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Article

The productivity of innovation in Portugal

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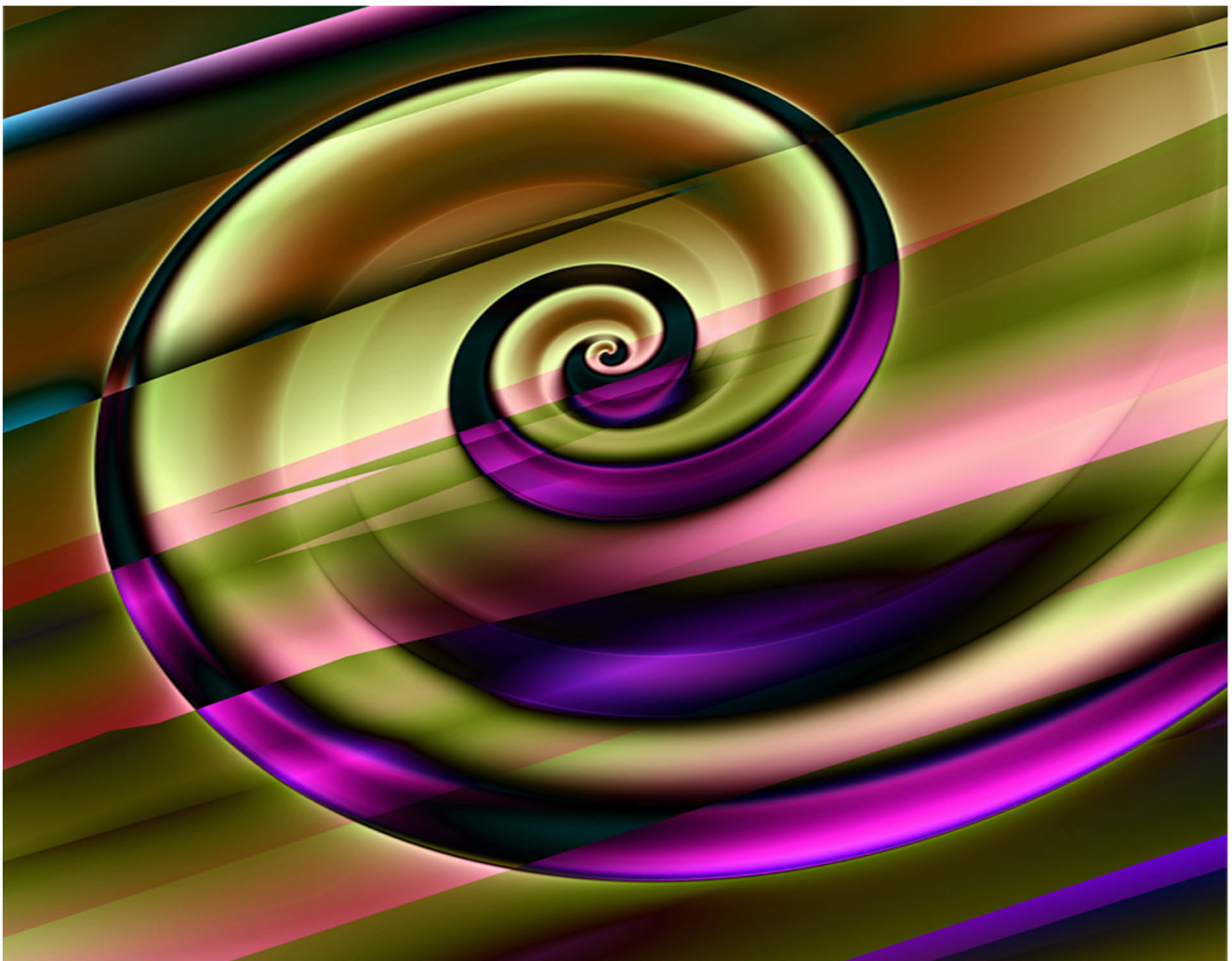
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The productivity of innovation in Portugal

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Abstract:

In this research innovation is considered as a production process, with outputs and inputs. The purpose is to compare the productivity of innovation across the twenty seven Member States of the European Union (EU-27), with a particular focus on Portugal. The data on inputs and outputs of innovation were collected from the Innovation Union Scoreboard 2010 report and cover the EU-27 Member States, from 2006 to 2010. The Total Factor Productivity index (TFP index) was used as the technique for data analysis. The choice of this technique was mainly determined by its flexibility and by data constraints. Two types of TFP indexes were computed: i) TFPT (time), which compares the productivity of innovation in each Member State with its productivity in a base year; ii) TFPs (space), which compares the productivity of innovation in each Member State with the productivity of the EU-27 average. Results show larger TFPs differences across Member States than TFPT differences. Concerning TFPT, there is a reduction of productivity in most of the Member States during the time length, which can be explained by the recent world financial crisis. This was the case of Portugal, where average TFPT in the time length is slightly below 1. The seven Member States that did not lose any productivity are mostly from Eastern Europe, Member States which have entered the European Union and acceded to its structural funds more recently. Concerning TFPs, Portugal presents average TFPs well above 1. The Portuguese average TFPs value is close to the one of Germany and higher than the one of Sweden. The Innovation Union Scoreboard 2010 report classifies Portugal as Moderate innovator and Germany and Sweden as Innovation leaders. This research has found the marginal productivity of innovation in Portugal to be similar to the one of Germany and higher than the one of Sweden. Differences between Portugal, Germany, and Sweden, such as the ones reported in the Innovation Union Scoreboard 2010, can be explained by the fact of Portugal having fewer resources allocated to innovation than Germany and Sweden have. The TFPs results show in which Member States innovation investment pays the most.

Keywords: EU-27, innovation, Portugal, production process, productivity, TFP index

1. Introduction

The focus of this research is the phenomenon of innovation in the 27 European Union Member States (EU-27). Innovation is seen as a production process, with inputs or innovation production factors and outputs or innovation products resulting from this process.

The data used in this research are included in the Innovation Union Scoreboard 2010 study (UNU-MERIT, 2011). This report compares the innovation performance of the EU-27 Member States, presenting inputs and outputs of innovation. It was intended in this research to deepen this idea of dealing with innovation as a production process, by calculating measures of relative productivity for the various Member States of the EU-27, including Portugal.

The motivation of the research is connected to one of the author's route of tracking processes of innovation in Portuguese Small and Medium Enterprises (SMEs). In the Portuguese business sector, SMEs represent 99.6% of the firms, create 75.2% of the jobs, and generate 56.4% of the volume of national business (Rocha, 2010). For lack of data in this area, this study has the Member States of the EU-27 as units of observation.

The investment in education, research, technology and innovation is seen as a key driver of growth. Innovative ideas can be converted into new marketable products and services that help to generate growth and quality jobs. The European Council called for the implementation of a strategy and integrated approach in order to foster innovation and take full advantage of the intellectual capital of Europe for the benefit of citizens, businesses (especially SMEs), and researchers. SME's engage in innovation processes as a way to conquer competitive advantages, which allow them to cooperate in networks and/or compete for quality in niche markets.

The article is organized into four sections. After this introductory section, in section 2 a description is made of the productivity indicators used (TFP indexes), justifying their choice, as well as of the database used (the inputs and outputs reported in the Innovation Union Scoreboard Study 2010). In section 3 results are illustrated and discussed. Finally, in section 4 the main conclusions are presented.

2. Data and Methodology

In this section a distinction is made between productivity and efficiency and the existent methodologies on productivity and efficiency analysis are described, justifying the use of the Total Factor Productivity index (TFP index) in the analysis performed in this research. The TFP index is a measure of productivity. The section ends with a description of the empirical model, that is, the two types of TFP index computed and the database used.

2.1 Productivity and efficiency

The terms productivity and efficiency are sometimes used interchangeably. According to Eltis (1996), the concept of productivity was first used by the French economist of the Physiocratic school François Quesnay in 1766: "the quotient obtained by dividing production by one of the factors of it". As described, it is a concept of partial productivity. In this research one has multiple outputs and inputs and thus he use measures of total factor productivity (TFP indexes).

The notion of total factor productivity embraces the notion of technical efficiency of the observed units. The latter can be firms, countries, or other units. Technical inefficiency is measured as the distance

between specific quantities of inputs or outputs and the amounts of inputs or outputs that define the efficient frontier (Caves *et al.* 1982; Fare *et al.* 1994). Total factor productivity assumes the existence of technical efficiency (zero distance).

In time, production technology and/or the efficient frontier may change, which affects the total factor productivity (Coelli *et al.*, 2005). In space, observed units may operate in different zones of the efficient frontier or in different efficient frontiers and thus they can differ in total factor productivity.

2.2 Methods of analysis of productivity and efficiency and the choice of the TFP index

Figure 1 illustrates the existing techniques for analysing productivity and efficiency. The most often used techniques are indicated with shading in the table: Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Total Factor Productivity (TFP).

Overview of Benchmarking Techniques

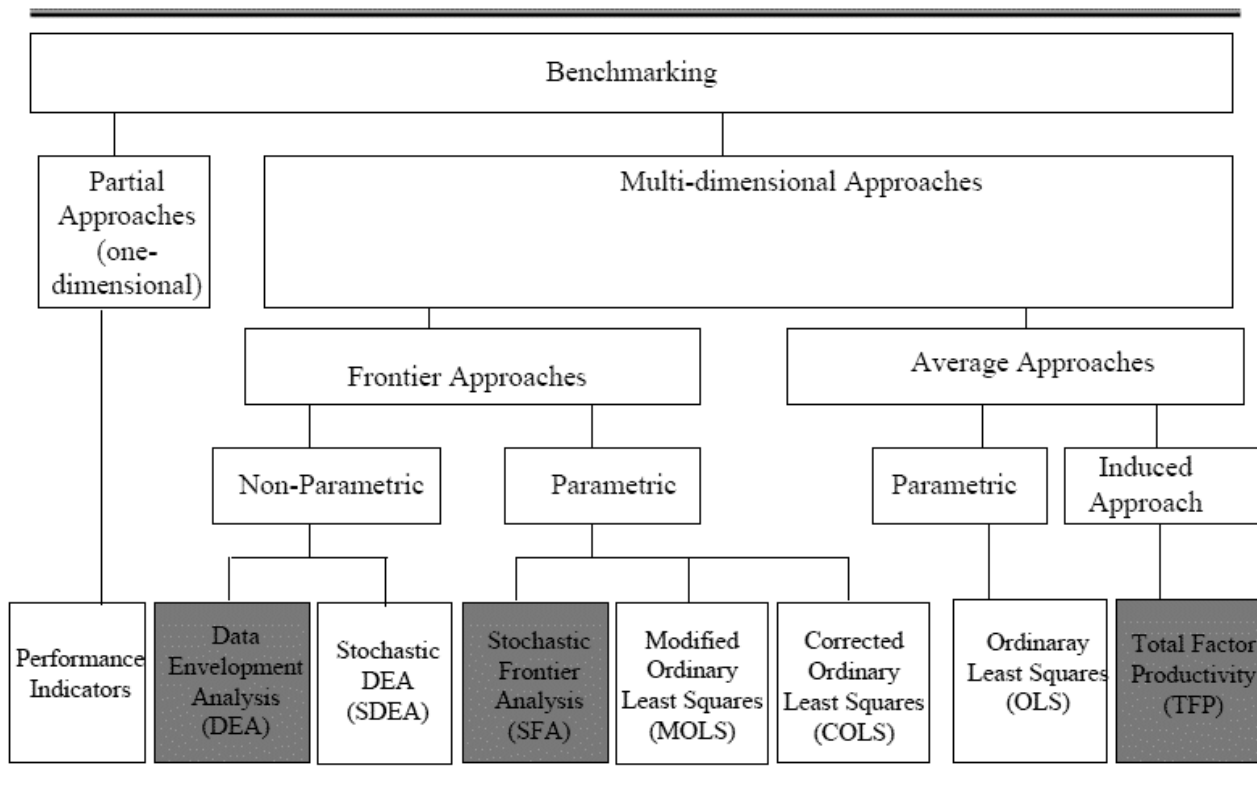


Figure 1 - Techniques for analyzing productivity and efficiency

Source: Cullmann, Kappeler, and Hirschhausen (2006)

The techniques for analysing productivity and efficiency can be grouped in various ways (Coelli *et al.*, 2005). Comparing the most used techniques:

- a) The TFP index assumes the existence of technical efficiency. The same is not true for DEA and SFA;
- b) The SFA involves the parametric estimation of functions. The same is not true for DEA and TFP index, which are non-parametric techniques;
- c) DEA and SFA provide measures of relative efficiency among observed units. The TFP index provides measures of relative productivity among observed units.

The technique used in this research is the TFP index. The TFP index is computed in each year for the EU-27 Member States, allowing the comparison, in time, of the relative to itself productivity for each Member State, and, in space, of the relative productivity across Member States. The used technique and data are described next.

Like DEA and as opposed to SFA, the TFP index is a non-parametric technique and thus more flexible in terms of assumptions. In addition, the TFP index may require less information than DEA, particularly on prices. The choice of the TFP index as the technique of analysis in this research is justified by these two reasons.

In economics, index numbers are defined as real numbers that measure changes in a set of related variables. Index numbers are used to measure changes in either prices or quantities, in time and in space. As quantity indexes, they may be on outputs, on inputs, or relating both, outputs and inputs, the latter being the case of the TFP index (Coelli *et al.*, 2005).

The TFP index was used in several empirical studies. For example, Hooper and Hensher (1997) used the Tornqvist TFP index to measure the performance of six Australian airports, from 1989 to 1991. Kulshreshtha and Parikh (2001) used the Tornqvist TFP index to measure productivity in the coal sector in India, from 1980 to 1992. Fuglie (2004) conducted a study on total factor productivity of agriculture in Indonesia, from 1961 to 2000. Oh *et al.* (2008) used a TPP index approach in the study of productivity growth of manufacturing industry in Korea, from 1993 to 2003. Kumar (2006) used a Malmquist–Luenberger (ML) TFP index to examine conventional and environmentally sensitive total factor productivity in 41 developed and developing countries, from 1971 to 1992. Kasman and Turgutlu (2009) employed the Malmquist TFP index to examine productivity changes in the life and non-life branches of the Turkish insurance sector, from 2000 to 2005. Carrol, Newman, and Thorne (2011) used a Malmquist TFP index to analyse the Irish tillage sector. Aghdam (2011) used a Malmquist TFP index approach to study the dynamics of productivity changes in the Australian electricity industry. Chou, Shao, and Lin (2012) used a Malmquist index to examine the productivity growth of information technology industries (IT) across 19 OECD countries, from 2000 to 2009. Rahman and Salim (2013) applied the Färe–Primont TFP index to analyse changes in agriculture productivity in 17 regions of Bangladesh, from 1948 to 2008.

The choice of the Laspeyres TFP index, instead of the Tornqvist TFP index or other most often used TFP indexes, relates to the available price information. The Laspeyres TFP index only requires base year prices.

The TFP index is a ratio between an output index and an input index:

$$(1) TFP_{sv} = \frac{Output.Index_{sv}}{Input.Index_{sv}}$$

s and *v* are two observations, in time or in space. To compute the Laspeyres TFP index, Laspeyres quantity indexes on output and input quantities are calculated first:

$$(2) q_{sv}^L = \sum_{i=1}^M \frac{p_b^i q_s^i}{p_b^i q_v^i}$$

Again, s and v are two observations, in time or in space. M is the number of outputs or inputs. Prices are base year prices that we assume as uniform and equal to 1.

2.3 Empirical model

To estimate the empirical model the database included in the study Innovation Union Scoreboard 2010 (UNU-MERIT, 2011) was used. The sample has a total of 135 observations, covering the Member States of the EU-27 from 2006 to 2010. Two types of TFP indexes, designated by TFPT (time) and TFPs (space), are estimated. To calculate these TFP indexes first the corresponding output and input indexes are computed.

Concerning the TFPT (time) index, for each year and Member State, the ratio among the values of outputs in the year and the values of outputs in the base year was computed. To get the input index a similar procedure was used with the inputs. The TFPT index results from dividing the value of the output index by the value of the input index.

In what refers to the TFPs (space) index, the ratio of the values of the outputs of each Member State in each year with the EU-27 average values of outputs in the same year was computed. Similar procedure was used with the inputs. The TFPs index results from dividing the value of the output index by the value of the input index.

In both cases, TFPT and TFPs, time averages were computed for each Member State in the period under analysis.

The list of inputs and outputs of innovation included in the mentioned database is the following:

- a) I1 (Input 1) – “Human resources” - includes 3 indicators and measures the availability of a high-skilled and educated workforce;
- b) I2 (Input 2) – “Open, excellent and attractive research systems” - includes 3 indicators and measures the international competitiveness of the science base;
- c) I3 (Input 3) – “Finance and support” - includes 2 indicators and measures the availability of finance for innovation projects and the support of governments for research and innovation activities;
- d) I4 (Input 4) – “Firm investments” - includes 2 indicators of both R&D and non-R&D investments that firms make in order to generate innovations;
- e) I5 (Input 5) – “Linkages & entrepreneurship” - includes 3 indicators and measures entrepreneurial efforts and collaboration efforts among innovating firms and also with the public sector;
- f) I6 (Input 6) – “Intellectual assets” - captures different forms of Intellectual Property Rights (IPR) generated as a throughput in the innovation process;
- g) O1 (Output 1) – “Innovators” - includes 3 indicators and measures the number of firms that have introduced innovations onto the market or within their organisations, covering both technological and non-technological innovations and the presence of high-growth firms;
- h) O2 (Output 2) – “Economic effects” - includes 5 indicators and captures the economic success of innovation in employment, exports and sales due to innovation activities.

Each of the above inputs and outputs results from the aggregation of the several indicators and/or dimensions they include. Inputs 1, 2, and 3 are classified as “Enablers” and capture the main drivers of innovation performance external to the firm. Inputs 4,5, and 6 are classified as “Firm activities” and

capture the innovation efforts at the level of the firm. The outputs cover the effects of firms' innovation activities. The reader is referred to the Innovation Union Scoreboard 2013 report (UNU-MERIT, 2013) for more details.

3. Results

In this section three types of results are presented:

- a) A correlation matrix that shows significant correlations between Member States time average inputs and outputs in the period from 2006 to 2010;
- b) Average TFP indexes in time and space for each Member State;
- c) The comparison of the results in this research with the results in the Innovation Union Scoreboard 2010 report (UNU-MERIT, 2011), with a particular focus on Portugal.

3.1 Innovation as a production process

Table 1 below shows the correlations between Member States time average inputs and outputs of innovation. Time average inputs and outputs were computed to ensure that there is no autocorrelation in the observations. All reported correlations are significant at least at a level of significance of 5%.

Table 1: Correlations between Member States time average outputs and inputs of innovation

| | I1 | I2 | I3 | I4 | I5 | I6 | O1 | O2 |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| I1 | 1,000 | 0,618 | 0,727 | 0,609 | 0,726 | 0,534 | 0,396 | |
| I2 | 0,618 | 1,000 | 0,776 | 0,469 | 0,840 | 0,837 | 0,522 | 0,620 |
| I3 | 0,727 | 0,776 | 1,000 | 0,473 | 0,723 | 0,750 | 0,390 | |
| I4 | 0,609 | 0,469 | 0,473 | 1,000 | 0,762 | 0,635 | 0,658 | 0,500 |
| I5 | 0,726 | 0,840 | 0,723 | 0,762 | 1,000 | 0,801 | 0,739 | 0,534 |
| I6 | 0,534 | 0,837 | 0,750 | 0,635 | 0,801 | 1,000 | 0,577 | 0,618 |
| O1 | 0,396 | 0,522 | 0,390 | 0,658 | 0,739 | 0,577 | 1,000 | 0,417 |
| O2 | | 0,620 | | 0,500 | 0,534 | 0,618 | 0,417 | 1,000 |

Source: Author's estimation

Three results should be highlighted from the above table:

- a) Inputs and outputs have positive and statistically significant correlations. More inputs generate more outputs. The correlation is not significant between O2 and I1 and between O2 and I3. Human resources do not seem to result in immediate economic results. Financing and support either. If a positive correlation exists between the variables in question it is not contemporaneous;
- b) The two outputs have a significant and positive correlation. That is, Innovators firms and Economic effects are complements;
- c) The six inputs of innovation considered have significant and positive correlations, that is, they are complements and not substitutes. Particularly, "Enablers" (Inputs 1, 2, and 3) have significant, positive, and mostly strong correlations with "Firm activities" (Inputs 4, 5, and 6).

The above results support innovation as a production process that transforms considered inputs into considered outputs. TFP indexes in time and in space are presented next.

3.2 TFP indexes in time and space

TFP indexes are obtained in two dimensions:

- a) TFPT (time), productivity of each Member State in each year is compared with productivity of the same Member State in the base year (2006);
- b) TFPs (space), productivity of each Member State in each year is compared with productivity of the EU-27 average in the same year.

Table 2 and Figure 2 illustrate the average results for the period under analysis. Results are obtained for each EU-27 Member State in time (vertical axis) and in space (horizontal axis). Thus, each point of Figure 2 corresponds to a coordinate (TFPT, TFPs) associated to a particular Member State. The circles, squares and triangles indicate the three groups of Member States that have resulted from a cluster analysis. The groups can be identified along the TFPs axis.

Table 2: Time average TFPT and time average TFPs per Member State of the EU-27

| Member State | Abbreviation | TFPT | TFPs |
|----------------|--------------|-------|-------|
| Belgium | BE | 0,929 | 0,998 |
| Bulgaria | BG | 1,230 | 1,429 |
| Czech Republic | CZ | 0,995 | 1,336 |
| Denmark | DK | 0,846 | 0,815 |
| Germany | DE | 0,955 | 1,311 |
| Estonia | EE | 0,844 | 1,164 |
| Ireland | IE | 0,867 | 1,553 |
| Greece | GR | 1,179 | 1,776 |
| Spain | ES | 0,942 | 0,929 |
| France | FR | 0,921 | 0,913 |
| Italy | IT | 0,907 | 1,156 |
| Cyprus | CY | 0,856 | 1,385 |
| Latvia | LV | 1,139 | 0,544 |
| Lithuania | LT | 0,993 | 0,729 |
| Luxembourg | LU | 0,849 | 1,450 |
| Hungary | HU | 1,117 | 1,207 |
| Malta | MT | 1,002 | 2,468 |
| Netherlands | NL | 0,918 | 0,763 |
| Austria | AT | 0,957 | 1,036 |
| Poland | PL | 0,948 | 0,899 |
| Portugal | PT | 0,964 | 1,289 |
| Romania | RO | 0,911 | 1,573 |
| Slovenia | SI | 0,932 | 0,960 |
| Slovakia | SK | 1,028 | 1,281 |
| Finland | FI | 1,028 | 0,729 |
| Sweden | SE | 0,919 | 0,717 |
| United Kingdom | UK | 0,852 | 0,764 |

Source: Author's calculations

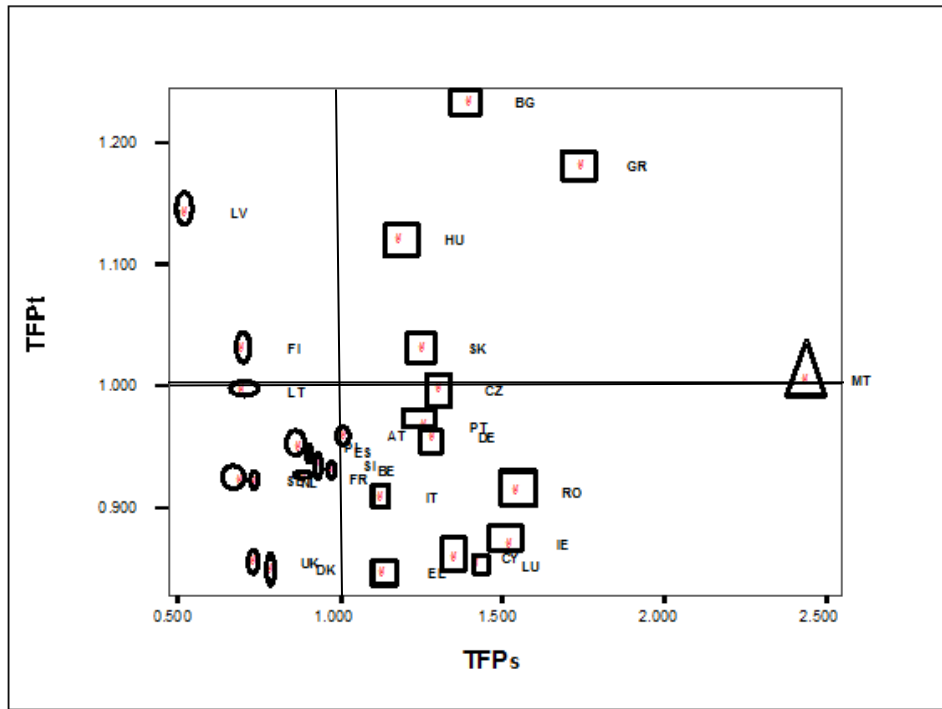


Figure 2: Time average TFPt and TFPs by Member State of the EU-27
Source: Table 2.

Two cross lines divide Figure 2 into four quadrants. Respectively, the lines indicate in the Figure values of TFPt = 1 and of TFPs = 1.

There are several results that derive from Table 2 and Figure 2:

- a) 20 Member States of the EU-27 are in line TFPt = 1 or below. This means that, in time, these Member States have maintained or lost the levels of productive efficiency that they had in the base year of 2006. This is the Portuguese case. However, of the 20 Member States listed, in time, after Lithuania, Portugal is the Member State that has kept the best results in this TFPt indicator, presenting even higher performance than Germany;
- b) The 7 Member States above the line TFPt = 1 are mostly Member States of the Eastern Enlargement of the EU. With the integration into the EU, these Member States have had a strong economic growth, foreign investment, EU funds, tax incentives, in addition to the existing high levels of education and qualification of their population and to low labour costs when compared to other EU-27 Member States, which may explain these results;
- c) The large differences across Member States are in space: i) 13 Member States have a TFPs equal to 1 or less than 1 (TFPs group average = 0.831); ii) 13 Member States have a TFPs higher than 1 but less than 2 (TFPs group average = 1.378) and iii) Malta has a TFPs higher than 2 (TFPs = 2.468);

- d) The 13 Member States with TFPs = 1 or lower have levels of innovation productivity equal to or lower than the EU-27 average. Most of Northern and Central Europe Member States are in this group. Sweden, the leader of innovation, has a TFPs = 0,717 and belongs to this group. Several factors can explain these results: decreasing returns to scale of innovation, economic sectoral specialization in services, etc;
- e) The 14 Member States with TFPs > 1 have levels of productivity in innovation above the EU-27 average. Southern Europe Member States as well as Germany and other Member States are placed in this group. Malta, with a TFPs= 2.468 is a case apart. Portugal, with a TFPs = 1.289, is located near the industrial Germany, with a TFPs = 1.311, both Member States with a level of productivity in innovation above the EU-27 average.

In the next section the innovation TFPs results obtained are compared with the results reported in the Innovation Union Scoreboard 2010 (UNU-MERIT, 2011), having a particular focus on Portugal.

3.3 – Comparison of TFPs and Innovation Union Scoreboard 2010 results

Figure 3 shows the innovation performance of the EU-27 Member States according to the Innovation Union Scoreboard 2010 report (UNU-MERIT, 2011) and average TFPs. The data have been normalized by the corresponding means.

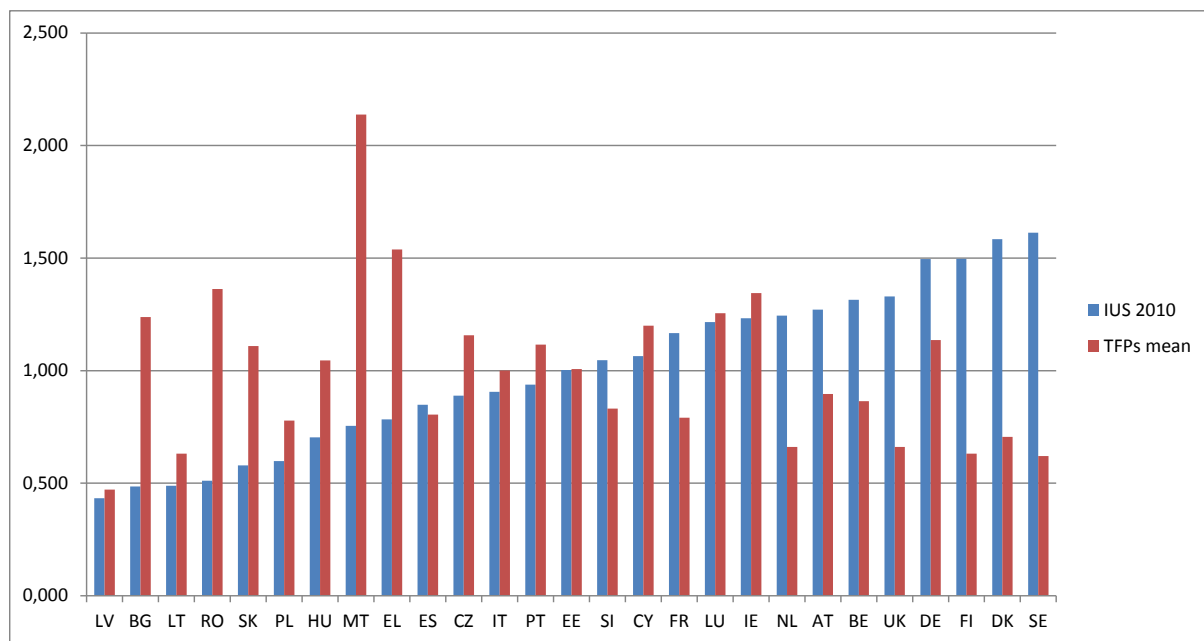


Figure 3 - Innovation Performance of EU-27 Member States

Source: Adapted from Innovation Union Scoreboard 2010 (UNU-MERIT, 2011, p.4).

The Innovation Union Scoreboard 2010 report (UNU-MERIT, 2011) calculates the innovation performance based on the combined amounts of inputs and outputs of each Member State in relation to the EU-27 average. For instance, *ceteris paribus* the amount of outputs, the innovation performance increases with the amount of inputs. In this research one has instead computed productivity measures of conversion of innovation inputs into innovation outputs.

Cornell University, INSEAD, and WIPO (2013) report The Innovation Efficiency Ratio (IER) as a ratio of the output sub-index over the input sub-index, showing how much innovation outputs a given country is getting for its inputs. IER can be seen as a measure of innovation average productivity while the TFPs measure used in this research is a measure of innovation marginal productivity.

According to the Innovation Union Scoreboard 2010 report (UNU-MERIT, 2011), among other Member States, Sweden and Germany are Innovation leaders, with Sweden leading this group while Portugal is a Moderate innovator. The TFPs results show Portugal as one of the more productive Member States of the EU-27 in terms of innovation, with a performance close to the one of Germany and well above the one of Sweden, the latter being below the EU-27 average. That is, the marginal productivity of innovation is high in Portugal and in Germany but low in Sweden.

Why is Portugal as productive in innovation as Germany is, and more productive than Sweden? These results can be understood in light of the ideas of Theodore Shultz (1964) on farmers of developing countries. Shultz supported that these farmers were efficient but poor. This research supports that Portugal is as productive in innovation as Germany is, and more productive than Sweden but has less resources allocated to innovation than these two Member States. The three Member States have different economic structures and, probably, are operating in different innovation frontiers and/or zones of these frontiers, with different returns. Returns to innovation are high in Portugal also because of the still low amount of resources allocated to innovation in the country.

The Innovation Union Scoreboard 2010 results show how innovators are Member States. The TFPs results of this research show in which Member States innovation investment pays the most, that is, in which Member States the EU-27 and the private sector may expect to have the highest returns to innovation investment.

4. Conclusions

In this research innovation was treated as a production process converting inputs into outputs of innovation. The data used were taken from the Innovation Union Scoreboard 2010 report (UNU-MERIT, 2011).

The research found significant, positive, and mostly strong correlations between inputs and outputs of innovation, which supports innovation as a production process and the calculation of productivity measures.

Using the TFP index technique, two types of TFP indexes were computed: i) TFPt (time), which compares in each year the productivity of innovation in each Member State with its productivity in a base year (2006); ii) TFPs (space), which compares in each year the productivity of innovation in each Member State with the productivity of the EU-27 average.

20 Member States of the EU-27 are placed in the $TFPt = 1$ line or below. This was the case of Portugal, where average TFPt in the time length is slightly below 1. The 7 Member States that are above this line are mostly from Eastern Europe. These results can be explained by the financial crisis, the EU structural funds, and the highly qualified and cheaper labour force of the Eastern Europe new Member States.

The biggest differences in marginal productivity of innovation across the EU-27 Member States are in space. 13 Member States have a $TFPs = 1$ or below. Most of these Member States are from Northern and Central Europe. Sweden, the leader of innovation, is included in this group. These results can be

explained by decreasing returns to scale of innovation, economic specialisation in services, and other reasons.

The other 14 Member States show a TFPs > 1. Southern European Member States as well as Germany and other Member States are placed in this group.

The TFPs results for Portugal, Sweden, and Germany are interesting because of the differences in innovation investment. In comparison to Portugal, Sweden and Germany allocate more resources to innovation. However, the TFPs in Portugal is similar to the one of Germany and higher than the one of Sweden. This appears to be a Theodore Shultz (1964) type of case. The marginal productivity of innovation in Portugal is similar to the one of Germany and higher than the one of Sweden. However, Portugal allocates fewer resources to innovation than these two Member States. The still low level of resources allocated to innovation in Portugal in part explains the country high marginal productivity of innovation.

The Innovation Union Scoreboard 2010 results show how innovators are Member States. The TFPs results of this research show in which Member States innovation investment pays the most.

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