1.2. How have technological progress and efficiency developments contributed to Portuguese growth?

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1. Motivation

Total factor productivity (TFP) is an indicator that reflects the ability of an economy to grow over and above the accumulation of inputs like capital and labour and it is typically obtained as part of a growth accounting exercise. Therefore, the analysis of TFP developments is a relevant part of the debate on Portuguese economic growth. However, in order to correctly understand economic performance, GDP growth must be disentangled in such a way that TFP is not obtained as a simple residual, i.e., not just in terms of what is not explained by the accumulation of inputs. Under the broad assumption that every economy can have access to the world technology, which evolves along time for different capital-labour combinations, it is possible to estimate an international stochastic production frontier and decompose TFP as the contribution of technological progress (shifts in the frontier) and efficiency (change in the distance to the frontier).

Intuitively, these two components represent different dimensions to be considered in TFP developments. In conceptual terms, technological progress corresponds to more *productive* techniques, associated with innovations, which are not captured by the conventional methods of computing the stock of inputs. In parallel, improvements in efficiency correspond to better institutional and organizational arrangements, i.e., the more *efficient* use of the current level of inputs and technology. Therefore, for given levels of capital and labour, an economy benefits from the world technological progress, though these gains may not entirely materialize due to efficiency developments. In practical terms the best performers within the set of countries in the sample determine the international frontier, which means that technology can deteriorate if all countries perform worse for each combination of inputs. Moreover, the direct causes for efficiency developments are not identified in this type of methodological approach. Nevertheless, growth accounting exercises based on

stochastic technological frontiers are a step forward in understanding the drivers of growth developments in each period of time.

The seminal contribution in empirical growth literature is that of Solow (1957), which decomposes GDP growth along input's accumulation and TFP. Later, the application of dynamic stochastic production frontiers to growth accounting, notably through Bayesian statistical methods, has been suggested by Koop *et al.* (1999) for a set of developed economies. A similar exercise was performed by Amador and Coimbra (2007b) for the G7 countries. Our exercise follows this methodological approach and updates the work of Amador and Coimbra (2007a), maintaining all its priors and assumptions, while using a different database and a broader set of countries. The data for GDP, capital and labour is taken from the latest vintage of the Penn World Tables (Feenstra *et al.* (2015)). The time period covered corresponds to 1995-2014 and the set of countries contains all Member States of the European Union (EU28). This group of countries faces a similar set of institutional constraints, making it likely that they can potentially assess a common technology.

2. The analytical framework

The growth accounting exercise carried out provides results for the contribution of inputs' accumulation and TFP to GDP growth. The TFP contribution is broken down into technological progress and efficiency developments. Moreover, the elasticities of capital and labour to GDP make it possible to disentangle input's accumulation into the contributions of capital and labour. The analysis focuses on three 11 year periods (10 annual growth rates), for which stochastic production frontiers are computed. The decades considered are 1995-2005, 2000-2010 and 2004-2014, covering the initial years of participation in the monetary union, as well as the crisis that followed the 2008 financial turmoil. All results are presented in terms of 10 year average growth rates or contributions.

The dynamic international stochastic production function is assumed to have a translog specification, with a linear trend. As presented in equation 2, for each country i in year t the production function considers capital and labour separately, their interaction and the squares of capital and labour, which is a flexible specification, like:

$$\begin{aligned} lnGDP_{it} = {} & (\beta_1 + t\beta_7)lnA_t + (\beta_2 + t\beta_8)lnK_{it} + \\ & + (\beta_3 + t\beta_9)lnL_{it} + (\beta_4 + t\beta_{10})lnK_{it}L_{it} + \\ & + (\beta_5 + t\beta_{11})lnK_{it}^2 + (\beta_6 + t\beta_{12})lnL_{it}^2 \end{aligned} \tag{2}$$

where K and L stand for capital and employment, respectively.

The sequential Gibbs sampling algorithm was run with 1.020.000 iterations for each decade, with a burn-in of the first 20.000 iterations to eliminate possible start-up effects. The posterior distributions of the relevant parameters show a smooth Gaussian shape, which is compatible with the convergence of the Bayesian algorithm. The posterior median of efficiency levels, i.e., how close the economies are to the technological frontier, in the three decades mentioned above is 89.1, 90.4 and 90.9 per cent, respectively.

3. Growth accounting decomposition

The basic ingredient coming out of the sequential Gibbs sampler is the posterior mean and median for the set of 12 technological parameters, which can be used to compute the elasticity of capital and labour in each country in each year (within each separate decade). These results are presented in Figure 3 for each EU28 country in the decades finishing in 2005 and 2014. The first evidence is that technologies are close to constant returns to scale (with elasticities summing up to nearly 1), which is the expected result. In addition, capital elasticities range from a maximum of 0.8 in Luxembourg to a minimum of 0.3 in Bulgaria in the latest decade. Moreover, labour elasticities increased from the decade ending in 2005 to the one ending in 2014, meaning that the capital elasticities decreased in this period. The Portuguese economy is characterized by relatively high capital elasticities (0.8 and 0.7 in the first and final decades, respectively), meaning that, in the segment of the EU28 production function where Portugal stands, further capital accumulation has a strong impact on GDP levels. In practical terms this highlights the importance of investment as an ingredient in Portuguese economic growth.

In this respect, it should also be noted that capital-labour ratios in the Portuguese economy are relatively low in the context of the EU15. According to the data in Penn World Tables, this ratio stood about 20 per cent below the EU15 average in the period 1995-2005. Although this ratio became closer to the average in the following period, there was a sizable contribution, via reduction of the denominator, coming from the strong job destruction that took place during the latest crisis. Amongst other drivers, the relatively low capital-labour ratios cannot be dissociated from the reduced qualifications of the Portuguese labour force.

Tables 2 and 3 report the results of the detailed growth accounting decomposition for Portugal and the average of the EU28, respectively. The latest decade witnessed a disappointing performance in

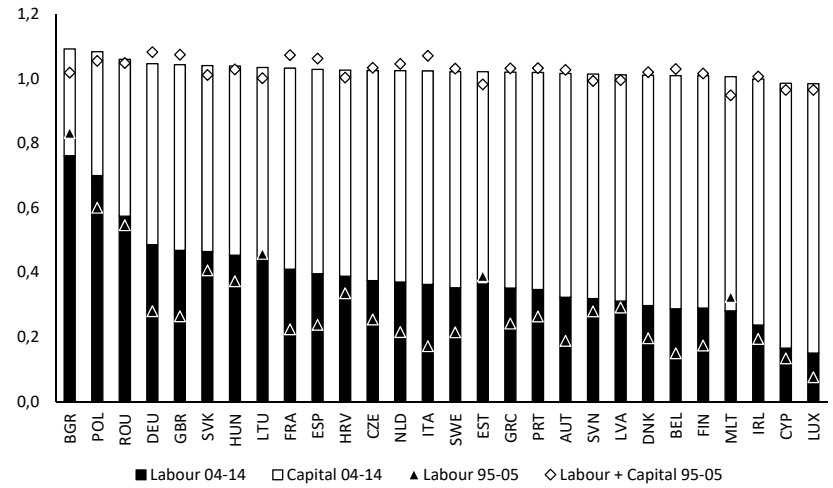


Figure 3: Estimated labour and capital elasticities for EU28 countries for periods 1995-2005 and 2004-2014

the Portuguese economy with an average GDP growth of -0.24 per cent. The average posterior Bayesian estimate is very close to this number (-0.22 per cent). Economic growth in the period 2005-2014 was affected by the 2008 global economic and financial crisis and by the following euro area sovereign debt crisis. The sharp correction in the macroeconomic imbalances prevailing in the Portuguese economy, associated with the sudden stop in external financing, had a negative impact on investment and led to the destruction of jobs. The obtained contribution of total input accumulation is small (0.43 percentage points (p.p.)), with capital posting a figure of 0.92 p.p. and labour -0.5 p.p. The contribution coming from technological progress was -0.74 p.p. This contraction in the stochastic EU28 production frontier is compatible with a crisis scenario, with several countries posting negative GDP growth rates. In this context, the Portuguese economy benefited from efficiency gains only to a minor extent (0.09 p.p.).

The comparison of these results with those obtained for the period that corresponds to the preparation and early participation in the monetary union is relevant. The decade ending in 2005 posts an overall better economic performance, driven by capital accumulation but with a negative contribution from TFP developments. The positive contribution from technology (1.10 p.p.) is overturned by efficiency losses (-1.52 p.p.), signaling that structural weaknesses in the Portuguese economy existed before the latest crisis and went beyond input accumulation.

Table 3 presents results for the average of EU28 countries and draws a better scenario for all contributions in both decades discussed. Although the contribution from technological progress was

Decades ending	Observed GDP	Expected GDP	Input			Total Factor Productivity	
			Total	Capital	Labour	Technology	Efficiency
2005	2.43	2.83	3.25	2.99	0.26	1.10	-1.52
		(2.09)	*(0.13)*			*(0.55)*	*(2.13)*
2010	0.74	0.86	1.80	1.92	-0.13	0.09	-1.03
		(2.03)	*(0.14)*			*(0.52)*	*(2.08)*
2014	-0.24	-0.22	0.43	0.92	-0.50	-0.74	0.09
		(2.05)	*(0.15)*			*(0.51)*	*(2.11)*

Table 2: Growth accounting results for **Portugal**

Note: Values in italics in parenthesis stand for interquartile ranges. Observed and expected GDP are presented as percentage average decade growth rates, while inputs and total factor productivity are presented as percentage points (geometric) average decade contributions.

negative in the latest decade, the overall scenario is more benign than in Portugal, notably in terms of efficiency gains. The results are even better if the set of most recent member countries is considered (EU13). This group of countries posted average GDP growth rates of 4.1 and 2.1 percent in the decades finishing in 2005 and 2014, respectively. Their combined TFP contributions to GDP has always been positive. These comparisons put in perspective the results obtained for Portugal and highlight the structural difficulties which existed before the latest crisis that are, to a large extent, still present.

One very important result that is made available by this methodology is the identification of efficiency levels in the economy, which are conditional on the position of the estimated international stochastic frontier. The panels of Figure 4 illustrate segments of the stochastic frontiers computed in terms of capital labour ratio and labour productivity levels. In each of the panels we plot the initial and final year of the decade considered and signal the position of Portugal with black dots. The frontiers are obtained using the estimated technological parameters in each decade and employment is fixed at a level that corresponds to Portuguese employment. With this anchoring and by changing the capital levels we are sure that the relevant segment is being considered.

Decades ending in:	Observed GDP	Expected GDP	Input			Total Factor Productivity	
			Total	Capital	Labour	Technology	Efficiency
2005	3.53	3.60	2.27	2.17	0.10	1.04	0.29
		(1.7)	*(0.12)*			*(0.84)*	*(1.62)*
2010	2.38	2.50	2.18	2.07	0.12	0.14	0.18
		(1.6)	*(0.16)*			*(0.81)*	*(1.54)*
2014	1.42	1.31	1.64	1.55	0.09	-0.50	0.17
		(1.5)	*(0.15)*			*(0.78)*	*(1.43)*

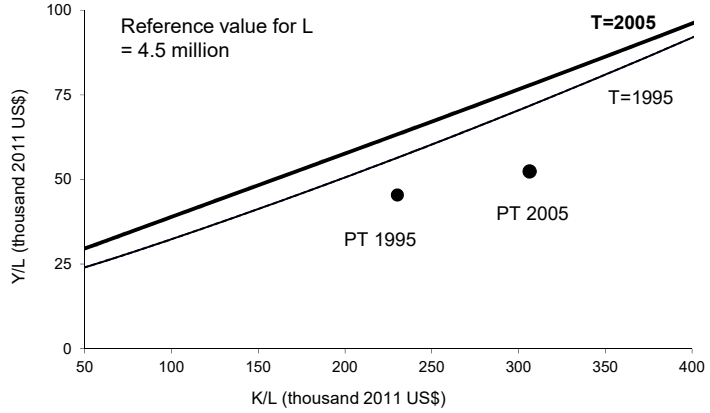
Table 3: Growth accounting results for the average of **European Union 28**

Note: Values in italics in parenthesis stand for interquartile ranges. Observed and expected GDP are presented as percentage average decade growth rates, while inputs and total factor productivity are presented as percentage points (geometric) average decade contributions.

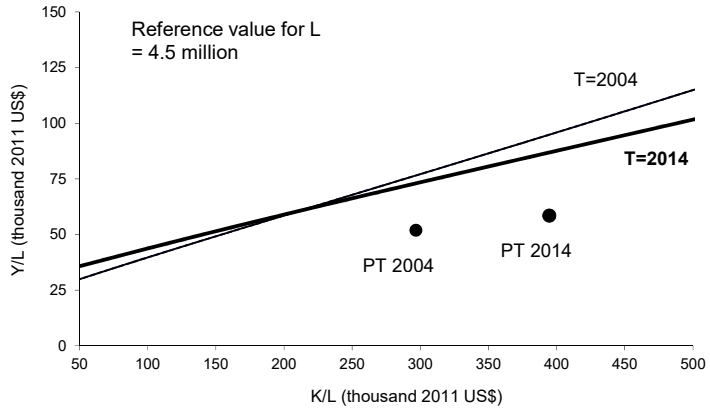
The important result emerging from the panels of Figure 4 is the existence of sizable persistence gaps in the Portuguese economy. The distance to the stochastic frontier, given the prevailing capital-labour ratios in Portugal explain an important part of the lower labour productivity of the economy. In both decades there was an increase in the capital-labour ratio, although in the latest one this was to a large extent driven by lower employment, but efficiency only slightly improved in the most recent period. Although the methodology is silent about explanations, aspects like the quality of inputs, the efficiency in their allocation across sectors and firms, as well as the institutional aspects are certainly part of the explanation.

4. Final remarks

It must always be borne in mind that results are sensitive to the hypothesis taken and statistical data. In this latter respect, the international data for the capital stock trends are affected by different accounting measures and deflation procedures. International databases like the Penn World Tables try to offer harmonized series, though they may sometimes deviate from national sources. In our exercise, if Portuguese official capital stocks are used and the coefficients estimated for the production function remain those initially obtained, results would be different. The lower capital stock feeds into a negative contribution from this input in the last decade and the lower capital-labour ratio would place the Portuguese economy in a segment of



(a) 1995-2005



(b) 2004-2014

Figure 4: Stochastic technological frontiers, thousand 2011 US$

the international production function where technological progress was positive. The hypothesis of fully replicating the exercise with official data for all EU28 countries is not viable due to numerous series breaks and limited time horizon. As for methodological hypothesis, it is important to underline that, although the translog production function offers substantial flexibility, this choice and the assumption of a linear trend for technological progress in each decade affect the results.

The latest decade witnessed a subdued performance in the Portuguese economy. Growth accounting exercises are mechanical by nature but offer a useful assessment of economic performance, especially if other countries are explicitly taken as benchmarks. This is possible to achieve with the stochastic production approach, notably in terms of detailing TFP developments. We confirm the long standing narrative that structural problems persist in the Portuguese economy as there are sizable efficiency gaps, side by side with relatively low capital-labour ratios.

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