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

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Abstract: 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 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 T-KIBS sector potentially have resource-based relatedness in their 'knowledge space' allowing their local manufacturing sector to more easily diversify production towards industry 4.0. The study assays whether the internal configuration of the local KIBS sector contributes to the economic outcome of local industry (GVA per worker). To do so we employ spatial econometrics models on a multiple sourced database that includes regional information for 24 EU countries. The main findings indicate that the local presence of Technology-based KIBS firms pays-off for the economic performance of regional industry.

Keywords: KIBS sector, T-KIBS, related diversification, territorial servitization, fourth industrial revolution

JEL codes: L26, O14, R58

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

1. Introduction

The study presented herein 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 the context of the fourth industrial revolution, it is argued that the internal configuration of the local KIBS sector contributes to improvements in the economic trajectories of local industry. The compatibility of that configuration with the knowledge-space required to perform better in the Industry 4.0 context makes it easier for local industries to take these improved economic trajectories.

Firms, and the regions that harbour them, need to continually extend their digital and technological knowledge and skills if they want to remain competitive in the current era of the fourth industrial revolution (Whittle & Kogler, 2020), which embraces 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). To avoid stagnation and remain competitive, industrial regions must embark on technological expansion (Boschma, 2005). In such a context, competitiveness is marked by the processes whereby regional economies restructure their industrial and service-augmented technological bases (Whittle & Kogler, 2020). Such diversification of the regional industrial base, by 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, 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 traditional manufacturing regions, the knowledge and skill sets required to produce and compete in the context of the fourth industrial revolution require radical changes to their 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. However, it has been repeatedly found that the success rate of regions diversifying into unrelated knowledge-spaces is extremely low (Boschma & Frenken, 2010; Pinheiro et al., 2018).

The guiding principles behind both the resource-based view (Penrose, 1959) and evolutionary theory (Nelson & Winter, 1982) have highlighted that industry develops skills, routines and specialisations over time that determine the possibilities of future diversification (Boschma & Frenken, 2010; 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 that 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).

While regions strive to adapt their innovation systems to the trends of Industry 4.0, their existing knowledge base strongly conditions their ability to successfully transform and adapt to the new conditions required to perform in the fourth industrial revolution (Kogler et al., 2017). In such innovation systems, the role of KIBS has been found to be crucial for the tenaciousness of local industry (Arnold et al., 2016; Horváth & Rabetino, 2019; Macpherson, 2008; Martinez-Fernandez, 2010; Shearmur & Doloreux, 2013). The self-reinforcing symbiotic relationship between KIBS and local industry has been observed by territorial servitization scholars to improve the performance of local industry in knowledge-driven economies (De Propris & Storai, 2019; Horváth & Rabetino, 2019; Lafuente et al., 2017; Wyrwich, 2019). Consequently, in the Industry 4.0 era, the type of value-adding industrial transformation and resulting performance is likely to vary according to the functions and dissemination of local knowledge that is readily accessible as a result of KIBS (Lafuente et al., 2019). However, it is now widely accepted that not all knowledge is equal (Whittle, 2019; Whittle & Kogler, 2020) and that, in their role as knowledge conduits and due to their heterogeneous nature, KIBS sectors may condition their contribution to local industrial performance in the context of the fourth industrial revolution (Corrocher et al., 2009).

KIBS sectors have been categorised into two main groups, technology-based KIBS (T-KIBS) and professional-based KIBS (P-KIBS) (Doloreux & Shearmur, 2011). T-KIBS, which include digital and smart manufacturing technologies, bear higher innovation investments and depend to a great extent on the creation, absorption and distribution of knowledge (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 regard, building on the related diversification trajectory of a region's industry, and based on the existing local knowledge space and capability set (Whittle & Kogler, 2020), the literature offers some clues as to how different kinds of KIBS impact the technological transformation of regions in different ways (De Propris & Storai, 2019; Lafuente et al., 2019).

However, the topic is still underexplored and there are no studies assessing the role of strong T-KIBS sectors in regions facing the challenges of the fourth industrial revolution.

The rationale put forth in this study is that regions with a strong indigenous T-KIBS sector are more likely to develop territorial servitization processes that are compatible with the fourth industrial revolution. The research objective is therefore 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 favour of T-KIBS, as compared to P-KIBS. It is argued that regions with strong T-KIBS sectors benefit from a resource-based relatedness that is compatible with the knowledge-space required to perform in the fourth industrial revolution.

To achieve this objective, we employ spatial econometric models on a database built from two separate sources (Regional Entrepreneurship & Development Index and Eurostat) that include information for the years 2012-2014 for 121 European Union (EU) regions in 24 countries. The results suggest that disruptive territorial servitization processes are occurring 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 T-KIBS firms pays off for industrial firms and the local economy.

We differentiate from previous literature by suggesting, and empirically assessing by means of an EU-wide analysis using spatial econometric methods, that in regions with a strong indigenous T-KIBS industry (as opposed to 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 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 (Corrocher & Cusmano, 2014; Macpherson, 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 their endogenous capability endowments (Fu et al., 2011; Lafuente et al., 2017). 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

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value-adding spillovers (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).

Innovation increasingly happens through collaboration (Crescenzi et al., 2016), which within a territorial system has become an increasingly important element of innovative activity, whether between firms, universities, public agencies or research teams (Boschma, 2005; Boschma & Frenken, 2010). 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) have been widely studied. However, as public administrations seek to develop innovative systems that favour 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 advanced business service providers is essential for knowledge-based transfer and collaboration, leading to capability development and local industrial innovativeness and competitiveness (Acs et al., 2015).

As opposed to the efficiency-based economies of the last century, the knowledge economy guiding the competitiveness of most industries today is 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 with value-chain complementarities and collective competence along the local value chains are more important than pure industry specialisation 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., 2019, p. 314).

For territorial economies, the proper configuration of local value chains has been found to stimulate knowledge flow and innovative capabilities. These can lead local innovation systems to benefit from a hybrid configuration of product and service providers that are compatible with Industry 4.0 (Mudambi, 2008). The renaissance of local industry and its shift towards automation and data exchange in manufacturing technologies and processes has been linked to the synergetic process called territorial servitization (Lafuente et al., 2017), where local innovative capabilities develop when tenacious incumbent manufacturers attract knowledge-intensive business service firms (KIBS) that in turn help to spur the renewed growth of new, innovative manufacturing start-ups (Lafuente et al., 2019). "*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 internalised 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 (Bustinza et al., 2019).

Götz & Jankowska (2017) observed that digital transformation in a region with tight inter-firm collaboration may be advantaged by the local knowledge base. But they stressed that only local value chains equipped with adequate expert knowledge 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 them are found to be more innovative (Muller & Zenker, 2001) and productive (Arnold et al., 2016) and generally more suited to compete in this context (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 that facilitate Industry 4.0 than a service-deficient local industrial specialisation. In such an innovation system, indigenous knowledge-intensive service provision plays a key role, and 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 system (Shearmur & Doloreux, 2019; Vaillant et al., 2012). They are especially important to compensate for the liability of smallness that often hampers the quest for innovation by manufacturing SMEs that lack the internal resources and capabilities required for internal, advanced service development (Lafuente et al., 2019). In a context of Industry 4.0, where servitization of the production process is a key factor 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 for greater industrial value-added in terms of the productivity of local industry. It is therefore hypothesised 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.

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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 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 categorised into two main groups, technology-based KIBS (T-KIBS) and professional-based KIBS (P-KIBS) (Doloreux & Shearmur, 2011).

Many distinctions have been reported in the service literature, in terms of knowledge intensity and innovation among services, that lead to the belief that KIBS are not necessarily uniform in the way they contribute to the transformation of local industry, and consequently, their gross value-added per worker (Miles et al., 1995; Snyder et al., 2016; Witell et al., 2016). Related literature and research have long categorised service innovation in ways that separate, for example, radical and incremental service innovations (Gallouj & Savona, 2009), as well as product and process service innovations (Vaux Halliday & Trott, 2010). More recent categorisations have proposed that service innovation differs according to the customers' character and function (Michel et al., 2008), level of digitalisation (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 variety. 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 tenaciousness of local manufacturing in a context of Industry 4.0, and the capacity of local industrial innovation systems to adapt to the current industrial revolution, the role and importance of KIBS may differ depending on the nature of the knowledge-intensive service supplied. Based on the distinctive properties of KIBS firms, Miles et al. (1995, pp. 29-30) proposed a definition of KIBS that distinguishes "professional services (P-KIBS)" from "new technology-based services (T-KIBS)." P-KIBS activities include traditional professional services (e.g., marketing, consultancy, legal, training, and audit services), whereas the activity of T-KIBS firms has more to do with ICTs and technical activities that directly support the operations of their corporate customers (e.g., big data management, cloud computing, computer networking, software development, and technical engineering). 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 injections of human capital, intangible resources and knowledge intensity (Doloreux & Shearmur, 2011). However, these two generic types of KIBS are fundamentally different (Doloreux et al., 2010). The characteristics as well as the positioning of T-KIBS within their clients' value chain are likely to be more connected to manufacturers' operations and, ultimately, to their economic outputs (Lafuente et al., 2017). On the 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 chains (Amara et al., 2016).

T-KIBS tend to use complex technologies, bear higher innovation investments and depend to a greater extent on the creation, absorption and distribution of knowledge. Their business model 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 these firms therefore 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, 2015: 2019). 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 to be more conducive to a data-enhanced industrial transition leading to innovation-driven improvements in industries' value chains 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 that 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 organisations. Compared to P-KIBS, T-KIBS have a much higher propensity to exchange resources and knowledge within localised value-chain networks, making the entire regional industrial innovation system better equipped to confront the fourth industrial revolution (Doloreux et al., 2010; Hervas-Oliver et al., 2019).

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The geographical distribution of both types of KIBS often coincides (Corrocher et al., 2009) (as shown by the correlation matrix in Table A2 of the Appendix). However, and regardless the size of KIBS sectors in the region, it is the internal configuration of the KIBS sector that plays the most influential role (Doloreux & Shearmur, 2011). New activities are never completely isolated from the region's existing knowledge base (Boschma, 2005). 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 essential 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 their 'knowledge spaces' that enables their local manufacturing sectors to more easily diversify production towards Industry 4.0.

From the arguments exposed above, the positive effect of KIBS on local value-adding industrial performance is expected to be stronger in regions with a greater proportion of T-KIBS than 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 a greater proportion of T-KIBS than P-KIBS.

3. Data, definition of the variables and method

3.1 Data and regions

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

In this study, the unit of analysis is the region, and both of these databases have been developed using standardised uniform data gathering and surveying methods across all the analysed territories in our study, making the data suitable for territorial comparisons. The data does not allow internal analysis of such matters as the properties of inter-firm relationships or the knowledge-intensive service utilisation of specific manufacturers, which would in any case go 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

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important conjunctural effects on industrial productivity, this effect was relatively heterogeneous across regions and countries. As such, the use of EU-wide data dampens any biases that a single-country analysis would be likely to offer.

The final sample used in this study includes information for 24 countries, totalling 121 EU regions. Due to constraints, the data includes 54 NUTS2 regions while the remainder are NUTS1 regions. Such a joint regional analysis is a similar approach to that used in several recent studies of regional industrial development in Europe (e.g., Content et al., 2019; Horváth & Rabetino, 2019). Table A1 in the Appendix presents a list of the regions included in the analysis. 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. 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, is a better reflection of local productivity as it excludes the indirect transfers and taxes that could distort production processes (Munday & Roberts, 2006). Traditional output measures such as GDP can record sharp increases merely on account of increased tax collection due to better compliance and not necessarily due to increased output. GVA therefore provides a better measure of local economic activity (Dunnell, 2009; Szerb et al., 2019).

Regional share 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 share of KIBS, defined as the proportion of KIBS out of the region's total number of businesses. Because of their specific knowledge- and technology-based processes, KIBS firms have been described as knowledge brokers with the capacity to generate and exploit technical and organisational knowledge which adds value for their customers (Muller & Zenker, 2001; Horváth & Rabetino, 2019; Wyrwich 2019). Additionally, based on the distinctive properties of KIBS firms, Miles et al. (1995, pp. 29-30) proposed distinguishing "professional services (P-KIBS)" from "new technology-based services (T-KIBS)". These arguments reinforce the idea of further scrutinising the specific effect of different types of KIBS on manufacturers' productivity at the regional level. Therefore, in line with the European Commission's (2016) classification of KIBS as well as previous studies on KIBS firms (e.g., Lafuente et al., 2017 and 2019; Horváth & Rabetino, 2019; Wyrwich, 2019), in this study we split KIBS firms according to whether they are technology- (T-KIBS) or professional-oriented (P-KIBS) businesses.

Operationally, we approximate this distinction using the NACE Rev-2 industry classification. Based on the categorisation used in the relevant literature in studies such-as Thomi & Böhn (2003), Zieba (2013), Feser & Proeger (2015), Malerba et al. (2015) and Sisti & Zubiaurre-Goena (2020), and adapted to the latest NACE Rev-2, T-KIBS are considered to be 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).

Multiple variables linked to KIBS firms are employed for the empirical analysis. First, we use the regional share of KIBS, defined as the number of KIBS firms divided by the total number of firms. We create two variables to measure the relative shares of T-KIBS and P-KIBS in each region as the number of T-KIBS divided by the total number of KIBS, and the number of P-KIBS divided by the total number of KIBS. The descriptive statistics in Table 1 reveal that, among the analysed EU regions, KIBS businesses are primarily oriented towards professional activities (P-KIBS). Finally, note that the proportion of T-KIBS is introduced to 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 environment, the size of manufacturing firms, agglomeration economies (population density and capital city), GDP per capita, and location in the different model specifications.

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First, the quality of the entrepreneurial environment is measured via the Regional Entrepreneurship and Development Index (REDI) score, originally developed by Szerb et al. (2014) as an index number to measure the quality of an entrepreneurial environment. As a composite indicator, the REDI captures multiple components of the regional entrepreneurial context, such as the quality of human resources—e.g., share of population with higher education (for a detailed description of the index structure, see Szerb et al., 2014). In this study, the REDI serves as a necessary complement to the impact singularly captured by the above-mentioned characteristics of regional KIBS industries. As Acs et al. (2015) argue, regions may benefit from entrepreneurial processes that help to better allocate resources to the local economy, and enhance innovativeness and, subsequently, the economic performance of an industry. This process is likely to be influenced by the local entrepreneurial environment (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 number to measure the quality of the regional entrepreneurial environment—offers a rich diversity of individual, micro and regional information related to entrepreneurial activity across Europe. REDI scores—which are computed at the regional level thus ensuring their compatibility with the other data used in this study—have been used in previous studies dealing with the quality of regional entrepreneurial environments (Acs et al., 2015; Lafuente et al., 2019b; Szerb et al., 2019).

Second, average size of manufacturers (employees) is used as a relevant indicator that helps to measure whether industrial firms can develop economies of scale and have more access to resources. Following previous work (e.g., Szerb et al., 2019), we expect larger businesses to also perform better 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 for businesses to exploit an increased local demand, greater access to cheaper production factors (Bottazzi & Gragnolati, 2015) and knowledge spillovers (Glaeser et al., 1992). Additionally, being located in large or densely populated cities may prove critical for accessing skilled labour resources (Meliciani & Savona, 2015). Therefore, in our study we follow Meliciani and Savona (2015) and Szerb et al. (2019) and assess the role of urbanisation 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 might explain differences in GVA per worker across regions.

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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 (Ordinary Least Squares - OLS) regression model takes the following form:

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

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). Vector **X** includes the control variables: the REDI index as a proxy of the entrepreneurial environment, average size of manufacturing firms, population density, capital city dummy, GDP per capita, and the set of country dummy variables. Note that we lagged the REDI index by one annual period, 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 there is a correlation between the geographic observations (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 neighbouring regions lies in the similarity (or dissimilarity) of their dependent variables (i.e., in our case, the productivity level of their regional manufacturing sector).

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

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:

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

In SEM models (equation (3)) the error term of unit *i* (ε_i) depends on the error terms of neighbouring regions (with λ parameter) determined by the spatial weights matrix (W) and an idiosyncratic component (μ_i). The spatial autocorrelation modelled in equation (3) (SEM model) can be a 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 indicate stronger spatial dependence with the use of the binary weight matrix. Therefore, and similar to L'Horty and Sari (2019), we employ the SEM model (equation (3)) in our analysis and estimate the regression parameters using the Maximum Likelihood 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 $\beta > 0$ for the variable measuring the rate of KIBS in the local economy to corroborate that KIBS businesses have a positive impact on the 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 Variance Inflation Factor (VIF) values for all models in order to evaluate the potential threat of collinearity. The 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, the regression results in Model 1 (Table 2) indicate that the mere presence of more KIBS businesses (regional share of KIBS) is not enough to generate value-adding interactions between manufacturing industries and KIBS firms that will arguably materialise in greater economic outcomes. Therefore, hypothesis 1 (**H1**) is rejected.

The positive effects of a strong KIBS sector might be conditional on the organisational 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 enhance regional productivity. Although previous 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 materialise in greater manufacturing economic performance in the case of a greater proportion of T-KIBS in the region. Therefore, the local presence of T-KIBS firms significantly benefits industrial firms as well as the territorial product-service innovation system.

The results in Model 2 of Table 2 indicate that, regardless of the overall regional share of KIBS firms, industrial sectors in a region will produce more economic output (GVA per worker) if the focal region has a KIBS industry with a local configuration skewed towards T-KIBS firms. Therefore, hypothesis two (**H2**), 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 environment (REDI) positively impacts GVA per worker and that this effect is consistent throughout the different model specifications. This result is similar to previous work emphasising that a healthy entrepreneurial environment is likely to generate innovative disruptions that are conducive to territorial outcomes (e.g., Horváth & Rabetino, 2019; Lafuente et al., 2019; Szerb et al., 2019).

Taken together, notwithstanding endogenic-based distortions, the relationships between the model's independent variables and the empirical findings reported in this section support the idea that the heterogeneity of KIBS should be taken into consideration when modelling 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, 2011). On the contrary, the superior innovation orientation as well as the higher involvement of T-KIBS in key Industry 4.0 operations will probably have a greater impact on the value chain of industrial businesses. From the perspective of the regional hybrid value chain (Lafuente et al., 2019), these potential interactions may facilitate the local uptake 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 presents evidence of the importance of the regional configuration of the heterogeneous nature of the KIBS sector for the economic and productive transformation of local industrial sectors in the context of the fourth industrial revolution. From the evolutionary resource-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; 2019), 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 their 'knowledge space' allowing their local manufacturing sectors to more easily diversify production towards Industry 4.0.

Overall, the findings are consistent with previous work emphasising 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 analysing 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 materialise in a more productively disruptive local product-service innovation system. Regions whose local manufacturing sectors have a readily available local source of technological capabilities through the strong local presence of T-KIBS are better prepared to embrace the fourth industrial revolution.

5.2 Policy implications

Industry is called upon to embark on 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 organisation 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 prioritising the design of coordinated actions that help endow local industry with smart manufacturing capabilities that will lead 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 in 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 small, new industrial ventures (Grönroos & Voima, 2013). In their role as knowledge conduits, the presence of a strong local KIBS sector, and of T-KIBS in particular, is found to facilitate the adoption and development of such smart manufacturing capacities. T-KIBS are therefore 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 position in 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 T-KIBS' activities are especially decisive for the renaissance of manufacturing sectors, the functioning of local territorial servitization processes, and the development of an entrepreneurial environment that is more Industry 4.0 compatible (Lafuente et al., 2017; 2019). Our results suggest that T-KIBS are a relevant dimension of the heterogeneous structure of regions and manufacturing productivity. We therefore suggest that, in order to develop a strong T-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 T-KIBS businesses and, subsequently, enhance the smart manufacturing capacity of local value chains (e.g., networking opportunities or digital infrastructure and platforms).

The implications for EU policy-makers reside in suggestions from our finding that policy should adopt 21st century reindustrialisation strategies on the basis of 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 ensuring that local incumbent manufacturers are not left behind may lie 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 prioritise the development of tailor-made policies that promote manufacturing productivity through the implementation of harmoniously

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interlinking regional hybrid value chains (Bailey et al., 2020). Such value-adding inter-organisational fit is found to be more appropriate for effective territorial servitization processes to occur and more innovative production to emerge. Because the key to local productive development no longer relates to economic territorial specialisation 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 essential. Consequently, recognition of the value of knowledge-intensive service activity firms as valuable conduits of this augmented innovativeness is also important.

Service firms, T-KIBS included, substantially differ from the manufacturing firms that support policies have mostly favoured 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. The adoption of these common selection norms discourages T-KIBS, which our study has found to be key requirements for localised 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 dichotomous ('yes' or 'no') with regard to new productive or new unproductive businesses, but should instead 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 mostly encourage productive entrepreneurship linked to more innovative, value-adding and co-creation enabling T-KIBS sectors (a concept closer to the entrepreneurship approach proposed 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 organisational 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 herein 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), the data does not permit direct analysis of the existing relationships between KIBS and manufacturing businesses. Neither can we evaluate how manufacturing businesses internalise knowledge-intensive services in their operations. Further research on this issue would be valuable. For example, future work could scrutinise the depth of the connections between KIBS and new manufacturing businesses at the 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, as mentioned, there are possible endogeneity issues between the independent variables and the KIBS sector. Future work could, for example, 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 name	Mean	Median	Standard deviation	Minimum	Maximum
Average manuf. GVA per manufacturing workers (in thousand euro)	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 (in thousand euro)	25.96	24.58	9.15	19.60	30.35

Sample size: 121 observations.

Table 2. Spatial Error Model (SEM): Regression results

Dependent variable:	**Model 1**	**Model 2**
Average manuf. GVA per employee (in thousands of Euros, ln)	**Coefficient (Robust standard error)**	**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 value	–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

Note: Robust standard errors adjusted by heteroskedasticity are presented in brackets. All spatially lagged models are calculated with row-standardized binary distance weight matrix. * = Significant at the 10% level; ** = Significant at the 5% level; *** = Significant at the 1% level.

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Appendix

Table A1. List of regions included in the analysis

Country	N	Regions
Austria	3	Ostosterreich, Sudosterreich, Westosterreich
Belgium	3	Region de Bruxelles-Capitale, Vlaams Gewest, Region Wallonne
Croatia	2	Jadranska Hrvatska (Adriatic Croatia), Kontinentalna Hrvatska (Continental Croatia)
Czech Republic	1	Ceska Republika
Denmark	5	Hovedstaden, Sjalland, Syddanmark, Midtjylland, Nordjylland
Estonia	1	Eesti
Finland	4	Etela-Suomi, Helsinki-Uusimaa, Lansi-Suomi, Pohjois- ja Ita-Suomi
France	8	Bassin Parisien, Centre-Est, Est, Ile de France, Nord - Pas-de-Calais, Mediterranee, Ouest, Sud-Ouest
Germany	16	Baden-Wurttemberg, Bayern, Berlin, Brandenburg, Bremen, Hamburg, Hessen, Mecklenburg-Vorpommern, Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz, Saarland, Sachsen, Sachsen-Anhalt, Schleswig-Holstein, Thuringen
Greece	3	Voreia Ellada, Kentriki Ellada, Attiki
Hungary	7	Del-Alfold, Del-Dunantul, Eszak-Magyarorszag, Eszak-Alfold, Kozep-Magyarorszag, Kozep-Dunantul, Nyugat-Dunantul
Ireland	2	Border Midland and Western, Southern and Eastern
Italy	4	Centro, Nord-Est, Nord-Ovest, Sud
Latvia	1	Latvia
Lithuania	1	Lithuania
Netherlands	4	Noord-Nederland, Oost-Nederland, West-Nederland, Zuid-Nederland
Poland	6	Region Polnocny, Region Polnocno-Zachodni, Region Poludniowy, Region Poludniowo-Zachodni, Region Wschodni
Portugal	5	Alentejo, Algarve, Centro (PT), Lisbon, Norte
Romania	4	Macroregiunea unu, Macroregiunea doi, Macroregiunea trei, Macroregiunea patru
Slovak Republic	4	Bratislavsky kraj, Stredne Slovensko, Vychodne Slovensko, Zapadne Slovensko
Slovenia	2	Vzhodna Slovenija, Zahodna Slovenija
Spain	15	Andalucia, Aragon, Asturias, Basque Country, Cantabria, Castille Leon, Castille La Mancha, Catalonia, Extremadura, Galicia, La Rioja, Community of Madrid, Region of Murcia, Navarra, Community of Valencia
Sweden	8	Mellersta Norrland, Norra Mellansverige, Ostra Mellansverige, Ovre Norrland, Smaland med oarna, Stockholm, Sydsverige, Vastsverige
UK	12	East of England, East Midlands (UK), London, North East (UK), North West (UK), Northern Ireland (UK), Scotland, South East (UK), South West (UK), Wales, West Midlands (UK), Yorkshire and The Humber

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Table A2. Correlation matrix

		1	2	3	4	5	6	7
1	Average manuf. GVA per manufacturing workers	1						
2	Rate of KIBS (regional level)	0.206**	1					
3	Proportion of T-KIBS (among KIBS)	0.376***	0.438***	1				
4	REDI	0.562***	0.531***	0.581***	1			
5	Size of manufacturers	0.227**	0.234***	0.364***	0.356***	1		
6	Capital city dummy	0.096	0.434***	0.201**	0.257***	–0.164*	1	
7	Population density	0.115	0.395***	0.146	0.347***	0.042	0.365***	1
8	GDP per capita	0.412***	0.523***	0.256***	0.769***	0.279***	0.373***	0.532***

Sample size: 121 observations. * = Significant at the 10% level; ** = Significant at the 5% level; *** = Significant at the 1% level.

Table A3. Spatial diagnostics for model selection

	Equation (1)		**Equation (2)**	
	χ^2	**p-value**	**χ^2**	**p-value**
LM lag (QUEEN)	12.928	0.000	13.363	0.000
Robust LM lag (QUEEN)	0.359	0.549	0.126	0.722
LM error (QUEEN)	13.861	0.000	15.630	0.000
Robust LM error (QUEEN)	1.291	0.256	2.394	0.122
LM lag (BIN)	10.613	0.001	11.255	0.001
Robust LM lag (BIN)	0.496	0.481	0.127	0.722
LM error (BIN)	19.331	0.000	18.637	0.000
Robust LM error (BIN)	9.214	0.002	7.509	0.006
LM lag (INV)	10.894	0.001	11.389	0.001
Robust LM lag (INV)	0.346	0.556	0.142	0.706
LM error (INV)	17.538	0.000	17.544	0.000
Robust LM error (INV)	6.990	0.008	6.296	0.012
LM lag (INV2)	8.975	0.003	9.201	0.002
Robust LM lag (INV2)	0.230	0.632	0.141	0.707
LM error (INV2)	12.908	0.000	13.194	0.000
Robust LM error (INV2)	4.163	0.041	4.135	0.042

Note: Spatial weight matrices are row-standardized. QUEEN- queen contiguity matrix; BIN- binary distance matrix, threshold distance: 377.95 km; INV- inverse distance matrix, threshold distance: 377.95 km; INV2- inverse distance squared matrix, threshold distance: 377.95 km.