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Portuguese Economic Growth Revisited: A Technology-Gap Explanation

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Portuguese economic growth revisited: a technology-gap explanation

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Abstract. After a period of convergence where many perceived the country as a success case, Portugal's economic performance proved to be disappointing in the last decade. In this study we focus on the relationship between technology and economic catching-up in order to answer to two major questions: (i) Has the technological structure of the Portuguese economy been an obstacle for catching up? (ii) What was the role played by the inefficient use of the available resources?

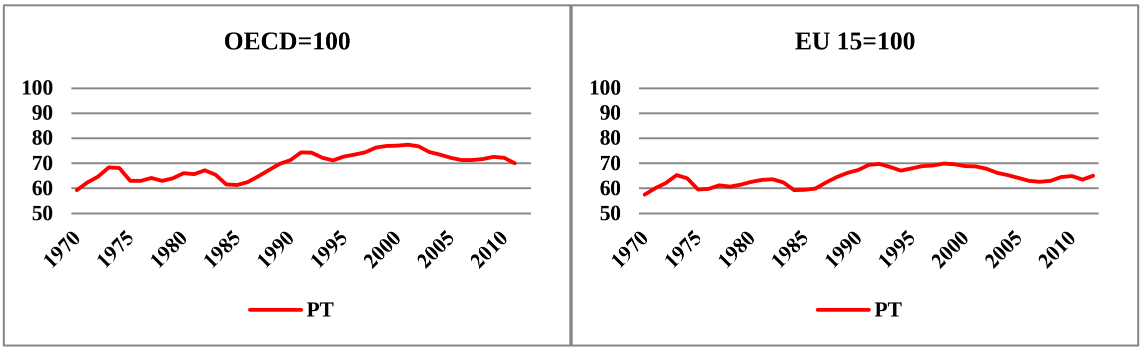
Using Data Envelopment Analysis (DEA), we show that over the last few decades the efficiency level of Portugal relative to a sample of 19 OECD countries fell sharply, which resulted in a divergent pattern of the Portuguese economy relative to the technological frontier.

Keywords: Economic growth; Catching-up, Technology, Structural Change, Innovation
JEL codes: O3; O43; L16.

1. Introduction

After a period of convergence where many perceived the country as a success case (e.g., Pereira and Lains, 2012), in the last decade the Portuguese economic performance proved to be disappointing. In fact, in 2010 the country was six percent poorer than at the beginning of the decade (Amaral, 2010).

Figure 1: Evolution of per capita income (Portugal; 1970-2011)



Note: GDP per head in 2005 US $, constant PPPs.
Source: OECD national accounts.

Although a growing literature has focused on the causes of Portugal's recent (dismal) performance (*e.g.* Amaral, 2010; Blanchard, 2007), few studies approach the role played by the country's technological backwardness on the process. Difficulties in creating and absorbing technology have been acknowledged by several economic historians (*e.g.*, Allen, 2003; Acemoglu and Robinson, 2012) as major explanations of current worldwide differences in economic growth and development. Since the Industrial Revolution, the world economy registered an enormous pace of technological change, which had a huge impact on countries' relative positions in development rankings, according to their capability of creating/adopting technology. Periods of global convergence have alternated with periods of divergence, but the available evidence seems to indicate the persistence of striking differences across economies, due to both the effects of globalization and the emergence of radically new technologies (*e.g.* Fagerberg and Verspagen, 2002, Fagerberg *et al.*, 2007).

Within this context, it is our aim to analyse the relationship between technology and economic catching-up, focusing on the Portuguese case. More specifically, we address two major questions:

(i) Has the technological structure of the Portuguese economy been an obstacle for catching up?

(ii) What was the role played by a potentially inefficient use of the available resources?

To this purpose, we use a non-parametric methodology in the estimation of a production frontier known as Data Envelopment Analysis (DEA), which to our knowledge has not yet been applied to the study of the Portuguese case. This approach allows us to explore novel features of the Portuguese growth path, addressing both the impact of technological change and (potential) inefficient use of resources during the last decades.

The paper is structured as follows. Section 2 provides a brief review of the literature on the interrelatedness features of innovation, technological change and economic growth, highlighting the most relevant findings. Section 3 introduces the empirical work, describing the methodology used, the data sources and assumptions. Section 4 presents the results. Section 5 concludes, providing a discussion of the main findings, relating to previous evidence on the matter and offering some guidelines for future research.

2. **Technology, structural change and economic growth**

Technological change may be seen as a specific feature of the broad concept of "structural change", seen as different arrangements of productive activity in the economy. As noted by Silva and Teixeira (2008) in their comprehensive survey on the matter, the composition of the economy and its relation with technology change has traditionally been seen as an important factor influencing growth, although with a varying degree of attention over time. In this regard, the seminal contribution stems from the work of Joseph Schumpeter (1942, 1939). Schumpeter saw economic development as an intrinsically dynamic process, in which innovation was the driving force of change: it altered market conditions and competition, changing the allocation of resources among sectors and generating growth. Such changes were part of a dynamic process, where new products and new businesses replaced those that became obsolete. In his two fundamental books, *Business Cycles* (1939), and *Capitalism, Socialism and Democracy* (1942), the mechanisms of growth and structural change are analysed in depth and the well-known notion of *creative destruction* emerges at the core of the development process.

The unequal access to technology and, more generally, differences in countries' capacities of creating and absorbing knowledge are also seen as major sources of divergence in the literature. Although the neoclassical tradition predicts convergence as a natural consequence of growth, the available evidence shows rather mixed results, where some countries catch-up or forge ahead, while others fall behind (Abramovitz, 1986). Such evidence has been seen, therefore, as being more in line with neo-Schumpeterian views, and more specifically, with a prolific stream of research known as the *technology gap* literature. Under this frame of analysis, innovation is seen as a source of divergence in countries' per capita income levels, whereas diffusion leads to the opposite result. The role of imitation seems, however, to have been significantly weakened in more recent times. Catching-up seems to be currently technologically more demanding than in the past (Fagerberg and Verspagen, 2007; Fagerberg *et al.*, 2010) and innovation itself appears as a necessary, though not sufficient condition to converge (*e.g.* Caldas *et al.*2009).

In this account, a number of factors, namely, openness to trade, productive specialization and education (human capital) have been identified by several studies as crucial factors for the adoption and development of innovation (Amable, 2000). Human capital, in particular, acts in two different fronts: directly, as as a production factor), and indirectly, by enabling imitation and technological catching up (Castellacci, 2011, 2008). To the extent that education backwardness makes difficult the development of more knowledge-intensive sectors and the adoption of new technologies, and since these sectors generally induce a significant growth bonus, relatively low human capital levels may inhibit growth. With regard to the Portuguese case, this seems, indeed, to constitute one of the most consensual factors underlying the country's growth difficulties (*e.g.* Veugelers and Mrak, 2009; Silva and Teixeira, 2011; Lains, 2008).

In this study we approach the country's poor performance in the last decades, focusing on the links between technology change and growth. Following the seminal work from Färe *et al*. (1994) and a prolific stream of subsequent research (*e.g.* Kumar and Russel, 2002; Färe *et al*. 2006), we use a non-parametric method (Data Envelopment Analysis - DEA), in the estimation of a technological frontier. In this methodology, shifts of the technological frontier are associated with innovation and technological change, and movements of a country towards the technological frontier are seen as reflecting processes of catching-up. The main goal consists precisely in distinguishing between these two processes - innovation and catching-up - decomposing the productivity increases into technical and efficiency changes. The former are associated to innovation and to the shift up of the frontier, whereas the latter reflects catching-up paths.

Although some cross-section studies include Portugal in the assessment of technology frontiers, until now no direct account of the Portuguese experience had been made. Moreover, the available evidence regarding the country is often contradictory, with some studies placing Portugal at the frontier (Afonso and St. Aubyn, 2010), whereas in others it appears as a notorious case of technological backwardness (Margaritis et al., 2007). Finally, none of the existing studies covers the first decade of the twenty-first century, which is precisely the most disappointing period (Amaral, 2010). It is our purpose to clarify these discrepancies, contributing to a deeper understanding of the Portuguese growth path up to the present.

3. Portugal´s relative efficiency (1970-2010)

3.1. DEA estimation method

Measurement of relative efficiency is made using DEA. This method consists in building an empirical technological frontier (also regarded as a production possibility frontier), estimating inefficiency of a particular country by computing its distance relative to the frontier. It is possible to do this calculus using constant or variable returns to scale. However, according to Färe et al. (1998) the assumption of constant returns of scale is the best option to measure TFP using a Malmquist index (as we use).[1]

Thus, considering that, at each time period *t*, a vector of inputs x^t produce the output y^t, under constant returns of scale, the technological frontier S^t is given by:

$$S^t = \{(x^t, y^t) : \sum_{k=1}^{K} z_k y_k^t \geq y^t, \sum_{k=1}^{K} z_k x_k^t \leq x^t\} \quad (1)$$

Where:

- S represents the technological frontier;
- x is the input vector;
- y is the output vector;
- k stands for the country, $k = 1,\ldots,K$;
- z is the intensity variable;
- t is the time period, $t = 1,\ldots,T$.

The frontier represents the best practice among the selected sample of countries. From its calculation, an output distance function D_0^t between each country and the best practice in *t* can be computed maximizing the output vector y^t, given inputs x^t (*output oriented estimation*), or minimizing the inputs for a given output (*input oriented estimation*).[2]

$$D_0^t(x^t, y^t) = \min\{\theta : (x^t, y^t/\theta) \in S^t\} = \left[\max\{\theta : (x^t, \theta y^t) \in S^t\}\right]^{-1} \quad (2)$$

When production is technically efficient, $D_0^t(x^t, y^t)$ equals 1.Values below 1 indicate that a country lies beneath the frontier, being therefore inefficient.

Then, we can calculate a Malmquist index[3] (M_0) in order to measure the TFP growth. This method, rather than growth accounting, allows us to estimate the TFP with no price

1 Also Grifell-Tatje and Lovell (1995) argue that the presence of non-constant returns to scale bias the results of Malmquist indexes.

2 Assuming constant returns of scale, as we assume, the results of the output distance function between each country and the frontier are the same independently of the orientation used in the estimation.

3 This index was first introduced by Malmquist (1953) in a consumption context analysis and by Caves *et al*. (1982) as a productivity index.

information or market assumptions. It allows us furthermore, decompose the TFP changes into efficiency and technical change components (Färe *et al.*, 1994):

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \overbrace{\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}}^{\text{Efficiency change}} \times \overbrace{\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right) \cdot \left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2}}^{\text{Technical change}} \quad (3)$$

The ratio outside the brackets measures the change in relative efficiency (*i.e.*, the change in the distance between the observed output and the maximum potential output), from *t* up to *t*+1. The geometric mean of the two ratios inside the brackets captures the shift in technology between the two periods (Färe *et al.*, 1994). Taking the efficiency-change component calculated using constant returns to scale, we can also decompose it into a pure efficiency-change component (calculated relative to the variable returns technologies) and a residual scale component which captures changes in the deviation between the variable returns and constant returns to scale technology.

A value of M_0 above unity reflects (relative) improvements in productivity, whereas the opposite stands for values below one. By the same token, improvements in any of the components of the index are associated with values above unity, whereas values below one indicate a negative performance of that particular component (Färe *et al.*, 1994). Subtracting 1 from the value obtained, we get the annual average increase (or decrease) of the performance of the component under analysis.

From these computations, each country in *t+1* is compared also to its previous performance, in *t*. More precisely, if a country does not change its inputs and outputs from *t* to *t*+1, then it will not show any change in productivity, but if the frontier shifts from *t* to *t*+1, indicating overall technical change, the country will be placed farther away from the frontier.

3.2. Sample and variables

The estimation of relative efficiency is performed using a sample composed by the 19 OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, the UK and the US.

The estimation procedure is conducted in two stages. Taking advantage of the wide availability of data of the Penn World Table (PWT8.0),[4] in the first stage we consider a longer period, analyzing the evolution of the Portuguese economy between 1970 and 2010.

[4] Available on line at http://www.ggdc.net/pwt.

Because PWT does not take into account a number of variables that are usually included in the estimation of aggregate production functions, in a second stage we use data from the OECD National Accounts database, which provides directly comparable data for the aforementioned countries over the last two decades (1990-2010). The use of two widely used databases allows us furthermore to test for the robustness of previous findings regarding the Portuguese economy, and to explore eventual differences in the results stemming from the use of different data.[5]

When using PWT database, only two inputs are considered: physical capital and labour. The use of OECD data allows for the inclusion of two additional inputs, namely, human capital and innovation. Table 1 presents the list of variables used and the correspondent data sources.

Table 1: List of variables and data sources

PWT Variables	Description	Source
Labour	Total number of hours worked, obtained as the product between the number of persons engaged (in millions) and the average annual hours worked by person engaged.	PWT 8.0
Ck	Capital stock at current reference prices (in mil. 2005US$).	
Rgdpe	Gross Domestic Product constant 2005 reference prices (in mil. 2005US$)	
OECD Variables		
Capital	Productive capital stock.	OECD Database
Labour	Product of the average annual hours worked per worker by total civilian employment.	
GERD	Expenditure in R&D (GERD) in constant 2005 US$.	
HK	Product of the average number of years of schooling of the adult population of OECD countries by total civilian employment.	De la Fuente and Doménech (2012)
GDP	Gross domestic product in 2005 million US$, constant prices, constant PPPs.	OECD Database

3.3. Estimation results

Table 2 presents the estimation results using PWT data, input orientation and constant returns to scale.

Table 2: Efficiency indices 1970-2010 (selected years)

Country	1970	1975	1980	1985	1990	1995	2000	2005	2010
Australia	0.837	0.840	0.879	0.863	0.813	0.793	0.770	0.753	0.872
Austria	1.000	1.000	0.996	0.735	0.762	0.812	0.795	0.739	0.787
Belgium	0.781	0.873	1.000	0.857	0.964	1.000	0.986	0.843	0.842
Canada	0.971	1.000	1.000	0.943	0.896	0.870	0.876	0.857	0.943
Denmark	0.826	0.791	0.839	0.876	0.816	0.826	0.846	0.736	0.788

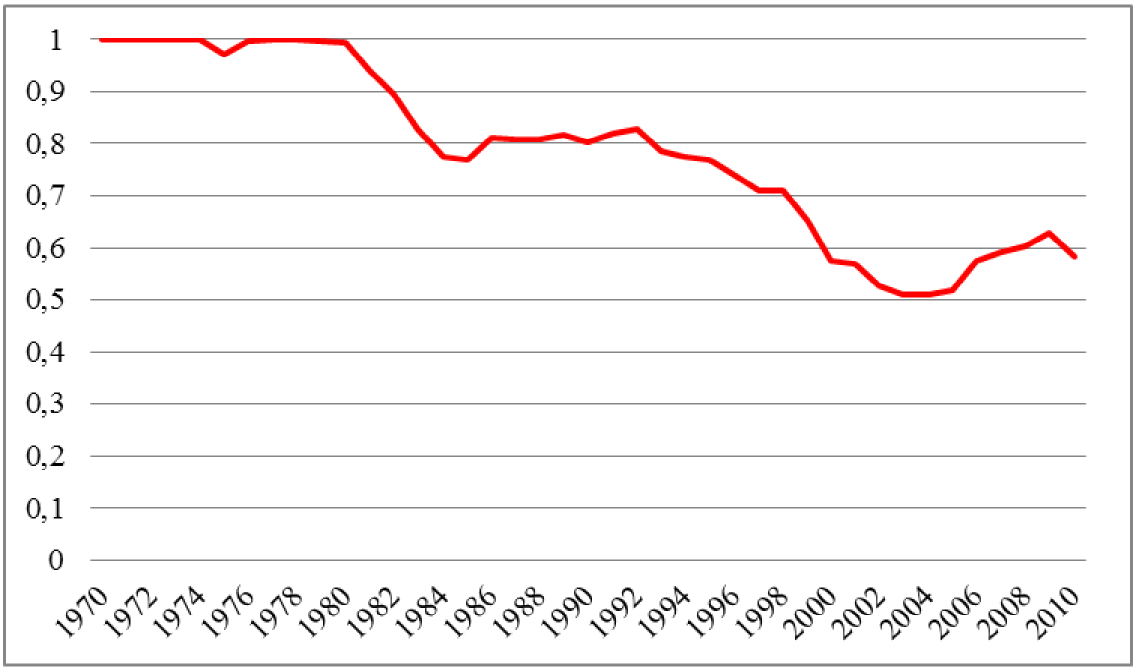
5 The use of different samples and databases is probably the source of the aforementioned contradictory results regarding Portugal in previous DEA estimations.

Finland	0.647	0.623	0.646	0.670	0.671	0.699	0.756	0.681	0.720
France	0.788	0.850	0.864	0.849	0.892	0.877	0.945	0.798	0.814
Germany	0.653	0.744	0.798	0.772	0.844	0.868	0.843	0.797	0.863
Greece	0.687	0.667	0.656	0.721	0.648	0.653	0.594	0.602	0.726
Ireland	0.902	0.961	0.870	0.893	0.861	0.859	1.000	1.000	0.882
Italy	0.755	0.797	0.915	0.858	0.821	0.810	0.776	0.650	0.701
Japan	0.908	0.797	0.759	0.846	0.828	0.722	0.646	0.604	0.659
Netherlands	0.771	0.891	0.934	0.910	0.879	0.872	0.963	0.859	0.855
Norway	0.807	0.819	0.889	0.876	0.853	0.858	1.000	1.000	1.000
Portugal	1.000	0.971	0.996	0.768	0.804	0.769	0.576	0.519	0.582
Spain	0.903	0.926	0.814	0.832	0.852	0.777	0.775	0.702	0.681
Sweden	1.000	0.997	0.941	0.927	0.918	0.926	0.951	0.908	1.000
UK	0.708	0.827	1.000	1.000	1.000	1.000	0.955	0.899	0.902
US	1.000	1.000	1.000	1.000	1.000	1.000	0.960	0.908	1.000

Looking globally to the results obtained, it can be seen that they are relatively similar to previous evidence (cf., Kumar and Russel, 2002; Los and Timmer, 2005), although the samples do not match entirely: the US, for example, are almost continuously at the frontier, whereas Japan presents results well below the technological frontier.

With regard to Portugal, which is the main focus of the work, relatively high efficiency levels occur between 1970 and 1980, but a strong downward trend took place in subsequent decades, as can be seen more clearly in Figure 2. These results are in line with those from Färe *et al.* (2006) and Margaritis *et al.* (2007), but contrast markedly with the evidence shown in Afonso and St. Aubyn (2010).

Figure 2: Relative efficiency indices (Portugal; 1970-2010)



In order to analyze in more detail the Portuguese case, we calculate the TFP (*tfpch*) during this period and decompose the distance relative to the frontier in the two factors indicated in Equation 3: a technology change effect (*techch*) and an efficiency effect (*effch*), using a Malmquist index. We also decompose the latter effect in "pure efficiency change" (*pech*) and "scale change" effects (*sech*), as in Färe *et al.* (1994)). As indicated earlier, an improvement in any of the components of the index is associated with values above unity, whereas values below one indicate a negative performance.

Table 3: Decomposition of the Malmquist index (PWT data)

Country	Time period	*tfpch*	*effch*	*techch*	*pech*	*sech*
Portugal	**1970-2010**	0.979	0.987	0.993	0.989	0.998
	1990-2010	0.986	0.984	1.002	0.985	0.999
Sample Mean	**1970-2010**	1.001	0.999	1.002	0.999	1.001
	1990-2010	1.005	0.998	1.007	0.998	1.000

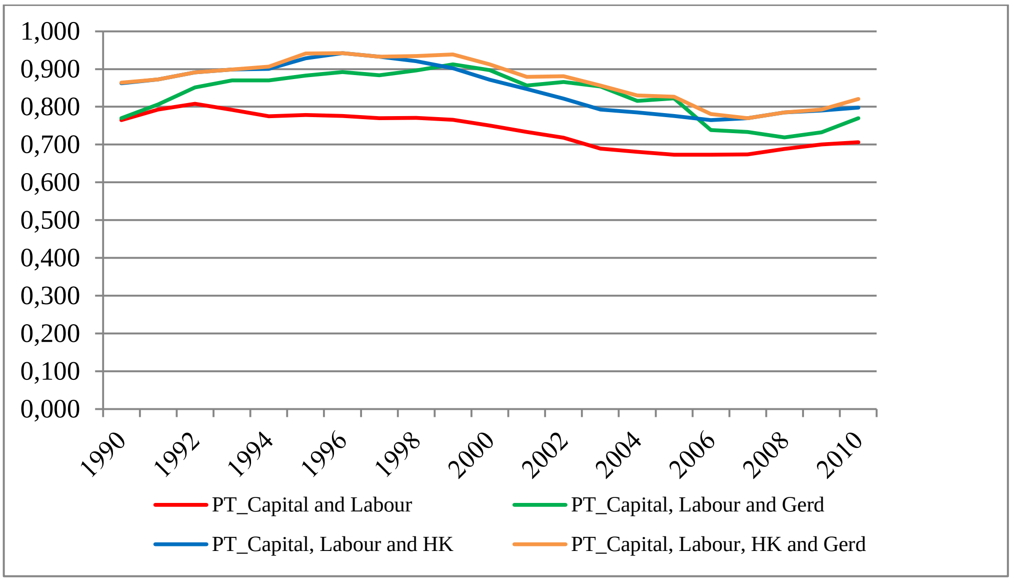
The results presented in Table 3 evidence the occurrence of technological progress in the sample as a whole, both in the extended period (1970- 2010), and in the last two decades. Over time there was also a globally positive evolution of TFP. The results point to a decline, albeit slight, in the efficiency component, which to a certain extent is compensated by the technology change effect.

In its turn, Portugal's results indicate a bad performance in the last decades. The Malmquist index (*tfpch*) is below unity in the four decade period, due mainly to the sustained decline in efficiency. It was precisely over the last two decades that the country presented a better performance in the technological change component, although one not sufficient to entitle a position on the best-practice frontier.

In order to get a deeper understanding of this more recent period, we replicate the analysis, this time using OECD data. Along with physical capital (K) and labour (L), we include human capital (HK) and R&D inputs. The efficiency estimation is performed considering different combinations of inputs. We start by using only physical capital and labour, as in the first calculus, and then include human capital and GERD variables. The full list of results is available in the appendix (Table A.1)

As expected, Portugal's results improve when a larger set of factors is considered (cf. Figure 3).

Figure 3: Evolution of the level of efficiency of Portugal 1990-2010



After a slightly positive trend until the mid-1990s, the country shows a sustained divergent trajectory relative the technological frontier until 2007, approximately, which is common to all combinations of inputs considered, *i.e.*, there are differences in levels, but not in trends. The last years of the sample seem to indicate a reversal of this trend, but more information is needed in order to see if this is something to endure.

Decomposing the distance to the frontier into technology change and efficiency effects, the results show that Portugal has the worst performance in the technical change component, which contrasts markedly with the sample average, in which it represented the major engine of TFP growth (cf. Table 5).[6]

Regardless of the inputs considered, Portugal's TFP performance between 1990 and 2010 is below the average.

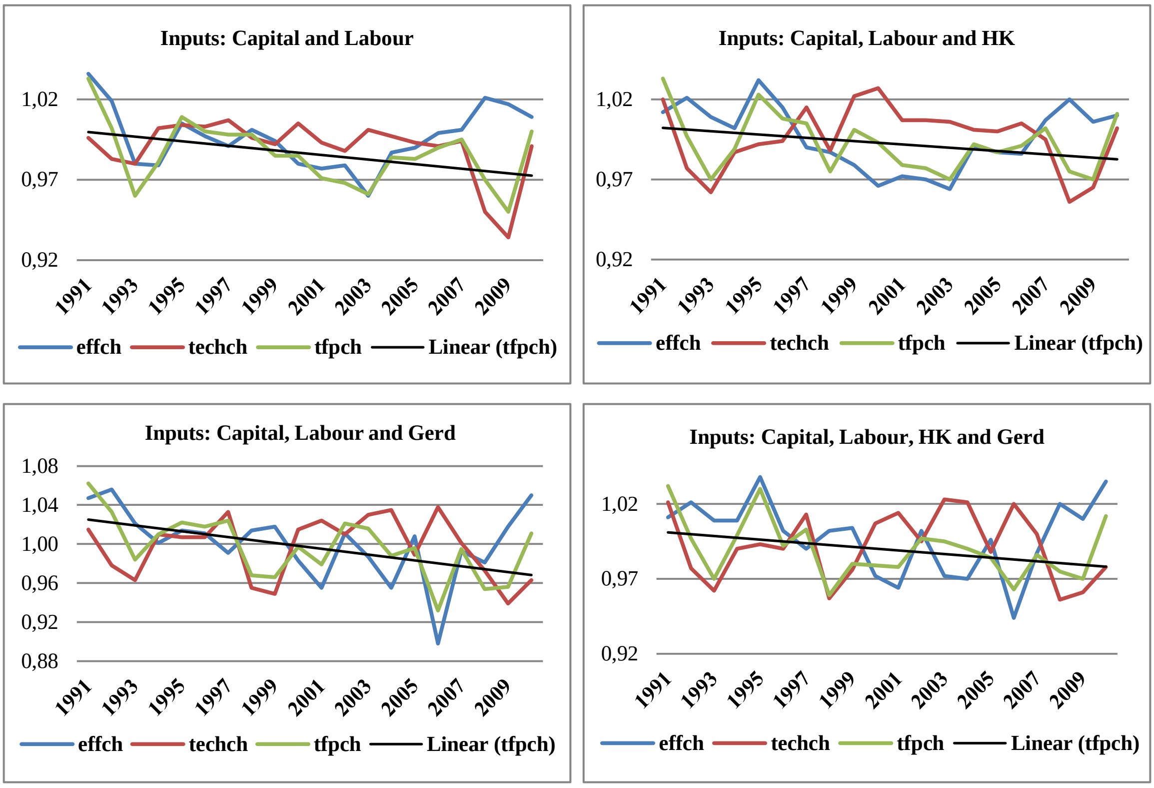
Table 5: Malmquist index and their components (OECD data 1990-2010)

Country	Inputs	*effch*	*techch*	*pech*	*sech*	*tfpch*
Portugal	Capital and labour	0.996	0.990	1.003	0.993	0.986
Sample Mean		0.999	1.011	1.000	0.998	1.010
Portugal	Capital, labour and GERD	1.000	0.996	0.999	1.001	0.996
Sample Mean		0.999	1.008	1.000	0.999	1.007
Portugal	Capital, labour and HK	0.996	0.996	0.997	0.999	0.992
Sample Mean		1.000	1.008	1.000	1.000	1.008
Portugal	Capital, labour, HK and GERD	0.997	0.992	0.997	1.000	0.989
Sample Mean		1.000	1.006	1.000	0.999	1.006

Figure 4 illustrates more clearly the evolution of the Malmquist index and its components over the last two decades in Portugal.

[6] It should be noted however that, although Portugal presents values below 1 in the technological change effect, that does not necessarily indicate technological regress, indicated instead a performance which is below other countries from the sample.

Figure 4: Malmquist index components with different inputs combinations **(Portugal, 1991-2010)**

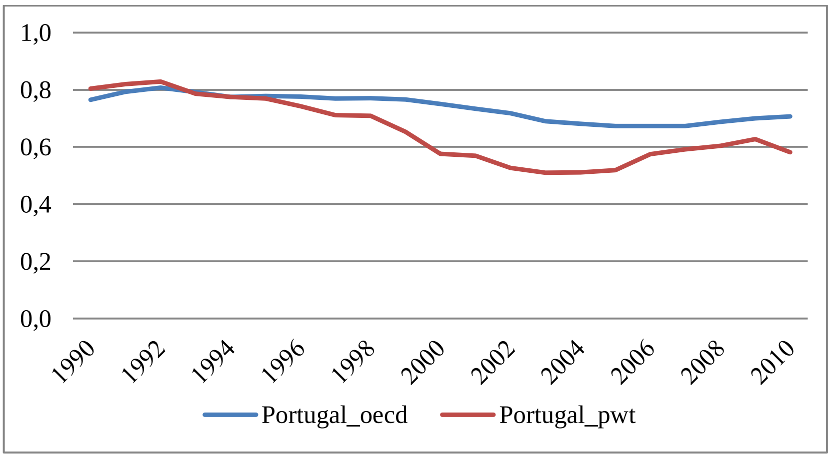


The strong decline in the Malmquist index is quite evident, although seems to there is some reversal in this path at the end of the period considered. This apparent inversion, nonetheless, should be looked with caution and be updated when new data are available.

In order to check for the robustness of results, we compare the findings obtained when using PWT and OECD data, for the overlapping period (1990-2010) based on the use of the same combination of inputs (physical capital and labour).

Portugal's PWT and OECD data based results show some discrepancies. Differences refer not only to magnitudes but also to the broad trajectories over the overlapping twenty years (Figure 6).

Figure 6: Differences between the results with PWT and OECD data: Portugal



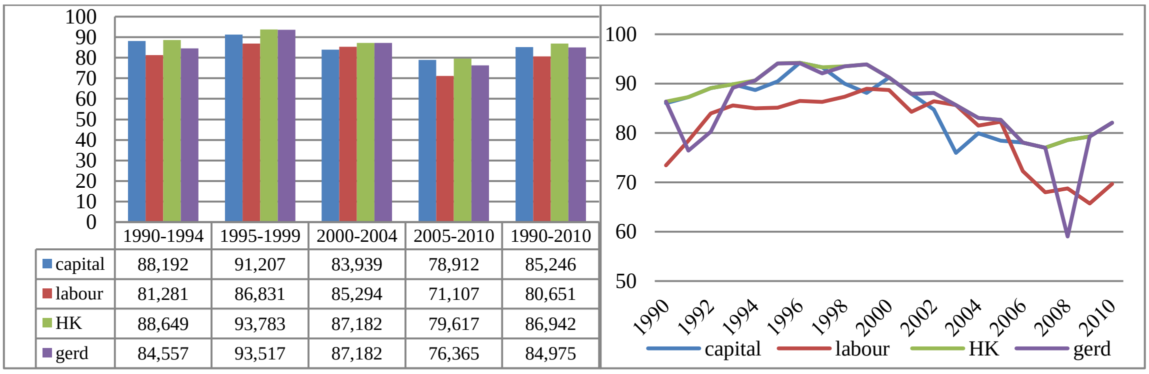
Although the divergent trajectory in relation to the technological frontier is confirmed using both databases, this trend is more pronounced when we use PWT data, particularly between 1992 and 2005. Thereafter, not only begins a process of convergence with the frontier, as the results with the two databases converge between them, at least until the last year of our analysis, where a new divergent trajectory seems to start.

A common conclusion emerges from both sets of results, namely, the deterioration of the Portuguese situation in the last decades, which is reflected on the divergent trajectory of Portugal to the EU-15 average.

Along with the inspection of overall trends in relative (in) efficiency it is also of the utmost importance to analyze the degree of efficiency in using the available resources and to signal what resources are used more inefficiently. To this purpose we estimate the optimum values of inputs (targets) for each level of output (input oriented calculation), along with efficient output targets, fixing the inputs (output oriented analysis).

Starting with the input oriented analysis, Figure 7 reports the optimal values (target input values) of each input as a percentage of the quantity effectively used of each input.

Figure 7: Target input values as a percentage of values of inputs effectively used: Portugal



	1990-1994	1995-1999	2000-2004	2005-2010	1990-2010
capital	88,192	91,207	83,939	78,912	85,246
labour	81,281	86,831	85,294	71,107	80,651
HK	88,649	93,783	87,182	79,617	86,942
gerd	84,557	93,517	87,182	76,365	84,975

Values of 100% indicate that the input target coincides with the quantity of that input effectively used, *i.e.*, means maximum efficiency. The lower this value, the greater the difference between the target and the amount actually used, *i.e.*, higher inefficiency.

The results show an overall decrease in efficiency from the beginning of the last decade, a pattern somewhat expected given the deviation from the technological frontier that occurred during this period. Although the divergent trend is common to all factors, labour emerges as the most inefficient input. The relatively good performance of human capital and of R&D expenditures confirms their influence in the overall improvement of results when these inputs are included in the analysis.

In fact, the country made a strong investment in innovation and education in order to reduce the chronic deficits in these areas (*e.g.* Santiago *et al.*, 2012; IUS, 2013). There are some signs of change in recent years: the education level of the population has increased, the investment in R&D has also progressively increased (especially in the last few years), which denote some structural changes in the productive structure of the country.

However, these results should be analysed in combination with the results previously obtained in our empirical study, *i.e.*, if, on one hand, there is evidence of structural and technological change over the last years in Portugal, on the other hand, these results have not been reflected in the reduction of the country's distance relative to the technological frontier. Since results are obtained in comparative terms, this should be interpreted as reflecting the fact that the other countries in the sample were able to go further than Portugal, despite all progress that has been achieved. Moreover, they can also signal an inefficient use of Portugal's investment in human and physical capital, along with R&D expenditure, thus explaining the country's inability to converge to OECD average levels. This leads us to the question: What if Portugal uses efficiently its available resources? Using the DEA methodology it is possible to predict GDP levels if the available resources had been used efficiently. That is made considering an output oriented estimation of the technological frontier (cf. Figure 8).

Figure 8: Evolution of the effective Portuguese GDP vs. efficient target

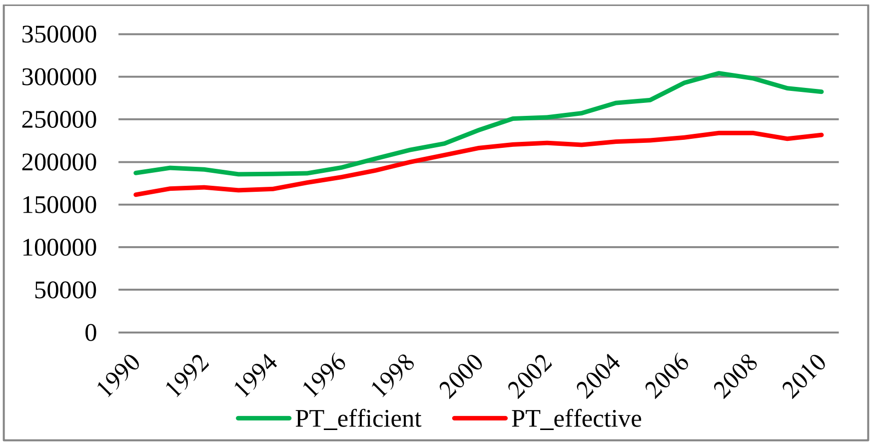
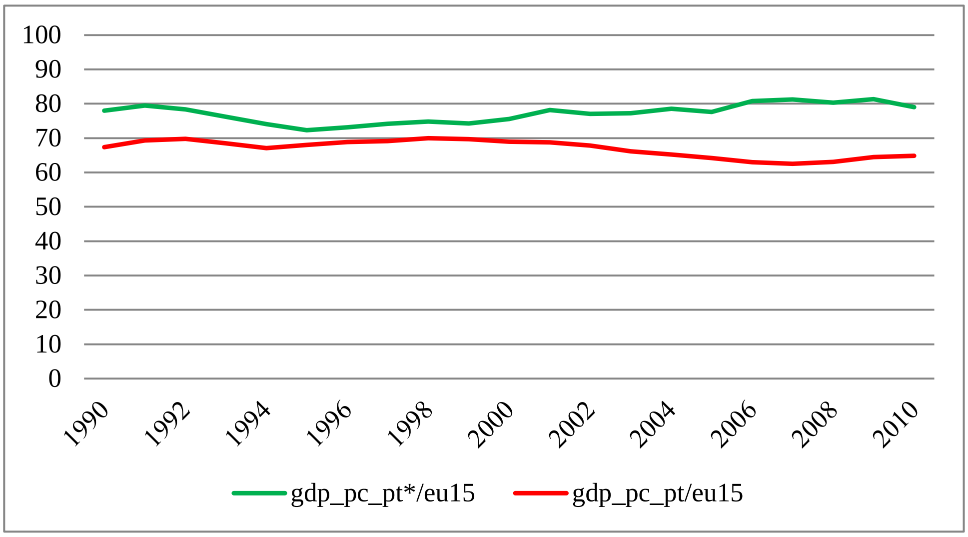


Figure 8 clearly shows that an efficient use of available resources would allow achieving higher GDP levels. The difference between actual product and the "potential" one is highly accentuated since the turn of the century. In fact, the available evidence seems to confirm a problem of inefficient use of the available resources.

Taking these values of the efficient GDP and calculating the efficient GDP per capita (gdp_pc_pt*/EU15) between 1990 and 2010, we can make an extrapolation of what would be the trajectory of convergence of Portugal over the last 20 years if the considered inputs (physical capital, labour, human capital and GERD) were efficiently used.[7]

[7] In this analysis we consider the efficient use of inputs by Portugal, but we maintain unchanged the results effectively recorded by the other countries.

Figure 9: Evolution of the effective Portuguese GDP vs. efficient target (EU15=100)



This exercise shows that if Portugal were more efficient in the use of resources, it could have converged to the EU15 average in the last decade, instead of registering an effective divergence.

This is, in fact, one of the main conclusions of the empirical exercise presented throughout this section. Despite the progress achieved by the country, our study reveals that over the last few decades the level of efficiency of the country sharply fell.

4. Concluding remarks

Portugal has made a great progress over the previous decades. Especially after the entry in EEC in 1986, the indicators of health, education and welfare reached levels well above those recorded in previous decades (Mateus, 2013). It was also in this period that convergence with EU15 partners was intensified. However, this convergent trajectory became very slow, and since the turn of the century Portugal has been diverging from the European average.

There are several factors that may help to understand this change. The adoption of the Euro and consequent loss of monetary sovereignty, the EU enlargement to the Eastern European countries and the entrance of countries such China in the World Trade Organization (WTO) are some of them (*cf.* Blanchard, 2007).

However, in this study we focus on a complementary set of explaining factors related to the country’s evolution regarding structure, technology and innovation, based on the estimation of technological frontiers. Although some studies included Portugal in the estimation of a technology frontier, no explicit analysis was done regarding to the Portuguese case.

With a sample comprising 19 OECD countries, we divided our empirical analysis in two stages. In the first one, we used PWT data, considering two inputs (physical capital and labour), and in the second we used OECD data, adding two new inputs (R&D and human capital) to the analysis.

The first set of results with PWT data showed the deterioration of the Portuguese situation. Since 1980 Portugal began a divergent path from the technological frontier, with this decline being accentuated in the 1990s. The Mamquist index that measures TPF also presented values bellow the unity, meaning that Portuguese TFP suffered deterioration during these decades.

When the four inputs were considered (OECD data), the results showed an overall improvement, blurring the differences between countries, being Portugal one of the countries that benefited more with the introduction of new inputs. The results indicated that in the first half of the 1990s there was an approximation to the frontier, however, the trend was reversed afterwards and the country diverged until almost the end of first decade of the XXI century. The trajectory does not suffer major changes when different input combinations are considered, being the alterations essentially in levels, rather than trends.

The comparison between the results of the first and second steps of our analysis did not reveal significant differences, which gives robustness to the conclusions. Once again, the differences are essentially in "level", with the trajectory always diverging from the frontier since the mid-1990s. We also concluded that labour was the factor that most penalized the country's efficiency results. In contrast, human capital and R&D expenditure were the factors with better efficiency level and thus more contributive for the improvement of Portuguese results.

Finally, we performed an output oriented exercise to estimate what would be the Portuguese GDP if the available inputs were spent efficiently. The results show that the country would have been able to keep converging to European partners in the last decade. In fact, if this has been the case, the country would be positioned almost 15 percentage points above the record actually achieved in 2010.

In short, despite the economic growth recorded in the second half of the twentieth century, our study showed that the country began to diverge from the technological frontier, even during this period. The main causes for this situation are structural deficits in several domains, with emphasis on education and innovation, and the inability to efficiently use the available resources. Despite the investments and the evolution recorded in recent years in these fields, Portugal still presents a negative gap compared to its competitors, and the efficiency levels show a negative trend since, at least, the beginning of 1990s until almost the end of the first decade of the XXI century.

5. References

Abramovitz, M. (1986), “Catching Up, Forging Ahead, and Falling Behind”, *Journal of Economic History*, Vol. 46, pp. 386-406.

Acemoglu, D. and J. A. Robinson (2012), *Why Nations Fail: The Origins of Power, Prosperity and Poverty*, Profile Books, London.

Afonso, A. and M. St. Aubyn (2010), “Public and private inputs in aggregate production and growth - a cross-country efficiency approach”, *European Central Bank Working Paper Series*, No. 1154.

Allen, R. C. (2003), “Progress and Poverty in Early Modern Europe”, *Economic History Review*, Vol. 3, pp. 403-443.

Amable, B. (2000), “International specialisation and growth”, *Structural Change and Economic Dynamics*, Vol. 11, pp. 413-431.

Amaral, L. (2010), *Economia Portuguesa, as últimas décadas*, Relógio D’Água Editores, Lisbon.

Blanchard, O. (2007), “Adjustment within the euro. The difficult case of Portugal”, *Portuguese Economic Journal*, Vol. 6, No. 1, pp. 1-21.

Caldas, J. C., M. M.Godinho and R. P. Mamede (2009), “Simulating the prospects of technological catching up”, *Economics of Innovation and New Technology*, Vol.18, No. 6, pp. 565-586.

Castellacci, F. (2008), “Technology clubs, technology gaps and growth trajectories”, *Structural Change and Economic Dynamics*, Vol. 19, No. 4, pp. 301-314.

Castellacci, F. (2011), “Closing the technology gap?”, *Review of Development Economics*, Vol. 15, No.1, pp. 180-197.

de la Fuente, A. and R. Doménech (2012), “Educational Attainment In The Oecd, 1960-2010”, *UFAE and IAE Working Papers*, No. 911.12, Unitat de Fonaments de l’ Anàlisi Econòmica (UAB) and Institutd’ Anàlisi Econòmica (CSIC).

Fagerberg, J. and B. Verspagen (2002), “Technology-gaps, innovation-diffusion and transformation: an evolutionary approach”, *Research Policy*, Vol. 31, pp. 1291-1304.

Fagerberg, J. and B. Verspagen (2007), "Innovation, growth and economic development: have the conditions for catch-up changed?", *International Journal of Technological Learning, Innovation and Development*, Vol. 1, No. 1, pp. 13-33.

Fagerberg, J., M. Srholec and M. Knell (2007), "The Competitiveness of Nations: Why Some Countries Prosper While Others Fall Behind?", *World Development*, Vol. 35, No. 10, pp. 1595-1620.

Fagerberg, J., M. Srholec and B. Verspagen (2010), "The Role of Innovation in Development", *Review of Economics and Institutions*, Vol. 1, No. 2, pp. 1-29.

Fare, R., S. Grosskopf, M. Noriss and Z. Zhang (1994), "Productivity growth, technical progress, and efficiency change in industrialized countries", *The American Economic Review*, Vol. 84, No.1, pp. 66-83.

Fare, R., S. Grosskopf and P. Roos (1998), "Malmquist productivity indexes: a survey of theory and practice", in Fare, R. et al (Eds.) *Index Numbers: Essays in Honour of Sten Malmquist*, Kluwer, Boston, 127–90.

Fare, R., S. Grosskopf and D. Margaritis (2006), "Productivity growth and convergence in the European Union", *Journal of Productivity Analysis*, Vol. 25, No.1, pp. 111-141.

Feenstra, R. C., R. Inklaar and M. P. Timmer (2013), "The Next Generation of the Penn World Table", available for download at www.ggdc.net/pwt , accessed on 13-07-2013.

Godinho, M. M. and R. P. Mamede (2004), "Convergência e mudança estrutural no âmbito dos "países da coesão"", *Análise Social*, Vol. 38, pp. 1069-1090.

Grifell-Tatje, E. and C. A. K. Lovell (1995), "A note on the Malmquist productivity index", *Economics Letters*, Vol. 47, pp. 169-75.

IUS (2013), Innovation Union Scoreboard report, available at: http://ec.europa.eu/enterprise/policies/innovation/files/ius-2013_en.pdf, accessed on 20-08-2013.

Kumar, S., and R.R. Russell (2002), "Technological change, technological catch-up, and capital deepening: Relative contributions to growth and convergence",*The American Economic Review*, Vol. 92, No.3, pp. 527-548.

Lains, P. (2008), "The Portuguese Economy in the Irish Mirror, 1960-2004", *Open Economies Review*, Vol. 19, 667-683.

Los, B., and M.P. Timmer (2005), "The "appropriate technology" explanation of productivity growth: An empirical approach". *Journal of Development Economics*, Vol. 77, pp. 517-531.

Malmquist, S. (1953), "Index numbers and indifference curves", *Trabajos de Estatistica*, Vol. 4, No. 1, pp. 209-242.

Margaritis, D., R. Fare and S. Grosskopf (2007), "Productivity convergence and policy: A study of OECD countries and industries", *Journal of Productivity Analysis*, Vol. 28, No. 1-2, pp. 87-105.

Mateus, A. (Eds.) (2013), *25 Anos de Portugal Europeu*, Fundação Francisco Manuel dos Santos, Lisboa.

OECD (2001), *Productivity Manual: A Guide to the Measurement of Industry - Level and Aggregate Productivity Growth*, OECD, Paris, available at: http://www.oecd.org/dataoecd/59/29/2352458.pdf, accessed on 20-07-2013.

OECD (2013), OECD Economic Outlook No 93-June 2013, available at: http://stats.oecd.org/index.aspx?queryid=48126 accessed on 19-07-2013.

Pereira, A. S. and P. Lains (2012), "From an agrarian society to a knowledge economy? The rising importance of education to the Portuguese economy, 1950-2009", In: Neave and G.Amaral, A (Eds.), *Higher education in Portugal 1974-2009: a nation, a generation*, Springer, London, pp. 109-134.

Santiago, P., G. Donaldson, A. Looney and D. Nusche (2012), *OECD Reviews of Evaluation and Assessment in Education: Portugal 2012*, OECD Publishing.

Schumpeter, J. A. (1939), *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, McGraw Hill, New York.

Schumpeter, J. A. (1942), *Capitalism, Socialism and Democracy*, Unwin, London.

Silva, E. G. and A. A. C. Teixeira (2008), "Surveying structural change: seminal contributions and a bibliometric account", *Structural Change and Economic Dynamics*, Vol. 19, pp. 273-300.

Silva, E. G. and A. A. C. Teixeira (2011), "Does structure influence growth? A panel data econometric assessment of relatively less developed countries, 1979-2003", *Industrial and Corporate Change*, Vol.20, pp.457-510.

Veugelers, R. and Mrak, M. (2009), "The knowledge economy and catching up member states of the EU", *Knowledge Economists Policy Brief*, No.5, The European Commission.

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