Trendy v podnikání - Business Trends (2020), 10(3), 50-56.
https://doi.org/10.24132/jbt.2020.10.3.50_56

PRODUCTION FUNCTIONS IN THE SECTOR OF KNOWLEDGE INTENSIVE SERVICES

Simona Hašková[1], Petr Šuleř[2], Lukáš Frýd[3]

[1] Ing. Simona Hašková, Ph.D., Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, haskova@mail.vstecb.cz
[2] Mgr. Petr Šuleř, Ph.D., Institute of Technology and Business in České Budějovice, School of Expertness and Valuation, 24786@mail.vstecb.cz
[3] Mgr. Ing. Lukáš Frýd, Prague University of Economics and Business, Faculty of Informatics and Statistics, xfryl00@vse.cz

Abstract: The sector of knowledge intensive services is very often neglected, although it is very important for today's economy – it is highly innovative, fast-growing and usually provides highly paid and stimulating employment, involved in the creation and transfer of knowledge. It provides knowledge-intensive inputs to other entities in the private and public sectors. It deals with activities concerned primarily with human capital, thanks to the knowledge and skills of employees who are available to other companies. The aim of the article is to estimate the Cobb-Douglass production function for the knowledge intensive services sector and to compare it with the production function of the manufacturing sector which is one of the decisive sources of gross domestic product. Data for the period 1995-2018 in the annual frequency come from the database of the Czech Statistical Office. The output of the industry is measured as gross output at current prices, the amount of capital expressed by means of Gross fixed capital formation and work as employment in the sector. The change in capital per worker has the highest impact on output in the case of the manufacturing industry, which is dependent on physical capital. In the case of the fields of information and communication activities and professional, scientific and technical activities, the increase in the capital adequacy of work will be reflected in a lower increase in output per worker. These sectors are linked to human capital, so the non-inclusion of human capital in the production function leads to misleading results.

Keywords: innovation; human capital; production functions; employment; manufacturing industry; knowledge intensive services

JEL Classification: J24; D24; D83; L86; O30

INTRODUCTION

The seemingly simple notion of production functions expressing the relationship between the size of inputs and outputs hides a number of questions and pitfalls. These are not only questions concerning the specific economic environment, age or size of the company, but also the sector and socio-economic development. In the past, the dominant sectors of industry, energy and mining have pushed the most productively efficient services in the background in the recent years (Cowling & Tanewski, 2019), and we must continue to distinguish between them. The key role of human capital accumulation and the emphasis on innovation in recent years has brought the knowledge intensive services sector to the forefront (Pellegrino & Piva, 2020). Here, however, researchers must take into account a number of new facts and findings, not only because it is not only the productivity of traditional business firms, but also of entities such as universities or research institutions that is in the main focus (Hermanson, McKelvey & Zaring, 2020). At the same time, from the point of view of research, the correct setting of parameters and performance indicators reflecting the specific position, location and dynamic development of this sector, is crucial. This is one of the reasons why the area is currently being intensively researched and is one of the most progressive research goals (Kekezi & Klaesson, 2020).

The aim of the paper is to estimate the Cobb-Douglass production function for the knowledge intensive services sector and compare it with the production function of the manufacturing sector which is one of the decisive sources of gross domestic product.

1. LITERARY RESEARCH

Production or services? An almost "Hamletian" dilemma which is the basis of most outputs related to production functions in current research. Many of them locate generally valid knowledge. According to Hyder & Hall (2020), using predictions of the new Keynesian Phillips curve for the Pakistani economy, manufacturing in the region is a more promising sector than services. However, according to Taştan & Gönel (2020), the situation is completely different in Turkey, where, in the case of the benefits of IT, services dominate over production. The problem of higher growth rates of prices in the services sector compared to prices in the manufacturing sector is solved by Ghavidel & Narenji Sheskalany (2017), according to whom the difference arises due to the income elasticity of services. Spatial models are then used by Gong (2020) to estimate the production function in the oil industry segment on a representative sample of companies, and Bottaso, Conti & Vannoni (2019) focus on another segment of production functions in the search for economies of scale for international airports. Similarly, the public transport sector is addressed by Hansson & Holmgren (2018) in terms of production functions in the case of Sweden.

The role of allocation efficiency for the cyclical dynamics of aggregate productivity is then examined in French manufacturing and supply companies by Osotimehin (2019), who states that this efficiency is countercyclical within the industry and tends to reduce productivity volatility in the industry. The amount of investment in the use of big data analytics and is then, according to Nebel, Rasel & Viete (2018), directly related in terms of production functions with innovative and secondarily the overall performance of the company. Holmgren (2018) uses Data Envelope Analysis (DEA) or Stochastic Frontier Analysis (SFA) to determine the level of efficiency of various decision units in measuring production functions in the public sector. The methodology for harmonizing energy production, agriculture and the improvement of ecosystem services and synergies within production functions is developed by Semeraro et al., 2018 and in the case of Portuguese hospitals by Ferreira, Marques & Nunes (2018).

The logic of demand diversification in telecommunications services and their production function requiring ownership of various strategic assets is examined by Manral & Harringan (2018) who claim that diversification in the service sector increases the quality of customer bases but also the intensity of the competitive market. The influence of the quality and availability of financial services intended for Vietnamese small and medium enterprises, through the production function of Levinsohn's and Petrin's approach, is addressed by Giang et al. (2019), who draw attention to the need for a regulatory approach by the state. Florentin (2019) presents an innovative approach in the field of greening of services provided by municipalities with the aim of their transformation into a multi-purpose company, taking into account the role of production functions. Vallet et al. (2019) also focus on ecosystem services in the form of qualitative research claiming that this area provides a significant opportunity to benefit from the knowledge intensive services offered to both the civil and business sectors.

In general, production functions for services are an attractive topic. The statistically most significant effects of research and development in the services provided are found by Smeets Kristkova et al. (2017) in the areas with the highest flexibility, i.e. in the sectors of high-tech production and transport, storage and communication. Sasaki (2020) focuses on the correlation between employment in services and economic growth, which generates two types of curves depending on the accumulation of human capital. Pace & Miles (2019) focus on the issue of effective use of environmental innovations with extensive qualitative research in the field of knowledge intensive business services (KIBS), according to whom the synergistic attributes of business partners influence absorption capacity building and lead to various patterns of KIBS interaction with their clients.

The difference in maintaining the productivity of knowledge intensive services (KIS) for large and small and start-up companies is assessed by Audretsch, Kritikos & Schiersch (2020), according to whom

the latter are significantly more likely to start innovation activities and successfully transfer knowledge to innovation output.
The influence of external sources of knowledge and uneven geography on innovation activity in small knowledge-intensive business services (KIBS) is examined on a sample of 342 entities by Savic, Lawton Smith & Bournakis (2020), who did not discover a significant impact of cooperation between these companies and regional universities and other public institutions. However, this is contradicted by the findings of Link, Morris & Van Hasselt (2020), who, by a quantitative analysis of 4004 knowledge intensive businesses (KIEs) based in ten European Union countries, show that those companies that can exploit the knowledge potential of public research institutions are more innovative and more successful than their competitors. Hydle & Brock (2020) reveal six types of configuration - bilateral, trilateral, chain, stellar, network, and common - in knowledge intensive services of international organizations.
An analysis of the balance of the capital structure of companies with knowledge services (KIS) before and after the entry of venture capital (VC) is presented by Sardo, Serrasqueiro & Félix (2020) who report a significant reduction in debt dependence and behaviour change just after the entry of VC. Cardinaleschi, Damiani & Pompei (2020) then find a significantly higher efficiency of performance-related collective rewards in knowledge intensive services (KIS) sectors than in other areas of business. Pemer (2020) focuses on the digitization and application of artificial intelligence in the knowledge intensive services sector in the form of qualitative research which also represents an optimized model for supporting the infusion of digital technologies into this sector.
The links between internal barriers of innovation and the tendency of technology-based SMEs to collaborate with universities and research institutes are explored by Moraes Silva, Lucas & Vonortas (2020), who analyse a sample of high-tech manufacturing and knowledge intensive business services (KIBS) and especially the financial demands of mutual cooperation. Tsai & Chuang (2019) point to the service creativity reinforcement (SCR) as one of the important factors in the performance of companies that are part of the knowledge business services sector (KIBS). Rydehell, Isaksson & Löfsten (2019) focus on innovative performance (number of patents and product differentiation) and state that knowledge intensive technological services dominate in this area, followed by medium-sized technological production and technological production.
The impact of the Eco-Innovation Communication on increasing the market valuation of technology-based knowledge societies is addressed by Szutowski (2020) who states that a high degree of novelty has led to greater increases in returns on major types of eco-innovation in the European Union, which generally confirms the trend of research development in this area, especially in a dynamic socio-economic environment focused on programs such as Industry 4.0, or similar programs in China and developed countries.

2. DATA AND METHODS

In this paper, we estimate the Cobb-Douglass production function for three industries. The first of them is Manufacturing which is classified according to CZ NACE into group C, the second branch of the sector from the knowledge intensive services sector is Computer programming, consulting and information service activities which is included in NACE 62-63 and then the third branch Scientific research and development which is classified in NACE 72.
The abbreviation CZ NACE denotes the classification of economic activities in the Czech Republic where individual sections are indicated by the letters A-U, and these sections are subsequently divided into subsections further categorized by numbers 1-99. Manufacturing itself is a section marked with the letter C and includes the mechanical, physical or chemical conversion of materials or components into new products (goods), although this cannot be used as a single universal criterion for defining the production of goods, i.e. manufacturing. The sections covered by Section C are numbered 10-33 and can be seen in Table 1.

Tab. 1: Section C division into subsections (according to the CZ NACE classification)

10 – Manufacture of food products
11 – Manufacture of beverages
12 – Manufacture of tobacco products
13 – Manufacture of textiles
14 – Manufacture of wearing apparel
15 – Manufacture of leather and related products
16 – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17 – Manufacture of paper and paper products
18 – Printing and reproduction of recorded media
19 – Manufacture of coke and refined petroleum products
20 – Manufacture of chemicals and chemical products
21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations
22 – Manufacture of rubber and plastic products
23 – Manufacture of other non-metallic mineral products
24 – Manufacture of basic metals
25 – Manufacture of fabricated metal products, except machinery and equipment
26 – Manufacture of computer, electronic and optical products
27 – Manufacture of electrical equipment
28 – Manufacture of machinery and equipment n.e.c.
29 – Manufacture of motor vehicles, trailers and semi-trailers
30 – Manufacture of other transport equipment
31 – Manufacture of furniture
32 – Other manufacturing
33 – Repair and installation of machinery and equipment

Source: NACE CZ (2018)

The mentioned production function generally expresses the technical relationships between the physical quantities of inputs and outputs. Supply performance on the economic side is often identified by the growth rate of potential output (Hossian & Al-Amri, 2010). In particular, the Cobb-Douglas production function is often used to analyse the performance on the side of the supply and to measure a country's productive potential. However, this functional form includes the assumption of a constant share of labor in production, which may be too restrictive for a converging country (Hájková & Hurník, 2007).
The output of each of the industries is measured as gross output at current prices (GO). The amount of capital is measured using the Gross Fixed Capital Formation (GFCF) and labor as employment in the given sector (L). Variables used span interval 1995–2018 with annual frequency. The data used in this paper were obtained from the Czech Statistical Office.

In this paper, we estimate the intensive shape of the production function:

$$\ln y_t = \beta_0 + \beta_1 cap_t + \epsilon_t, \quad (1)$$

where $y_t = GO_t/L_t$, $cap_t = GFCF_t/L_t$ and $\epsilon_t \sim IID(0, \sigma^2)$.

3. RESULTS

Using the ADF test, we tested all variables for the presence of a unit root while testing versions with intercept and next entercept with trend. However, it was not possible to reject the null hypothesis for all variables. We could reject the null hypothesis of the presence of a unit root after the subsequent difference. For this reason, we assume that the individual time series follow the I (1) process.
Since Equation 1 represents a long-run relationship, we estimated this equation using dynamic OLS (DOLS) by Stock & Watson (1993). This estimation method is suitable due to the robustness to the potential of simultaneity bias and small-sample bias.

Table 2 contains the results of the estimation of each individual sector. We used the Engle and Granger two step cointegration test (1987) to test for the presence of a long-term relationship. The residues obtained from the estimate expressed by Equation 1 are stationary for all three given sectors. For this reason, we assume that there is a long-term relationship between the variables.

Tab. 2: Estimation result from the Equation 1

Variable	**Coefficient**	**Std. Error**	p-value
Manufacturing			
Intercept	-3.70	0.162	0.0774
cap	1.524	1.963	0,000
Computer programming, consultancy, and information service			
Intercept	6.169	0.467	0,000
cap	0.662	0.038	0,000
Scientific research and development			
Intercept	3.648	1.521	0.0290
cap	0.789	0.114	0,000

Source: Authors.

It is clear from Table 2 that the change in capital per employee has the highest impact on output in the case of industry C, i.e. in the case of Manufacturing. With a 1% increase in the cap variable, there is a 1.5% increase in output. Worse results are shown in the field of Computer Programming, Consultancy, and Information Service, where in the case of this field, the 1% increase in capital adequacy will be reflected in only 0.6% increase in output per employee. Compared to Manufacturing, there was not even an increase of 1%. A similar result is shown in the field of Scientific research and Development, where a 1% increase in the capital adequacy of work will be reflected in a 0.78% increase in output per employee. This result is not surprising given the type of business. Manufacturing is an industry heavily dependent on physical capital. On the contrary, the other two sectors are more related to human capital. It is thus clear that the non-inclusion of human capital in the production function leads to misleading results.

CONCLUSSION

Despite the fact that the knowledge-intensive services sector has long been neglected in research, although being very important for the economy of today's world, it has become more important in the field of research in recent years. One of the research options in the field of knowledge intensive services sector appeared to be the estimation of the Cobb-Douglass production function for the knowledge intensive services sector and its comparison with the production function of the manufacturing sector which is one of the crucial sources of gross domestic product. Data for the research were obtained from the database of the Czech Statistical Office, for the period 1995-2018 at an annual frequency. The results of this work show that although manufacturing is the only one of the three industries that is heavily dependent on physical capital, the change in capital per worker in this industry has the highest impact on the output. Although there was a 1.5% increase in output in the manufacturing sector at 1% cap, the remaining two sectors did not even reach an increase in output of 1% (Computer 0.6%, scientific research 0.78%). In addition to the ADF test for all variables and the DOLS (Stock & Watson, 1993) for Equation 1, the Engle and Granger two step cointegration test (1987) was used to test the presence of a long-term relationship in the results. The aim of the article was to estimate the Cobb-Douglass production function for the knowledge intensive services sector and to compare it with the production function of the manufacturing sector which is one of the decisive sources of gross domestic product. To conclude with, this goal was met.

Acknowledgement
This paper represents an output of the project Analysis of higher moments in the time-frequency domain F4 / 34/2020 and the project TL02000136 – Knowledge intensive services sector adaptation to the conditions of Society 4.0.

REFERENCES

Audretsch, D. B., Kritikos, A. S., & Schiersch, A. (2020). Microfirms and innovation in the service sector. *Small Business Economics.* Early Access.
Bottasso, A., Conti, M., & Vannoni, D. (2019). Scale and (quasi) scope economies in airport technology. An application to UK airports. *Transportation Research Part A: Policy and Practice*. *125,* 150-164.
Button, K. (2020). The economics of Africa's floriculture air-cargo supply chain. *Journal of Transport Geography. 86.*
Cardinaleschi, S., Damiani, M., & Pompei, F. (2018). Knowledge-intensive sectors and the role of collective performance-related pay. *Industry and Innovation. 27*(5), 480-512.
Cowling, M., & Tanewaki, G. (2018). On the productive efficiency of Australian businesses: Firm size and age class effects. *Small Business Economics. 53*(3), 739-752.
Engle, R., & Granger, W. J. C. (1987). Co-integration and error correction: representation, estimation, and testin. *Econometrica: Journal of the Econometric Society*. 251-276.
Ferreira, D. C., Marques, R. C., & Nunes, A. M. (2018). Economies of scope in the health sector: The case of Portuguese hospitals. *European Journal of Operational Research. 266*(2), 716-735.
Florentin, D. (2018). From multi-utility to cross-utilities: The challenges of cross-sectoral entrepreneurial strategies in a German city. *Urban Studies. 56*(11), 2242-2260.
Ghavidel, S., & Narenji Sheshkalany, A. (2017). Cost disease in service sector. *The Service Industries Journal. 37*(3-4), 206-228.
Giang, M. H., et al. (2019). The causal effect of access to finance on productivity of small and medium enterprises in Vietnam. *Sustainability. 11*(19).
Gong, B. (2020). Multi-dimensional interactions in the oilfield market: A jackknife model averaging approach of spatial productivity analysis. *Energy Economics. 86.*
Hájková, D., & Hurník, J. (2007). Cobb-Douglas production function: The case of a converging economy. *Finance a úvěr – Czech Journal of Economics and Finance*. *57*(9-10), 465-476.
Hansson, L., & Holmgren, J. (2018). Cost effect of reorganising – A study of special transport services. *Research in Transportation Economics. 69*, 453-459.
Hermanson, I., Mckelvey, M., & Zaring, O. (2020). Organising an early phase of academic engagement: a case study of interactions between engineering and equestrian sports. *Innovation.* 1-21.
Holmgren, J. (2018). The effects of using different output measures in efficiency analysis of public transport operations. *Research in Transportation Business and Management*. *28*, 12-22.
Hossain, M. Z., & Al-Amri, K. S. (2010). Use of Cobb-Douglas production model on some selected manufacturing industries in Oman. *Education, Business and Society: Contemporary Middle Eastern Issues*. *3*(2), 78-85.
Hyder, K., & Hall, S. G. (2019). Estimates of the New Keynesian Phillips Curve for Pakistan. *Empirical Economics. 59*(2), 871-886.
Hydle, K. M., & Brock, D. M. (2020). Global collaboration in knowledge intensive firms: The role of activity configurations. *Journal of Management & Organization*. *26*(4), 519-535.
Kekezi, O., & Klaesson, J. (2020). Agglomeration and innovation of knowledge intensive business services. *Industry and Innovation. 27*(5), 538-561.
Link, A. N., Morris, C. A., & Van Hasselt, M. (2020). The impact of the third sector of R&D on the innovative performance of entrepreneurial firms. *Small Business Economics*. Early Access.
Manral, L., & Harrigan, K. R. (2018). The logic of demand-side diversification: Evidence from the US telecommunications sector, 1990-1996. *Journal of Business Research*. *85*, 127-141.

Moraes Silva, D. R. D, Lucas, L. O., & Vonortas, N. S. (2020). Internal barriers to innovation and university-industry cooperation among technology-based SMEs in Brazil. *Industry and Innovation. 27*(3), 235-263.
NACE CZ (2018). *NACE*. Praha: Andrej Kesely. Retrieved Semptember, 14, 2020, from http://www.nace.cz/
Niebel, T., Rasel, F., & Viete, S. (2018). BIG data – BIG gains? Understanding the link between big data analytics and innovation. *Economics of Innovation and New Technology. 28*(3), 296-316.
Osotimehin, S. (2019). Aggregate productivity and the allocation of resources over the business cycle. *Review of Economic Dynamics*. *32*, 180-205.
Pace, L. A., & Miles, I. (2019). The influence of KIBS-client interactions on absorptive capacity-building for environmental innovation. *European Journal of Innovation Management*. *23*(4), 553-580.
Pellegrino, G., & Piva, M. (2020). Innovation, industry and firm age: are there new knowledge production functions? *Eurasian Business Review*. *10*(1), 65-95.
Pemer, F. (2020). Enacting professional service work in times of digitalization and potential disruption. *Journal of Service Research*. Early Access.
Rydehell, H., Isaksson, A., & Löfsten, H. (2019). Business networks and localization effects for new Swedish technology-based firms' innovation performance. *The Journal of Technology Transfer*. *44*(5), 1547-1576.
Sardo, F., Serrasqueiro, Z., & Félix, E. G. S. (2020). Does Venture Capital affect capital structure rebalancing? The case of small knowledge-intensive service firms. *Structural Change and Economic Dynamics*. *53*, 170-179.
Sasaki, H. (2020). Is growth declining in the service economy? *Structural Change and Economic Dynamics*. *53*, 26-38.
Savic, M., Lawton-Smith, H., & Bournakis, I. (2020). Innovation and external knowledge sources in knowledge intensive business services (KIBS): evidence from de-industrialized UK regions. *Entrepreneurship & Regional Development*. 1-22.
Semeraro, T., Pomes, A., Del Guidice, C., Negro, D., & Aretano, R. (2018). Planning ground based utility scale solar energy as green infrastructure to enhance ecosystem services. *Energy Policy*. *117*, 218-227.
Smeets-Křístková, Z., Gardebroek, C., Van Dijk, M., & Van Meijl, H. (2017). The impact of R&D on factor-augmenting technical change – an empirical assessment at the sector level. *Economic Systems Research*. *29*(3), 385-417.
Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica: Journal of the Econometric Society*. 783-820.
Szutowski, D. (2020). The impact of eco-innovation on the stock returns of technology-based KIBS: role of eco-innovation type and its degree of novelty. *Sustainability Accounting, Management and Policy Journal*. Early Access.
Taştan, H., & Gönel, F. (2020). ICT labor, software usage, and productivity: firm-level evidence from Turkey. *Journal of Productivity Analysis*. *53*(2), 265-285.
Tsai, K. H., & Huang, C. T. (2019). Service creativity reinforcement and firm performance. *Journal of Service Management*. *31*(1), 1-23.
Vallet, A., Locatelli, B., Levrel, H., Dendoncker, N., Barnaud, C., & Quispe Conde, Y. (2019). Linking equity, power, and stakeholders' roles in relation to ecosystem services. *Ecology and Society. 24*(2).