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Spatial Distribution of Total Factor Productivity (TFP) in the EU Regional Scope

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Abstract:

Purpose: *The aim of the paper is to analyse the differences in the level of productivity among the EU regions illustrated by the spatial distribution of total factor productivity (TFP). Since the level of productivity has an important geographical component the answer to the question, which regions are characterised with high or low level of productivity is being undoubtedly of high political importance.*
Design/Methodology/Approach: *To calculate TFP defined as the aggregated output-input ratio, we employ the multiplicatively-complete Färe-Primont index. This index satisfies all economically-relevant axioms and tests from index number theory. The research sample consists of 256 European Union (EU) regions at NUTS 2 level.*
Findings: *The results of the study indicate that relatively high TFP values are observed in core Western European regions, while the bottom of the TFP distribution is dominated by regions in Bulgaria, Poland and Romania. This may suggest a polarised specialization of the EU regions and limited interregional diffusion of technological knowledge. Our findings also show a high degree of dispersion in TFP within countries.*
Practical Implications: *Identification of the spatial distribution of Total Factor Productivity (TFP) across European regions has implication for the EU regional and innovation policies. Designing policies basing on smart specialization strategies, which foster linkages to release positive knowledge externalities both within as well as between regions, constitutes the desired strategic development aim to enhance the performance of TFP. In particular, these strategies are crucial for the regions characterized by low TFP levels.*
Originality/Value: *The methodological approach followed in this paper, in contrast to most of the existing studies on productivity differences at the regional level, satisfies all economically-relevant axioms and tests from index number theory.*

Keywords: *TFP, productivity, innovation, regional policy, regional development, convergence, Färe-Primont index, EU regions.*

JEL codes*: R11, R12, O31, O33, O47.*
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1. Introduction

Last decades of the European regional policy show a significant increase in public actions to enhance the processes of convergence and innovativeness. Development and regional policies in the EU strongly support actions and investments both in physical and human capital to accelerate these processes (European Commission, 2010). However, differences in the level of economic development within the EU countries are large and persistent. Therefore, the question arises which factors contribute to these differences: the availability of input factors such as capital, labour and human capital or the differences in the level of productivity.

A growing body of evidence in the relevant literature supports the view that the existing differences in regional economic development can be predominantly attributed to differences in productivity. A crucial measure of productivity is Total Factor Productivity (TFP), that determines how efficiently and intensely the available inputs are used in production.

Bearing in mind the above considerations the aim of the paper is to analyse the differences in the level of productivity across the EU regions illustrated by the spatial distribution of TFP. To calculate TFP we employ the multiplicatively-complete Färe-Primont index as this index is considered to be better applicable in wider economic context in comparison to the Malmquist TFP index (O'Donnell, 2012). Since the level of productivity has an important geographical component the answer to the question, which regions are characterised with high or low level of productivity is being undoubtedly of high political importance.

The reminder of the paper is organised as follows. In the second section a brief overview of the literature illustrating the concept of TFP, its features and measurement is presented. The third section describes the data and methods adopted to calculate TFP using Färe-Primont index in the EU regions. The forth section presents the results of the analysis along with a brief discussion of the main findings. The final section summarises the results and discusses their policy implications.

2. Literature Review

Considerable evidence in the empirical literature supports the view that the existing differences in regional economic development can be predominantly attributed to differences in productivity. A significant part of identified differences in the per capita income remains unexplained after taking into account the differences in physical or human capital. The hypermobility that characterises the traditional production resources, i.e. capital and labour reduces their geographical concentration and contributes to the shift of the drivers on which regional growth depends to immobile local resources connected with local environment, its culture and competences – in general to its innovation potential (Capello and Lenzi, 2013).

As the differences in economic development exist between and within countries, it can be stated that the spatial diffusion of technology and efficient production practices is limited and that the limits extend beyond national borders (Beugelsdijk *et al.,* 2018). An empirical contributions revealed a misleading character of the assumption made in the early studies on growth differences across countries, regarding technology as a pure public good, freely available to all (Di Liberto *et al.*, 2008). Even though assuming that the access to new technology is the same at the national level, the differences among regions appear in the level of technological development and their capacity to absorb and implement innovation (Berlemann and Wesselhoft 2012; Capello and Lenzi, 2015). The empirical analysis reveals that technology diffusion may follow a spatial pattern as characteristics of a given area such as the levels of human capital and the domestic R&D affect its rate of adopting foreign technology (Abreu *et al.*, 2004).

As Di Liberto and Usai (2013) state constant feature of productivity distribution along time is the spatial dependence as the changes in its distribution have a significant geographical component. This approach is consistent with the New Economic Geography paradigm (Krugman, 1998), according to which geographical concentration and localised spillovers are beneficial for productivity and growth (Ottaviano and Thisse, 2004). The productivity dynamics is differentiated by the effects of agglomeration externalities according to the product life cycle and the maturity stage of a given area (Marrocu *et al.*, 2013).

A crucial measure of productivity is Total Factor Productivity (TFP). TFP is the part of output which cannot be directly attributed to the amount of inputs used in the production process. The level of TFP thus determines how efficiently and intensely the available inputs are used in production. A large range of different approaches is currently used in the literature to determine TFP. As Schatzer *et al.* (2019) revealed the model selection has an essential impact on estimation results for both TFP levels and TFP growth rates.

The classical TFP approach evolves from the Solow (1957) macro-economic model based on the aggregate production function in which the total output depends on the productive inputs and the current level of technology. Assuming that all units of production operate efficiently, economic growth can be decomposed into contributions due to factor accumulation (capital and labour) and TFP growth, which is identified with technological progress. Under this approach TFP is calculated residually and it is often referred as the “Solow residual” (Salinas-Jimenez *et al.,* 2006).

Some recent studies have focused on the decomposition of TFP growth into efficiency change, represented by movements of the economy towards or away from the production frontier, and technological progress represented by shifts of the production frontier adopting a production frontier approach (O’Donnell, 2012). Under this approach, labour productivity growth is broken down into components attributable to efficiency change, technological progress and capital accumulation. The frontier approach allows avoiding the possible bias derived from the assumption, common in the classical literature on economic growth, that all economic units operate efficiently. This approach allows to consider the possible existence of inefficiencies (inefficient behaviour measured by the difference between the actual level of production and the maximum possible level defined by the frontier) (Şeker and Saliola, 2018).

To estimate a common production frontier the two main techniques are used: non-parametric linear programming Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) (O'Donnell, 2014). TFP is decomposed by means of productivity indexes of which the most frequently employed in the empirical analyses is the Malmquist index. However, as O'Donnell (2012) argues, the popular Malmquist TFP index is incomplete, implying it cannot always be interpreted as a measure of productivity change. He considers multiplicatively-complete aggregated TFP indexes to be better applicable in wider economic contexts. One of them is the Färe-Primont index, which we employ in the analyses conducted in the present paper.

European regional policy is regarded as successful if disparities between regions decrease and the convergence process among the EU regions proceeds. To enhance the performance of TFP its determinants should be indicated enabling policy actions to focus on them. The literature review by Isaksson (2007) allowed to identify several determinants that have impact on TFP, or are at least associated with, TFP growth. Of these, human capital (education and health), infrastructure, imports (but not trade in general) institutions, openness, competition, financial development, geography, and capital intensity/deepening occupied prominent positions, some directly and others indirectly affecting TFP growth. What is worth to point out, innovation and R&D turned out to be important for TFP growth in industrialised countries, but there is little evidence of their importance for developing countries.

The above considerations have allowed us to formulate the following research question: how the level of productivity, as measured by TFP, is distributed spatially across the EU regions? Since the level of productivity has an evident geographical component the answer to this question has undoubtedly important regional policy implications.

3. Data and Methods

Our sample consists of 256 European Union (EU) regions at NUTS 2 level. Regions from Spain and Estonia have been excluded from the analyses due to missing data. For the purpose of TFP estimation, we use one output and two inputs. Our measure of the output variable is gross domestic product (GDP) at current market prices. In turn, the input variables are employment (E) in thousand hours worked and gross fixed capital formation (GFCF). The latter consists of resident producers' investments, deducting disposals, in fixed assets during a given period. To avoid numerical errors, all input and output quantity variables are scaled to have unit means. The regional data on GDP, employment and gross fixed capital formation come from the Eurostat and cover the year 2015.

To calculate the total factor productivity (TFP) defined as the aggregated output-input ratio, we use the Färe-Primont index. This index satisfies all economically-relevant axioms and tests from index number theory and is multiplicatively-complete (O'Donnell, 2011). The class of non-negative, non-decreasing and linearly homogeneous output-input aggregator functions included in the Färe-Primont index are as follows (O'Donnell, 2011):

$$Q(q) = D_O(x_0, q, t_0) \tag{1}$$

$$X(x) = D_I(x, q_0, t_0) \tag{2}$$

where x_0 and q_0 are vectors of representative input and output quantities, t_0 denotes a representative time period, and $D_0(.)$ and $D_I(.)$ are output and input distance functions.

The aggregator functions (1) and (2) give rise to the Färe-Primont index that measures TFP of region i in period t relative to TFP of region h in period s. The index has the form (O'Donnell, 2011):

$$TFP_{hs,it} = \frac{D_O(x_0,q_{it},t_0)}{D_O(x_0,q_{hs},t_0)} \times \frac{D_I(x_{hs},q_0,t_0)}{D_I(x_{it},q_0,t_0)} \tag{3}$$

DPIN program has been employed to calculate the Färe-Primont index. The program uses data envelopment analysis (DEA) linear programs (LPs) to estimate the production technology and levels of productivity. DEA is underpinned by the assumption that the output and input distance functions representing the technology available in period *t* take the form:

$$D_O(x_{it}, q_{it}, t) = (q_{it}'\alpha)/(\gamma + x_{it}'\beta) \tag{4}$$

$$D_I(x_{it}, q_{it}, t) = (x_{it}'\eta)/(q_{it}'\phi - \delta) \tag{5}$$

DPIN estimates Färe-Primont aggregates by first solving the following variants of linear programs (O'Donnell, 2011):

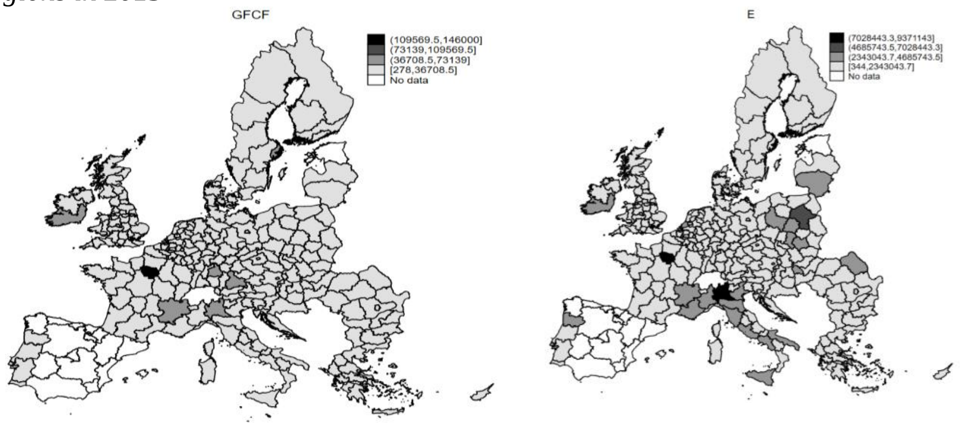
$$D_O(x_0,q_0,t_0)^{-1} = \min_{\alpha,\gamma,\beta}\{\gamma + x_0'\beta : \gamma\iota + X'\beta \geq Q'\alpha; q_0'\alpha = 1; \alpha \geq 0; \beta \geq 0\} \tag{6}$$

$$D_I(x_0,q_0,t_0)^{-1} = \max_{\phi,\delta,\eta}\{q_0'\phi - \delta : Q'\phi \leq \delta\iota + X'\eta; x_0'\eta = 1; \phi \geq 0; \eta \geq 0\} \tag{7}$$

4. Results and Discussion

Figure 1 presents the levels of the input variables used in the analyses. It is worth noting that the region with the highest level of employment and investments in the fixed assets is Île de France. Other top ranking regions by input variables are Oberbayern, Lombardia and Rhône-Alpes. The regions characterized by the lowest level of hours worked are nested in Germany. In the case of the second input variable the lowest regions in the ranking are Åland, Ionia Nisia, Mayotte, Voreio Aigaio, Ipeiros, Região Autónoma dos Açores, Região Autónoma da Madeira and Notio Aigaio.

Figure 1. *Gross fixed capital formulation (GFCF) and employment (E) in the EU regions in 2015*

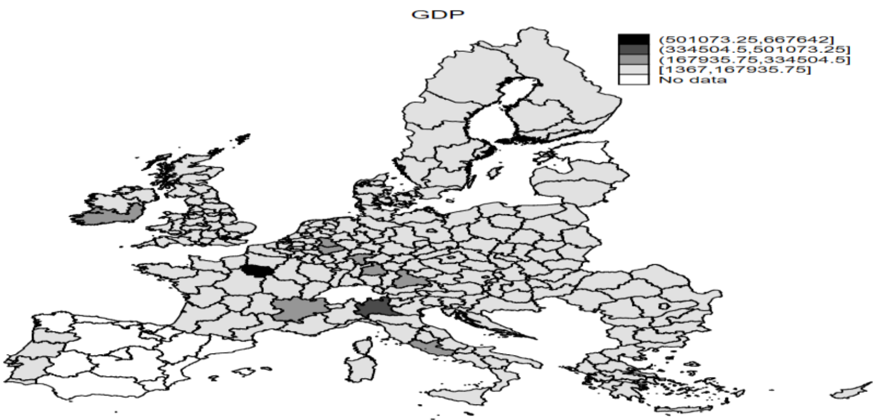


Source: *Own elaboration based on the Eurostat database, https://ec.europa.eu/eurostat/data/database.*

As regards the output variable, it ranges from 1367 mln euro in Åland to 667642 mln euro in the French region of Île de France (Figure 2). The next top 3 regions in the ranking of regional GDP in 2015 are Lombardia, Inner London – West and Oberbayern. There are 29 regions with GDP 100% or more above the EU average, i.e. 9 regions are in Germany, 6 in Italy, 5 in France, 4 in the United Kingdom, one each in Belgium, the Czech Republic, Denmark and Sweden, as well as Ireland. At the other end of the list there are Åland, Mayotte, Voreio Aigaio and Severozapaden having the lowest GDP.

Calculating TFP using the the Färe-Primont index, the most productive regions in EU are situated along London, Düsseldorf and Liguea (Figure 3) corridor, where Inner London shows the highest value. It should be noticed that there are 18 German regions within the group of top 25 productive regions. The most productive German regions are located in West Germany. Similar findings are presented by Bertlemann and Wesselhoft (2012), who find that differences in the level of total factor productivity account for most of the remaining gap between East and West Germany.

Figure 2. *GDP in the EU regions in 2015*



Source: *Own elaboration based on the Eurostat database, https://ec.europa.eu/eurostat/data/database.*

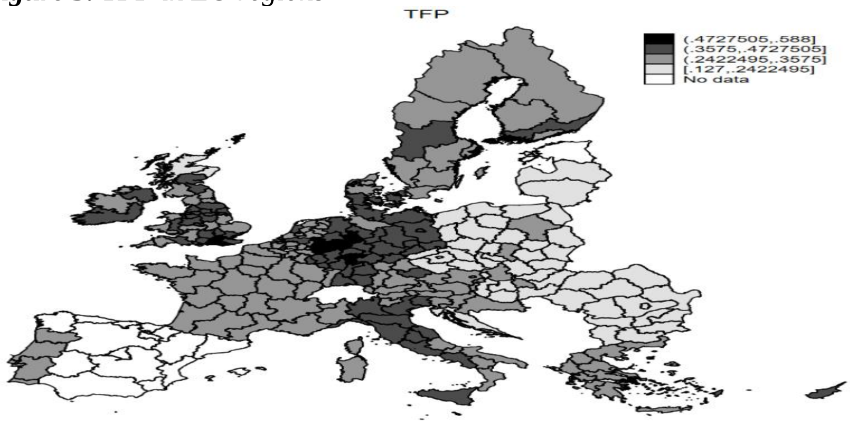
The bottom of the TFP distribution is dominated by regions in Bulgaria, Poland and Romania recording extremely low TFP scores. The lowest levels of TFP in peripheral regions in Eastern Europe are also documented by Beugelsdijk, Klasing and Milionis (2018). Contrary to our methodology, these authors apply the technique of development accounting to find differences in total factor productivity (TFP) in EU regions.

Such a polarised TFP performance observed among the EU regions is undoubtedly the result of the EU enlargement to a set of 28 countries. In the last decade the western countries have experienced a growth six times slower than new member countries. This has induced them to delocalize part of their traditional industries eastwards, generating a specialization in knowledge-intensive services (KIS) in the Old Europe while the New Europe specializes in low-tech manufacturing (LTM) (Marrocu *et al.*, 2013).

What is worth to point out, is that while specialisation in high-tech manufacturing appears to be quite diffused across the European regions, specialization in KIS reveals significant concentration rates. The TFP distribution is also interrelated with urban–rural distribution of specialisation levels. KIS specialization is found to be the strongest in more densely inhabited areas, i.e. agglomerated regions (Capello and Lenzi, 2013).

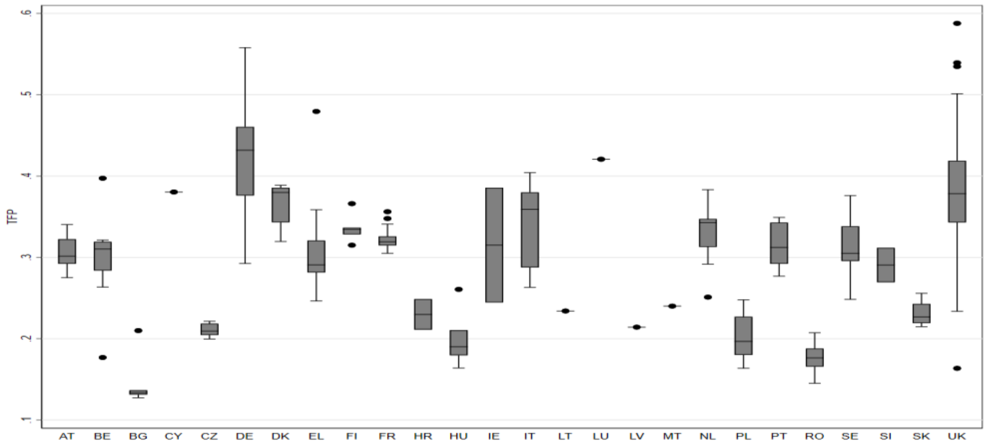
Figure 3 also shows a high degree of dispersion in TFP within countries. To assess more carefully the dispersion in TFP, we draw a box-plot showing the variation (i.e. interquartile range) in TFP within each country (Figure 4). The box-plot reveals that the degree of variation in TFP varies across countries. Some large countries, including Germany, Italy and UK, where TFP is on average high, there is considerable interregional dispersion in TFP. On the other hand, there are examples of large countries, including France and Sweden, characterized by relatively low levels of TFP variations. Going to the Eastern European countries, we find that the distribution of TFP variation is also polarised. The interregional dispersions of TFP in Czechia and Bulgaria are relatively low, while the variation of TFP in Poland outperforms the variation in the rest of Eastern European countries.

Figure 3. *TFP in EU regions*



Source*: Own elaboration based on the Eurostat database, https://ec.europa.eu/eurostat/data/database.*

Figure 4. *TFP variation within countries*



Source*: Own elaboration based on the Eurostat database, https://ec.europa.eu/eurostat/data/database.*

5. Conclusions

This study examines the spatial distribution of total factor productivity (TFP) at the regional level. TFP captures the overall sophistication of the production process, since it reflects how different production inputs are utilized. Using data from Eurostat and focusing on 256 NUTS 2 regions nested in 26 EU countries, the paper employs the Färe-Primont index to find the TFP levels. The methodological approach followed in this paper, in contrast to most of the existing studies on productivity differences at the regional level, satisfies all economically-relevant axioms and tests from index number theory.

The results reveal that differences in the TFP levels among the EU regions are large. The TFP levels tend to be highest along London, Düsseldorf and Liguea corridor and lowest in the Eastern Europe regions. A great opportunity to take the European regions forward and diminish the existing productivity gap among them is the development and implementation of smart specialization strategies. According to them, regions should identify the sectors and technological fields representing their presumed competitive advantages and then focus their regional policies so as to stimulate innovation processes in these areas. The desired strategic development aim is also to design policies which will foster linkages to release positive knowledge externalities both within as well as between regions. In particular, these strategies are crucial for the regions characterized by low TFP levels (Mc Cann and Ortega-Argilés, 2015).

Since the ability to create and absorb innovation is regarded as a crucial factor of economic development, the further research should focus on the investigation of the impact of the level of regional innovative performance on TFP distribution in the EU regional scope.

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