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Growth of total productivity of the factors, innovation and spillovers from advanced business services

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ABSTRACT
Advanced business services (ABS) are seen as generators and disseminators of innovation among their client companies, and their use by client companies can improve efficiency and productivity. However, one question that has not been addressed is whether ABS provision can be an explanatory factor for the total productivity of the factors (TPF). This paper aims to determine whether the innovation generated and/or transmitted by ABS companies is reflected in the TPF growth in the manufacturing sector. For this purpose, a Cobb-Douglas function was estimated using panel data analysis on data of ten OECD countries in the period 1977-1996. ABS labour was considered the proxy variable for the provision of these types of services and treated as a separate factor in the production process. The quantitative study shows that the contribution of labour endowment in ABS to the efficiency and productivity of manufacturing industry is significant, that it generates spillovers and that it is an explanatory factor for the TPF.

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1. Introduction

Nowadays, industrial production requires traditional factors such as capital and labour, but also skills, organizational structures and processes, and other intangible assets. Business services (BS), in their modalities of ABS and knowledge-intensive business services (KIBS), can provide firms with factors needed at different stages of the innovation process.

The current literature has shown the innovative nature of BS activities using different methodologies. Examples include pooled regression analysis and tests with a fixed effect model to analyse the influence of knowledge sources on innovation performance in the KIBS sector (Tseng et al., 2011), logistic regression to explore the extent and determinants of knowledge exchange between KIBS and their clients (Landry et al., 2012), spatial autoregressive (SAR) models to study localisation patterns and transmission of the

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knowledge-based intermediate inputs KIBS firms provide (Gallego & Maroto, 2015) and a binary choice model to analyse the role of the process innovation on KIBS firms (Moreno-Gómez et al., 2021).

The literature has also dealt with the relationship between BS and productivity. Examples include BS growth and its variance in manufacturing productivity (Gatrell, 2002), the aggregate productivity contribution of BS (Kox, 2004; Di Meglio et al., 2018), the effects of KIBS on productivity growth (Musolesi & Huiban, 2010; Katsoulacos & Tsounis, 2019), the effect on productivity growth diffusion of KIBS in relation to information and communication technology-based innovations (Broersma & Van Ark, 2007; Pöschl et al., 2016), and the impacts of KIBS agglomeration on productivity-enhancing (Zhang, 2016).

On the other hand, growth models developed in the 1980s and 1990s emphasized the role of technology and knowledge as major drivers of growth (Ståhle et al., 2015). In the pioneering work by Solow (1957), TFP (which by definition reflects all the factors affecting productivity, whether or not they are directly factored in the production function) is mainly determined by technical progress. Since this seminal work, PTF has been studied within the extended Solow models. Romer (1986) and Lucas (1988) argued that the Solow model should be augmented by including human capital, as human capital is crucial for technology absorption and the stimulation of economic growth. The level of human capital influences technological development, entrepreneurship, and the creation of innovations (Mankiw et al., 1992). Lucas (1988) considered R&D investments. Aschauer (1989) studied the effect of infrastructure as a new production factor. Barro (1998) showed that the growth rate of real per capita GDP is enhanced by better maintenance of the rule of law, smaller government consumption, lower inflation, higher starting levels of life expectancy, improvements in the terms of trade, or higher levels of human capital related to increased levels of schooling. Other researchers have investigated sociological factors (social capital, innovation, value-added efforts) and considered a wide range of institutional factors and organisations that influence growth.

The availability, quality and productivity of ABS/KIBS could also be related to TFP. As the literature indicates, ABS/KIBS can innovate and help clients to innovate, act as a vehicle for innovation, enhance client companies' productivity and efficiency (insofar as they anticipate and reinforce change, responding to individual corporate, technical and market conditions). Technology spillovers then occur between firms, because one firm's innovations affect other firms' productivities (Akcigit et al., 2022). Following Sakurai et al. (1997), as ABS/KIBS companies interrelate with companies in different sectors, there would be a positive link with Solow's productivity paradox, because inter-industrial flows of new technologies offer great potential for productivity growth. Thus, deploying ABS may have a micro effect on the enterprise that uses them and a macro effect on the whole economy.

However, as far as we know, BS, ABS or KIBS as a constituent factor of TFP have not been studied within the extended Solow models. This study, therefore, aims to cover this gap in the literature. It does so by addressing the following questions: are ABS a component of PTF? Does ABS endowment influence the growth of the TPF? Do innovations developed or transmitted in the provision of ABS give rise to spillovers in the manufacturing industry? Are ABS drivers of innovation? In order to answer these questions and for the ulterior analysis of the spillover effects resulting from the use of ABS at the macroeconomic level, the methodology used is based on a Cobb-Douglas function adapted to the case of ABS. The basic reference is the work of Aschauer (1989), studying the case of public capital.

The functional form chosen here was an enlarged Cobb-Douglas function (which is the most common in the literature that has studied TPF and technological spillovers), where, instead of public capital, ABS labour is treated as a separate factor in the production process. The expanded Cobb-Douglas production function provides an appropriate tool for estimating elasticities for different production factors. The estimation was carried out using panel data techniques for ten OECD countries between 1977 and 1996.

The paper is organised as follows. After this introduction, Section 2 briefly reviews the literature on the role of BS, ABS and KIBS as generators of innovation and as diffusers of innovation. Section 3 deals with data and the empirical model, a parametric modelling where ABS are a factor of production in an aggregate function Cobb-Douglas. Section 4 shows the estimations and the results and provides the results of empirical analysis for the period 1977 to 1996. Finally, Section 5 offers a discussion and presents the conclusions.

2. Theoretical framework

'Business services' are a sub-section of 'production services' (sectors or industries that provide services to producers as intermediate inputs). They are specialised services, **'**demanded by firms and public organisations and are not produced for private consumption**'** (Strambach, 2001, p. 53). They include finance, insurance, communications, computer-related services, R&D, accounting services, legal services, technical services, and consulting. BS that require little technology and do not need highly skilled human resources are considered traditional, and BS that require high levels of technological intensity and highly skilled human resources are considered advanced (Martínez-Argüelles & Rubiera-Morollón, 2006). ABS are still BS but rely on the knowledge and expertise of their employees. They consist of real services (not financial) that are aimed at businesses, offering information, problem analysis, advice, assistance and specialised interpretive expertise complementary to their customers' own resources. Following Miles et al. (1995), ABS can be defined as 'services that involved economic activities which are intended to result in the creation, accumulation or dissemination of knowledge'. This group of services was later determined as KIBS. They are taken to include computer and related activities, research and development, and legal, technical and advertising activities (NACE Rev. 1.1 codes 72–74). Primarily KIBS produce knowledge, and their services constitute secondary offerings (Chung & Tseng, 2019).

ABS/KIBS are increasingly important in modern economies. The companies that provide these services are creators of technological and organisational innovation (García-Quevedo & Mas-Verdú, 2008; Doloreux & Frigon, 2020). They act as innovators in developing methods to utilize knowledge (Hu et al., 2013); they are also innovation transmitters and knowledge transmitters between markets and science

(Asikainen, 2015). They play an important role in providing firms with access to technological and scientific information, and they increase connectivity between firms (Katsoulacos & Tsounis, 2019).

ABS/KIBS function as facilitators, carriers or sources of innovation. Through their almost symbiotic relationship with client firms, some of these BS function as co-producers of innovation. This is because the clients of BS firms play a critical role in helping to co-innovate, co-create or co-produce knowledge-based solutions (Den Hertog, 2000; Bettencourt et al., 2002; Aarikka-Stenroos & Jaakkola, 2012; Castaldi et al., 2013; Petri & Jacob, 2016; Zieba et al., 2017; Grandinetti, 2018).

Companies that provide ABS/KIBS occupy privileged places in the creation, development, dissemination and adaptation of technological innovation and knowledge intended to incorporate technological product or organisational innovation. All of this flows from their participation in networks. ABS/KIBS firms are affected by their inherently high rates of interactions with clients and partners, and they are exposed to knowledge flows from other organisations (Janssen et al., 2018).

The Weak Ties Hypothesis of Granovetter (1983), suggests that ABS/KIBS companies' innovation strategies, and the intensity with which they act as a vehicle for the dissemination of new technologies, depend on the relationships between ABS firms, the networking by agents and the performance of ABS providers within these structures. In particular, they depend on the information-carrying connections between agents who are simply acquaintances. That is to say, on weak ties and the availability of weak-tie contacts. ABS companies can therefore learn from these networks and, as a result, improve their capacity to exploit business opportunities. There is a likelihood of variations among countries in the spillover effects from services innovation in and through BS, and in the degree to which they are integrated with other economic activities (Den Hertog, 2000).

On the other hand, strong, rather than weak, ties contribute to the development of innovations in products, delivery, strategy, management and marketing, while such ties have a negative impact on the development of process innovations. The knowledge provided through strong and very strong ties is, then, more important than the knowledge exchanged through weak ties in the development of many forms of innovation for the case of KIBS (Amara et al., 2009). Trust-building processes are drivers of knowledge exchange in KIBS producer–user meetings (Growe, 2019).

2.1. ABS as generators of innovation

Innovation can consist in the implementation of a single significant change, or of a series of smaller incremental changes that together constitute a significant change. This innovation could be a new product or service, method of production (technical innovation) or new organisational structure or administrative system.

As the traditional characterisation of innovation has generally been associated with goods, innovation in ABS/KIBS companies clashes with the classic vision, particularly around novelty, risk, degree of ownership and product-process distinction (Gallouj & Savona, 2009). The application of these traditional criteria supposes the denial or underestimation of internal innovation via the type of advisory activities such as those included in ABS/KIBS and limits the spread of technology to the secondary sector (industrialist vision). But contrary to this view, there is a developing theoretical literature exploring the relationship between services and innovation [see Morrar (2014) and Moreira et al. (2020)].

With different degrees of novelty, in ABS/KIBS is possible to detect six forms or types of innovation: product, process, delivery, strategic, managerial (organisational changes) and marketing innovations (Amara et al., 2009; Musolesi & Huiban, 2010; Shearmur & Doloreux, 2013; Amara et al., 2016). ABS/KIBS innovation differs from the typical innovation in manufacturing, in terms of firm size [firm size is not a significant determinant (Savic et al., 2020)] and of the importance of formal research in the development of services (Leiponen, 2005).

Innovation in ABS/KIBS especially affects small and medium enterprises (SMEs). Although the company is the leading actor in innovation, SMEs present deficiencies such as limited numbers of decision-makers, lack of professional management methods, and lack of the knowledge, resources and experience necessary to compete in the current phase of technological progress. SMEs are confronted by the high costs and risks of research and the difficulty of accessing information. This is important because in-house design capacity is strongly linked to a firm's ability to absorb external knowledge for innovation (Love et al., 2011). Therefore, small manufacturers have relationships with ABS/KIBS in order to compensate for their internal deficiencies and fill the gaps in their knowledge and skills (Seclen and Barrutia (2018). ABS/KIBS support innovation and promote it through research and expertise in companies that cannot do it for themselves.

However, the relationship between ABS/KIBS and SMEs should not be regarded as a unidirectional one. Small businesses are significant sources of innovation because their interactions with client companies are positively related with innovation derived from ABS companies (He & Wong, 2009). Knowledge input, knowledge spillover and knowledge absorptive capacity are three knowledge sources that increase the innovation performance of ABS/KIBS firms (Tseng et al., 2011).

2.2. ABS services as diffusers of innovation

ABS/KIBS are not only sources of innovation: they are also involved in generating R&D spillovers. ABS/KIBS are widely perceived as important drivers (diffusers) of innovation, knowledge transfer and technological progress (Fernandes & Ferreira, 2013; Brunow et al., 2020; Chichkanov et al., 2021). In practice, ABS act as channels for the transmission of modern technology, which is as important as formal technology transmission agreements. The key is in the innovation ownership process.

Actors in the intellectual services sector cooperate mainly with firms from other sectors, and their activities influence the whole economy through innovation spillover (Asikainen, 2015). In this way, they contribute to progress in the knowledge-intensive economy (Firsova et al., 2022). There are two explanations for this: through their interdependent relationships with users and other producers, ABS/KIBS both collaborate in the innovation process *per se* and participate in the innovation appropriation process.

Although R&D, innovation and diffusion are integrated processes, some parts of innovation and new knowledge cannot be appropriated by firms. When a firm cannot appropriate an innovation, any firm can use an 'idea' embodied in that innovation

(Akcigit et al., 2022). In the case of ABS/KIBS, innovations are co-produced (Leiponen, 2006; Rubalcaba et al., 2010; Lessard, 2014; Chichkanov, 2021), although, for different reasons, the customers are not always able to participate actively, and there is limited customer participation (Santos & Spring, 2015). As new knowledge is partly collectively generated and partly tacit, it is likely to overflow to suppliers, customers or competitors, at an intra- or inter-industry level (although there may be bi-directional spillovers). In this overflow, employees play an important role, as they can transfer this knowledge to other agents in an informal way or as a result of local intra-sectoral labour mobility (Kekezi & Klaesson, 2020), or even use this knowledge to create their own company. In fact, spinouts from KIBS-firms operating in the same sector are more likely to survive, which indicates the importance of inherited knowledge (Andersson et al., 2012).

3. Data and empirical model

3.1. Data

In this approach to the relationship between ABS/KIBS and technological spillovers, annual observations between 1977 and 1996 were used for two reasons. Firstly, the estimation of the Cobb-Douglas function requires data on the stock of fixed capital in the manufacturing sector and the latest published by the OECD Directorate for Statistics was in 1997. Secondly, employment growth was strong in BS in this period, partly explained by the outsourcing process. According to Aharoni (2014), employment in the professional BS field grew much faster than employment in general (in the period 1979-86, employment growth in BS was 53.8% and 13.1% overall). The data refer to ten OECD countries: Germany, Belgium, Denmark, Spain, Finland, France, Italy, Norway, UK and Sweden.

In order to carry out the empirical analysis, a data panel set of annual observations of four variables was used: the dependent variable is output, specifically production (measured by Gross Domestic Product at factor cost); the dependent variables are the production inputs. These are employment (number of employees) and fixed capital stock (durable and reproducible tangible assets) in the manufacturing industry (excluding the energy and construction sectors), and employment in the ABS subsector. According to NACE, this subsector includes computer and related activities, research and development, and other BS.

The output and employment data in manufacturing were obtained from homogeneous series of national accounts published by the OECD. Except for Spain, where the source data was the database of the IVIE-BBVA Foundation, the data on manufacturing capital stock (in constant values) are those published in 'Flows and Stocks of Fixed Capital' (Statistics Directorate & OECD, 1997) for the period 1977-1996 (which limits the scope of the investigation).

3.2. Empirical model

Growth accounting is one of the tools most commonly used to separate the sources of economic growth. This approach distinguishes clearly between the contribution of accumulated factors (capital and labour) and the productivity or efficiency with which these resources are used.

The measurement of productive efficiency generally used is that based on the contribution of Solow (1957) on the role of technical progress in the aggregate production function. The production function in Solow's approach takes the form of a Cobb-Douglas:

$$Y_t = A_t \cdot K_t^{\alpha} \cdot L_t^{\beta} \;\; \alpha + \;\; \beta = 1 \tag{1}$$

which, expressed in terms of logarithms, is

$$ln \;\; Y_t = \ln A_t + \alpha \ln K_t + \;\; \beta \ln L_t \tag{2}$$

where Y is a measure of aggregate real output of goods and services, L is aggregate employment, K is the non-residential capital stock, α and β are the respective output elasticities with regard to the production factors capital and labour (coefficients that indicate the percentage change in output for a given percentage change in factor input) and A is the efficiency indicator, the technological efficiency parameter, the measure of productivity or Hicks-neutral technical change. The equation in growth rates (3) is obtained by fully differentiating (2):

$$\dot{TPF}_t^S \;\; = \;\; \dot{A}_t = \dot{Y}_t - \alpha_t \dot{K} - \beta_t \dot{L} \tag{3}$$

The methodology used in this paper is based on estimating an expanded Solow model. Augmented growth models are aimed mainly at identifying the crucial qualitative or intangible variables that impact productivity. Augmented growth models have been widely used, and among them should be noted initial developments such as those of Romer (1986), with human capital (in practice, education), or Aschauer (1989), with public capital explicitly incorporated in the aggregate production function to study the effect of the public capital stock on a country's economic efficiency. More recently there have been new developments, such as those of Ishise and Sawada (2009) with social capital and Ståhle et al. (2015) with intellectual capital (intangible capital).

The present paper uses a linear production function model that replicates the Cobb-Douglas model used by Aschauer (1989). In this study, ABS are incorporated in an aggregate production function, representative of the manufacturing industry, as an additional productive factor, trying to determine whether ABS can be considered a relevant factor in the industrial production process, contributing differently to the generation of output. To estimate the impact of ABS on productivity, labour input is split, distinguishing between labour in a manufacturing framework and that undertaken in ABS activities. Sforzi and Boix (2019) also unbundled labour in BS from total labour in their study of territorial servitisation in Marshallian industrial districts. The justification for this split is that ABS/KIBS firms, being highly immaterial, are low-capital intensive but highly-labour intensive (Bumberová & Milichovský, 2020). Their development is more strongly based on labour growth than is the case of industry.

As emphasised above, labour is a key factor in the success of ABS/KIBS firms in creating dynamic and productive services for their client companies. Although ABS/KIBS companies do not generally have very many employees, they often need their staff to be very highly qualified. This is because these firms' activities rely on the capabilities and knowledge of their human resources, i.e., highly qualified human capital (Pinto et al., 2015; Hidalgo & Herrera, 2020; Bumberová & Milichovský, 2020) represents a key strategic asset in the innovation processes.

In this sense, human capital (both owners/creators and employees) is a deciding factor for the creation and development of these businesses. As a high proportion of their personnel have higher education qualifications and know-how, they are continuously being trained and retrained (primarily through learning by doing), and they have substantial intra-sectorial mobility, which in turn is an important factor for the generation of weak ties relationships.

Furthermore, unlike in other sub-sectors and economic activities, the influence of technological innovation does not downplay the importance of human resources. This is because the technological innovation and techniques incorporated into ABS/KIBS companies and their corporate customers generally require high-qualified employees who can use and interpret the services purchased.

In short, the proposed split can be justified by the high labour intensity that characterises ABS/KIBS companies, as they are based on information and knowledge: 'professional experience' is an input that cannot easily be automated. Additionally, the comparative advantage of ABS/KIBS companies is based on the knowledge of their employees. The sustained success of an ABS/KIBS company depends on the solutions that their employees provide to their clients as it is these employees who develop and deliver the service solutions to its clients (Lahti & Beyerlein, 2000).

Note that the labour factor employed in the manufacturing sector is not considered unskilled, nor intended to reduce the importance of the human capital in this sector. On the contrary, the contact between skilled labour in manufacturing and skilled labour in the ABS/KIBS sector is precisely what in many cases favours (the co-creation of) the innovation.

Thus, to estimate the effects that ABS have on production, the starting point is an expanded and transformed production function, as carried out by Aschauer (1989):

$$Y = A \cdot F(L_M, L_{BS}, K) \tag{4}$$

where Y is manufacturing output, K is capital stock in manufacturing, L_M is employment in manufacturing and L_{BS} is employment in the ABS sector. This specification explicitly models the contribution of the ABS as a determinant of the level of technology (not just the mere passage of time). It is flexible enough to capture the basic effects of technological spillovers.

If ABS are expressly included in (1), Eq. (5) is obtained:

$$Y_t = A_t \cdot K_t^{\alpha} \cdot L_t^{\beta} \cdot B_t^{\varphi} \tag{5}$$

which expressed in terms of logarithms is:

$$ln\ Y_t = \ln A_t + \alpha \ln K_t + \beta \ln L_t + \varphi \ln B_t \tag{6}$$

where B is employment in the ABS sector firms and φ is the elasticity of output with respect to employment in the ABS sector.

Constant returns to scale over capital and labour have been the traditional assumption underlying most analyses of the Cobb-Douglas production function. Following

Munnell (1990), the inclusion of ABS could raise some questions about returns to scale. Given that increasing economies of scale play such an important role in determining the ABS provision of a good or service, one might be tempted to conclude that ABS labour in total may yield increasing returns to scale within the production function. Such a leap may be unwarranted, however. Whereas a given ABS provision may yield increasing returns to scale, additional employment in ABS sector may not. Moreover, a doubling of employment in ABS would most certainly produce diminishing returns.

Given the uncertainty of the impact of ABS on returns to scale, several forms of the equation could be estimated in addition to the original unconstrained equation. Following the approach of Aschauer (1989), the existence of possible economies of scale resting behind the provision of ABS to the manufacturing production suggests that a reasonable specification of the industrial technology would involve assuming that the production function exhibits constant returns to scale over the traditional factors, capital and labour ($\alpha+\beta=1$) but increasing returns to scale over all factors, including ABS ($\alpha+\beta+\varphi>1$) [the alternative is that constant returns to scale apply to the entire production function, so that $\alpha+\beta+\varphi=1$, which implies diminishing returns on traditional factors (Aschauer, 1989)]. In production functions without ABS, the coefficients can be defined more precisely by making some further assumptions about factor markets and the nature of the production function. Specifically, if factor markets are assumed to be perfectly competitive, so that factors are paid according to their marginal productivity, and if the production function exhibits constant returns to scale, then the coefficients equal the relative share of total income paid to capital and labour respectively.

From Eq. (6), the TPF can also positively relate with the ABS provision:

$$\begin{gathered}\ln A_t = \ln Y_t - \alpha \ln K_t - \beta \ln L_t - \varphi \ln B_t \\ \ln \mathrm{TPF}_t^S = \ln A_t + \varphi \ln B_t\end{gathered} \tag{7}$$

Therefore, if the production function does not show constant returns to scale in traditional factors, additional assumptions should be made to enable us to establish the relationship between TFP and the true measure of efficiency.

Following the argument of Hulten and Schwab (1993), which does not impose any condition on the type of returns to scale, participation and the elasticity coincide for labour but not in the capital factor allowing $\rho=\alpha+\beta$ to be different from unity. Under these assumptions, it would be demonstrated [see Hulten and Schwab (1993) and Uriel et al. (1994)] that the relationship between A_t and PTF^S is:

$$\ln \mathrm{TPF}_t^S = \ln A_t + (\rho-1)\ln K_t + \varphi \ln B_t \tag{8}$$

Moreover, following their argument, an additional channel through which ABS can affect the output can be considered: ABS is an 'environment' or 'spillover' productive factor (included in the term of efficiency A_t) which increases the productivity of inputs:

$$\ln A_t = \ln A_0 + \lambda\,(t) + \varphi \ln B_t \tag{9}$$

where λ is the constant rate (common to all economies considered) that accumulates disembodied technical progress in production factors, and A_0 is an intercept representing the initial efficiency level, different for each country. But given that in this specification is not possible to identify the influence of the ABS for each of the tracks, the following expression is used:

$$\ln A_t = ln\ A_0 + \lambda\ (t) \tag{10}$$

Under these assumptions, the TFP[S] of the manufacturing sector of each country (i) is [see Hulten and Schwab (1993) and Mas-Ivars et al. (1993)]:

$$\ln\ \mathrm{TPF}^{S}_{it} = \ \ln A_{i,0} + \lambda\ (t) + (\rho - 1)\ln K_{i,t} + \ \varphi \ln B_{i,t} \tag{11}$$

Specification (10) allows us to isolate the effect of the provision of ABS in TFP, leaving the parameter A_t as the other factors that may impact it (public capital, human capital, etc.). This approach is much more complex because, in addition to including a term of initial efficiency for each country and the contribution of the ABS in TFP, it also specifies a term trend reflecting the growth rate of exogenous technological progress and a term that includes the discrepancy regarding the returns to scale.

4. Empirical analyses and results

Following the exposition order used in the section on methodology, the empirical analysis starts by estimating the impact of the provision of ABS on output. Eqs. (2) and (6) are the reference points in the estimates presented in this section. These two different specifications of a Cobb-Douglas production function were estimated using a panel of annual data, with a stochastic specification ($\varepsilon_{i,t}$ is a random perturbation). Formulation, in logs, is as follows:

$$ln\ Y_{i,t} = \ln A_t + \alpha \ln K_{i,t} + \ \beta \ln L_{i,t} + \varepsilon_{i,t} \tag{2a}$$

$$ln\ Y_{i,t} = \ln A_t + \alpha \ln K_{i,t} + \ \beta \ln L_{i,t} \ + \ \varphi \ln B_{i,t} \ + \varepsilon_{i,t} \tag{6a}$$

Table 1 shows the specification estimates made by generalised least squares (GLS), considered in Eqs. (2a) and (6a), using the random effects model. The same specifications are estimated including a trend term (2b and 6b in the Table 1) that indicates the growth rate of exogenous technological progress.

From the estimated Eqs. (2a) and (6a), for a ρ-value of 0.05 (used in all estimations), it can be stated that manufacturing capital and labour parameters are significant with the expected positive signs, as well as the occupation variable in ABS, in estimates both with and without trend. Improvements in the provision of ABS have a relevant impact on manufacturing output.

On the other hand, even when the trend is introduced, (2b) and (6b), and the variables relating to the aggregate of ABS lose significance (in the analysed period the ABS endowment followed a steadily increasing trend), the ABS still represent a way of specifying an important part of technical progress. ABS are a vehicle through which technical progress may be incorporated.

Table 1. Production function of manufacturing.

Variable	(2a)	(6a)	(2b)	(6b)
Constant (A)	0.65214	2.33891	1.62161	2.57244
	(1.0343)	(3.19391)	(2.19845)	(3.34075)
Trend (λ)			0.00704	0.00303
			(2.44149)	(0.98205)
K	0.82410	0.69825	0.74168	0.67624
	(17.370)	(12.7626)	(12.8611)	(11.4366)
L	0.23223	0.22283	0.30433	0.25561
	(5.53428)	(5.40334)	(5.98736)	(4.81757)
B		0.12338		0.10965
		(3.82562)		(3.1188)
R^2	0.98009	0.98190	0.98076	0.98201
Adjusted R-squared	0.97986	0.98158	0.98042	0.98158
S.E. of regression	0.16245	0.15566	0.16016	0.15568
Sum squared resid	4.53926	4.09502	4.38636	4.07165
Log likelihood	71.2376	78.3382	74.2358	78.8333
Durbin-Watson stat	0.24731	0.26767	0.32531	0.29623
Mean dependent var	24.7919	24.7815	24.7919	24.7815
S.D. dependent var	1.14468	1.14701	1.14468	1.14701
Akaike info criterion	−0.77986	−0.85940	−0.8027	−0.85356
Schwarz criterion	−0.72561	−0.78649	−0.73036	−0.76243
F-statistic	4233.45	3056.60	2905.69	2292.21
Prob(F-statistic)	0	0	0	0
Test Lagrange multiplier	101.064	91.575	35.261	62.709

Significance: 0.05.
Source: own elaboration.

Table 2 shows the estimation of Eq. (11) with the intra-group estimator or fixed effects (11a). The estimates presented in the table are based on two assumptions: an exogenous growth rate common to all (λ) and the existence of significantly different fixed effects in each country, identified as the initial levels of efficiency of each, $lnA_{i,0}$. With this second hypothesis, the aim is to verify whether the constant differs between countries, as it might be that some special circumstances are not collected by the

Table 2. Total factor productivity (TFPS) with fixed effects (11a).

Variable			Coefficent
Trend (λ)			0.00446 (2.67780)
ln B			0.03675 (1.9672
ln K			−0.2833 (−3.5858)
R^2	0.11660	Mean dependent var	−0.00065
Adjusted R-squared	0.05035	S.D. dependent var	0.04734
S.E. of regression	0.04614	Akaike info criterion	−3.24226
Sum squared resid	0.34057	Schwarz criterion	−3.00530
Log likelihood	293.455	F-statistic	1.75987
Durbin-Watson stat	0.82674	Prob(F-statistic)	0.05911
		Fixed effects	
Germany		6.95720	(3.29507)
Belgium		6.39610	(3.30725)
Denmark		6.30178	(3.32506)
Spain		6.75829	(3.31195)
Finland		6.41651	(3.32438)
France		6.83672	(3.28857)
Italy		6.88981	(3.29296)
Norway		6.26467	(3.33215)
UK		6.83564	(3.28597)
Sweden		6.47258	(3.31991)

Significance: 0.05.
Source: own elaboration.

explanatory variables (composition of output, location, etc.), with effects on the production results. The value of the fixed effects can be identified with the initial situation of the efficiency parameter ($lnA_{i,0}$).

The exogenous growth rate of technical progress (λ) is estimated at 0.4465 per cent per annum. The value of the F-statistic was 82.24, which allows us to reject the hypothesis of equality of the individual effects (H_0: $A_i = A$). The conjunction of these two factors means that the absence of technological convergence between countries must be assumed.

As shown in the table, employment in ABS has a small positive and statistically significant effect on the TFP^S countries, with an elasticity of 0.036749. Thus, employment in the ABS is shown to be relevant in explaining the productivity gains of these countries.

The negative and statistically significant parameter that accompanies the capital, $(\rho - 1) = -0.283339$, with a t-statistic of −3.585814, allows us to accept the existence of diminishing returns in traditional inputs ($\alpha + \beta = 0.716661$). In addition, the estimated values of the parameters ρ and φ (0.716661 and 0.036749, respectively) point to the existence of decreasing returns to scale in all inputs ($\rho + \varphi < 1$).

Table 3 shows the estimate of Eq. (11) considering the exogenous growth rates of technical progress for each country, $\lambda_{i,t}$, (11b).

The estimated individual effects now include the value of the 'true' measure of efficiency in the initial year ($A_{i,0}$). An F-Snedecor value of 6.46 allows us to reject both the hypothesis of equal rates of exogenous technical progress in the period studied (H_0: $\lambda_{i,t} = \lambda$) and the specification of the Eq. (11a). The values obtained for the different countries show the existence of positive and significant growth rates of exogenous technical progress for each country.

Again, the estimate allows us to accept the hypothesis of decreasing returns to scale in traditional inputs (the parameter $(\rho - 1) = -0.4866$ is statistically different from zero). It also shows the relevance of labour endowment in ABS in explaining the TFP^S of the countries studied ($\varphi = 0.0565$ with a t-statistic of 2.7275).

Table 3. Total factor productivity (TFPS) with growth rate of technical progress (11b).

Variable				Coefficent
ln B				0.05651 (2.72751)
ln K				−0.48662 (−4.65517)
R-squared	0.17825		Mean dependent var	−0.00065
Adjusted R-squared	0.06397		S.D. dependent var	0.04734
S.E. of regression	0.04580		Akaike info criterion	−3.21055
Sum squared resi	0.31680		Schwarz criterion	−2.80955
Log likelihood	299.713		F-statistic	1.55972
Durbin-Watson stat	0.90559		Prob(F-statistic)	0.06639
	Growth rate of technical progress (λ_i)		Fixed effects	
Belgium	0.01295	(3.521.436)	12.09356	(−44.0031)
Denmark	0.00854	(2.901.830)	11.97028	(−43.9432)
Finland	0.00846	(3.310.266)	11.85534	(−43.9105)
Sweden	0.00757	(2.370.341)	11.84138	(−43.8563)
UK	0.00755	(2.713.163)	11.70943	(−44.1099)
Spain	0.00643	(2.262.980)	11.19879	(−44.0997)
France	0.00598	(2.452.981)	11.09022	(−44.0961)
Italy	0.00384	(1.232.831)	11.01628	(−44.0655)
Norway	0.00336	(1.151.471)	10.89273	(−44.1802)
Germany	0.00245	(0.879489)	10.87960	(−44.3319)

Significance: 0.05.
Source: own elaboration.

5. Discussion and conclusions

A better understanding of KIBS innovation processes may benefit firms' innovation management and policymaking, and lead to higher levels of social and economic development (Hipp et al., 2015). For this purpose, this paper proposed an approach to the empirical study of the relationship between the provision of ABS and TPF that adapts the work of Aschauer (1989) to ABS.

Two models with a parametric linear approximation were considered in order to study the impact of ABS on TFP. The results confirm the hypothesis that ABS endowment favourably influences the manufacturing sector with respect to TPF, through technological innovations and spillovers. According to our estimates, if ABS are treated as a separate input in the production process, the trend that reflects exogenous technical progress (which includes efficiency improvements not caused in any of the productive factors considered) and the contribution of labour endowment in ABS to the production efficiency in manufacturing industry are both significant.

The theoretical implication of the above results is that ABS endowment does influence TPF growth, and there are efficiency spillovers from ABS to the companies and industries that use them. That is, the innovation developed or transmitted in the provision of ABS does give rise to spillovers, at least in manufacturing industry. Thus, the generation and diffusion by ABS of innovation and best practices in production and management may be linked to efficiency improvements. Therefore, ABS represent a way of specifying an important element of technical progress, they are a vehicle through which technical progress is incorporated. These results thus provide more evidence of what the literature had pointed out: BS/ABS/KIBS can act as 'carriers of knowledge' in their role as providers of intermediate inputs into the activities of their clients.

All this has several practical implications for innovation policymaking and knowledge management and for industrial and regional policies, which are closely interrelated with regional development policy. There is a vast body of research that suggests an important role for BS/ABS/KIBS in the innovation, productivity and growth processes of regions (Musolesi & Huiban, 2010; Meliciani & Savona, 2015; Zhang, 2016; Brenner et al., 2018).

In brief, measures should be introduced to favour the provision of BS/ABS/KIBS, in keeping with the specific factors of the country and region. In the peculiar competitive environment in which most professional and some technical ABS/KIBS operate, regulatory restrictions hindering easy access to the market or specific laws (Corrocher et al., 2009) should be removed. In order to foster innovative cooperation, regional policy should strengthen the formal networks that create trust between ABS/KIBS and SMEs and disseminate information on specific ABS/KIBS (Feser & Proeger, 2018).

These policies of BS/ABS/KIBS promotion may have a direct benefit on productivity growth in the user manufacturing industries. But indirect benefits will also flow from the enabling role of the ABS sector and its contribution to supporting innovation and growth in other industries and the public sector (Love et al., 2011). In any case, if ABS/KIBS help in some way to increase aggregate productivity (as the results suggest), their contribution favours downstream-using industries. In turn, an industrial policy that strengths the industrial base in peripheral regions could induce knowledge-intensive start-up activity (Wyrwich, 2019).

6. Limitations

The limitations of this paper relate to the OECD data. First, the available manufacturing capital stock data is old. Second, the data also did not allow for other countries to be included of in the estimation, as the series were not complete. Third, there is the problem of the reliability of the relationship between data and BS, because the current statistics of the sector have major limitations. BS statistics are clearly inadequate: there is not enough of the sub-sectoral disaggregation that could provide information on the many heterogeneous sub-sectors that are included in BS, ABS/KIBS. Further disaggregation would have allowed a fitted estimation to be made.

7. Future lines of research

The first future line of research should perhaps be to apply the model presented in this paper at the regional level, specifically to the 17 Spanish regions, in which manufacturing industry has different weights and sectoral structures. Unlike in this forthcoming study, the data on the regions' capital stock does not constitute a temporal limitation since the IVIE-BBVA Foundation's 'Capital Stock and Services' database covers the period from 1961 to 2017. In this case, the availability of data on the labour endowment in BS is presented as a limiting factor with respect to the beginning of the period to be studied. Another line of research to be considered is to study the spillovers generated by BS companies in different industrial districts in the Valencia region.

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