings reported in this section support the idea that KIBS' heterogeneity should be taken into consideration when modeling their economic impact on territorial performance. P-KIBS are important economic players but they tend to be less engaged in disruptive innovation and co-creation activities, which may reduce the economic impact of their services (Amara et al., 2016; Doloreux & Shearmur, 2010). On contrary, the superior innovation orientation as well as the higher involvement of T-KIBS in key Industry 4.0 operations will likely have a greater impact on the value chain of industrial businesses. From the perspective of the regional hybrid value chain (Lafuente et al., 2019a), these potential interactions may facilitate the local development of fourth industrial revolution processes that translate into superior economic performance, in terms of manufacturing productivity (GVA per worker).

5. Concluding remarks, policy implications and future research lines

5.1 Concluding remarks

This study gives evidence of the importance that the regional configuration of the heterogeneous nature of the KIBS sector has for the disruptive economic and productive transformation of local industrial sectors in the context of the fourth industrial revolution. From the evolutionary resourced-based perspectives that a region's industrial development mostly builds upon existing local capability endowments to form a trajectory of related diversifications (Whittle & Kogler, 2020), and building on the framework of territorial servitization (Lafuente et al., 2017; 2019a), we argue that the impact of KIBS businesses on manufacturing performance (GVA per worker) is conditioned by the specific nature of the locally present knowledge-intensive service provision through KIBS businesses. Regions with T-KIBS have a potential resource-based relatedness in its 'knowledge space' allowing its local manufacturing sector to more easily diversify production towards industry 4.0.

Overall, the findings are consistent with prior work emphasizing the heterogeneity of KIBS sectors as well as the relevance of taking into consideration these differences to understand how KIBS contribute to regional outcomes (e.g., Amara et al., 2016; Lafuente et al., 2017; Wyrwich, 2019). By analyzing the role of T-KIBS on the economic output of manufacturing sectors in 121 EU regions from 24 countries, the results suggest that industrial firms can benefit more from the relative greater local presence of T-KIBS (than P-KIBS). This is not to say that P-KIBS do not carry economic benefits, but a dynamic local value chain containing a generous proportion of T-KIBS is found to materialize in a more productively disruptive local product-service innovation system. Regions where their industry already has a readily available local source of technological capabilities through the strong local presence of T-KIBS, are better prepared due to their related capability base to evolve into industry 4.0 and be competitive in the fourth industrial revolution.

5.2 Policy implications

Industry is called upon to embark in technological change brought about by the fourth industrial revolution (De Propris & Bailey, 2020). A new wave of technological innovations has started to fundamentally alter industrial production, disrupting its organization and processes. In such an increasingly complex European productive environment where the mechanisms driving regional development have become key policy targets, policy makers are progressively prioritizing the design of coordinated actions that help endow local industry of smart manufacturing capacity leading them to consolidate their knowledge-based economies (OECD, 2011).

The transition of local industry to these new data-intensive smart productive models can be very challenging for incumbent manufacturers that work on established routines and often lack the resources and capabilities for the product-service innovation embedded in the fourth industrial revolution (Benedetti et al., 2015). At the same time, the adoption of smart manufacturing technologies such as artificial intelligence, real-time monitoring, robotics, 3D, mobile tech, space technology and drones can also be very challenging for new and small industrial ventures (Grönroos & Voima, 2013). In their role as knowledge conduits, the presence of a strong local KIBS sector, but T-KIBS in particular, is found to help facilitate the adoption and development of such smart manufacturing capacity. Thus, T-KIBS are found to play an active role in the operational processes of manufacturing businesses and are likely to facilitate the transition of local industry towards a more competitive stance within the fourth industrial revolution. As such, certain policy implications emerge from the results of the study.

Regional hybrid value chains.—KIBS businesses are both sources and conduits of knowledge that are potentially conducive to territorial performance by providing high value-adding services facilitating smart capacity-building for local manufacturers. We argue that KIBS' activities are decisive for the renaissance of manufacturing sectors, the functioning of local territorial servitization processes, and the development of an entrepreneurial ecosystem that is more Industry 4.0 compatible (Lafuente et al., 2017; 2019a). Our results suggest that KIBS are a relevant dimension of the heterogeneous structure of regions and manufacturing productivity. Thus, we suggest that, to develop a strong KIBS sector, policy makers need to turn their attention to the specific characteristics of the focal territory and implement support actions that facilitate the connection between manufacturing and KIBS businesses and, subsequently, enhance the smart manufacturing capacity of the local value chains (e.g., networking opportunities or digital infrastructure and platforms).

The implications for EU policy-makers reside on suggestions from our finding that policy should adopt 21st century reindustrialization strategies based on knowledge-based development and regional competitive advantage (European Commission, 2017). The balance of regional policy between achieving the benefits of the current industrial revolution and assuring that local incumbent manufacturers are not left behind may lay in the adoption of discriminating choices concerning the local presence of a healthy knowledge intensive business service industry (Hervas-Oliver et al., 2019). Our findings reveal a variety of economic structures across European regions. We suggest that regional industrial policy needs to prioritize the development of tailor-made policies that promote manufacturing productivity through the implementation of harmoniously interlinking regional hybrid value chains (Bailey et al., 2020). Such value-adding inter-organizational fit is found to be more appropriate for effective territorial servitization processes to occur and disruptive production to emerge. Because the key to local productive development no longer comes from economic territorial specialization or from the pure quantitative agglomeration of firms in a particular region, policy should first and foremost abandon these ill-founded premises. Recognition of the value of local hybrid value-chain inter-connections and complementarities that link the local product-service innovation system together is primordial. Consequently, recognizing the value of knowledge-intensive service activity firms as valuable conduits of this disruptive innovation system is important.

Service firms, T-KIBS included, substantially differ from the manufacturing firms that support policies have mostly favored in the past. Distributing and evaluating the effectiveness of assistance based on employment, investment or even R&D capacity criteria may not be compatible with service-based firms. Adopting these common selection norms disfavor needed T-KIBS, which as our study has found, is key for localized manufacturing productivity, in terms of GVA. By excluding T-KIBS, policy may actually be omitting the main component required within the local product-service innovation system to allow manufacturers to prosper and generate the sought-after employment, investment and R&D capacity.

From a territorial servitization perspective, the approach to entrepreneurship policy should not be a dichotomous one (‘yes’ or ‘no’) to new productive or new unproductive businesses, but rather should seek a new form of governance of entrepreneurship policy that is more compatible with the characteristics of the local economy as well as the local industrial fabric. In our view, regions with a strong manufacturing tradition where territorial servitization is taking place should encourage mostly productive entrepreneurship linked to more disruptive, value-adding and co-creation enabling T-KIBS sectors (a concept closer to the entrepreneurship approach by Schumpeter (1934)). The promotion of generic entrepreneurial action as well as specific investments that support local business complementarities and coherent innovative entrepreneurial activity (Corrocher & Cusmano, 2014) may well be an optimal policy to stimulate greater organizational fit in those regions lacking a consolidated hybrid value chain, setting the conditions that enable industrial progress (Bellandi et al., 2019).

5.3 Directions for future research

As with any study, the results presented in this study are open to future verification, and it would be valuable to extend the proposed analysis in various directions. First, like other studies on territorial servitization (e.g., Horváth & Rabetino, 2019; Lafuente et al., 2017; Wyrwich, 2019), data do not permit the direct analysis of the existing relationships between KIBS and manufacturing businesses. Also, we cannot evaluate how manufacturing businesses internalize knowledge-intensive services into their operations. Further research on this issue would be valuable. For example, future work should scrutinize the depth in the connections between KIBS and new manufacturing businesses at territorial level, and determine the properties of the collaborations between KIBS and manufacturing firms as well as the impact of such associations on territorial outcomes.

Second, there is the already mentioned possibility that the independent variables related to the KIBS sector are endogenous. In models like ours—in which spatial models are used to correlate KIBS-related variables to manufacturing outcomes in a cross-sectional setting—this may condition the conclusions that can be drawn from the analysis. Future work in this direction should be developed. For example, prior studies have reported a relationship between public R&D infrastructures and the development of a strong KIBS sector (e.g., Corrocher & Cusmano, 2014). Future research can explore the economic response of KIBS and territorial servitization to different support programs and infrastructures (R&D-related or entrepreneurship-related) in different geographic settings.

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List of tables

Table 1. Descriptive statistics for the study variables

Variable	Mean	Median	Standard deviation	Minimum	Maximum
Average manufacturing GVA per manufacturing workers (€ thousands)	72.34	74.30	38.00	47.70	86.50
Rate of KIBS (regional level)	0.2199	0.2118	0.0846	0.1551	0.2625
Proportion of T-KIBS (among KIBS)	0.1707	0.1756	0.0520	0.1400	0.2024
REDI	44.57	44.70	14.84	33.20	55.90
Size of manufacturers	16.08	13.28	9.32	9.56	20.54
Capital city dummy	0.1983	0.0000	0.4004	0.0000	0.0000
Population density	349.80	112.30	907.56	73.37	285.83
GDP per capita (€ thousands)	25.96	24.58	9.15	19.60	30.35

Sample size: 121 observations. GDP, gross domestic product; GVA, gross value added; KIBS, knowledge-intensive business service; REDI, regional entrepreneurship and development index; T-KIBS, technology-based knowledge-intensive business service.

Table 2. Territorial Servitization: Fixed-effects regression results

Dependent variable: Average manufacturing GVA per employee (€ thousands, ln)	Model 1 Coefficient (robust standard error)	Model 2 Coefficient (robust standard error)
Rate of KIBS	–0.0078 (0.0057)	–0.0080 (0.0056)
Proportion of T-KIBS (among KIBS)		3.1750 (1.4951)**
REDI (ln)	1.0324 (0.3135)***	0.7339 (0.3725)**
Size of manufacturers (ln)	–0.0174 (0.1237)	–0.0699 (0.1153)
Capital city dummy	–0.0781 (0.1899)	–0.1567 (0.1983)
Population density (ln)	–0.0123 (0.0442)	0.0061 (0.0431)
GDP per capita (ln)	0.1829 (0.2961)	0.2829 (0.3024)
Country dummies	Yes	Yes
Constant	–1.2230 (2.0361)	–1.5966 (2.0401)
Spatial Lambda (λ)	0.6234 (0.1676)***	0.6123 (0.1712)***
R2	0.4661	0.4915
Adjusted R2	0.3956	0.4188
Log-likelihood	–61.3318	–59.2788
F-test	6.1123***	6.2820***
RMSE	0.4846	0.4752
Average VIF (minimum–maximum)	2.47 (1.23–7.62)	2.80 (1.26–8.35)
Observations	121	121

Notes: Robust standard errors adjusted by heteroskedasticity are presented in parentheses. All spatially lagged models are calculated with a row-standardized binary distance weight matrix. GDP, gross domestic product; GVA, gross value added; KIBS, knowledge-intensive business service; REDI, regional entrepreneurship and development index; RMSE, root mean square error; T-KIBS, technology-based knowledge-intensive business service; VIF, variance inflation factor.
*, **, *** = significance at the 10%, 5% and 1%, respectively.