Sources of TFP growth in the European Union at the sector level

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Abstract:

This paper analyses Total Factor Productivity (TFP) growth in the EU for the main sectors of private activity. Productivity gains are decomposed into technical progress (innovation) and efficiency change (catching-up) by means of Malmquist indices. This decomposition enables us to gain more insight on patterns and factors explaining sectoral productivity growth. A dynamic model is estimated by system-GMM, exploiting the panel structure of the dataset and taking into account unobseved country-specific effects and the possible endogeneity of the explanatory variables. In spite of sectoral differences in TFP growth, our results show that all sectors experienced shifts in their production frontier due to innovation but need an enhancement of their catching-up capabilities. The results also point out the importance of the sector structure in explaining productivity, and public and human capital are found to be maior contributors to TFP growth.

JEL: O47, D24, O47

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1. Introduction

Research on economic performance comparisons in EU countries has intensified in recent years. These studies show noticeable diversity both in terms of growth and performance levels between European countries. To fully understand these differences it becomes useful to adopt a sectoral perspective of productivity performance. Productivity is not the only determinant of economic growth, but it provides a good measure of economic performance and its growth rate determines economic growth in the long term. At the national level, productivity analyses are usually based on aggregated data and show the average contribution of all sectors of the economy. Acknowledging the interest of the aggregate analysis to study the economic evolution of the economies, it is also of interest to focus on the contribution of the different sectors of activity to economic growth. The different rates of productivity growth at the sector level and the industry composition of the economies will condition their aggregated performance. Moreover, the sources of productivity growth may differ among sectors, so looking at the sector level may provide new insights into the sources of productivity growth in countries showing different sector structures and productivity performance. In this paper we intend to analyse productivity differences and trends in the European Union over the last decades, since the beginning of the 1980s, looking into the sources of productivity growth for both the aggregate of the economy and the large sectors of private activity (agriculture, industry, construction and services).

Most of the studies focusing on productivity generally adopt partial measures of productivity -such as output per worker or output per capital- or estimate productivity in a residual way from a growth accounting exercise. Recently, however, the estimation of production frontiers and productivity indices has been used at the macroeconomic level[1]. The production frontier approach provides a benchmark technology and allows evaluating the performance of the economies with regard to a best-practice frontier. This performance is evaluated by an efficiency measure which relates the actual production of an economy to the optimal production given by the frontier for different sets of inputs. One advantage of this approach is that, unlike partial productivity measures, several inputs are considered to evaluate the performance of an economy. In

[1] See, for instance, Färe *et al*. (1994), Perelman (1995), Taskin and Zaim (1997), Domazlicky and Weber (1997), or Boisso *et al*. (2000).

turn, the use of productivity indices allows the decomposition of productivity growth into efficiency changes, associated to movements of an economy towards the production frontier, and technological progress, related to shifts of the frontier itself. Thus, the advantage of this approach over the growth accounting framework is that, taking into account the existence of inefficiencies, it allows for the decomposition of productivity growth into efficiency gains or catching-up and technological change or innovation, a decomposition which is appealing to identify the sources of productivity growth.

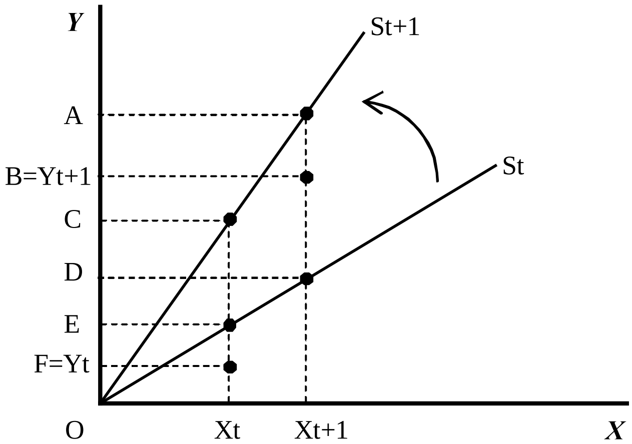
In this context, this paper attempts to analyse productivity growth in the European sectors by adopting a production frontier approach. A non-parametric technique (Data Envelopment Analysis) is used to estimate the production frontier and the associated levels of efficiency of the economies and Malmquist productivity indices are used to decompose TFP growth into efficiency change and technical progress. Then, in a second-stage, we try to identify what factors could lie behind differences in productivity growth and whether the contribution of these variables manifest through either changes in efficiency or technological progress. To this end, we use the system-GMM approach proposed by Blundell and Bond (1998), which is especially suitable to deal with models in empirical growth work (Bond *et al.*, 2001). The explanatory variables considered in this analysis are the role of investment in public infrastructure, the degree of capitalization of the economy, the endowments of human capital, asymmetries in the economic cycle and the sector structure of the economies.

In accordance with these objectives, the structure of this paper is as follows: section 2 introduces the frontier approach used to estimate the levels of relative efficiency, and productivity growth is decomposed into efficiency change and technological progress by means of Malmquist productivity indices; section 3 focuses on the empirical analysis, regressing TFP growth estimates on several explanatory variables with the aim to analyse the sources of productivity growth and to identify the channels through which they affect productivity growth; lastly, section 4 presents the main conclusions of the study.

2. Efficiency and TFP growth in the European Union. A non-parametric approach

The motivation for adopting a frontier approach is to consider the possible existence of inefficiencies when evaluating the performance of an economy and to decompose TFP growth into efficiency change and technological progress. In order to study the efficiency with which productive inputs are employed, it becomes necessary to estimate a production frontier which represents the maximum technically attainable level of production. Inefficient behaviour would then be regarded as the difference between the level of production actually obtained and the maximum potential product given by the frontier. This in turn would allow one to decompose TFP growth into technological progress (represented by a shift of the production frontier) and changes in efficiency (or movements toward or away from the frontier). This analysis is illustrated in Figure 1, which bases on the case of a single input (X) and a single output (Y) in order to simplify the representation. The pairs (Xt, Yt) and (Xt+1, Yt+1) represent observed values for an economy while the maximum potential production in periods t and t+1 (points E and A) correspond to the reference technology (St and St+1). As one observes, productivity growth may be due to either an approximation to the frontier or to a shift of the production frontier itself. The change in relative efficiency represents movements towards the frontier, and is shown graphically by the distance OF-OE and OB-OA. Likewise, technological change is measured by the geometric mean of the shift of the frontier in period t (the distance OE-OC) and t+1 (the distance OD-OA).

Figure 1: Decomposition of TFP growth



In order to estimate the production frontier and the associated levels of relative efficiency for each of the economies, we shall use the Data Envelopment Analysis

(DEA) non-parametric technique of linear programming[2]. Furthermore, variations in total factor productivity are estimated by means of Malmquist productivity indices, as proposed by Färe *et al*. (1994), which in turn can be decomposed into technical progress and changes in relative efficiency, allowing one to analyse which part of productivity growth is due to each of these factors[3].

The study refers to the European countries and covers the period 1980-2002, both for the aggregate of the economies and for the large sectors of private activity. The sample countries include Austria, Belgium, Denmark, Finland, France, Germay, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom[4]. The data used to estimate the sectoral production frontiers come from World Development Indicators (2005). This database contains sectoral information for employment, gross value added (GVA) and gross investment expressed in constant terms that are homogenized with purchasing power parity (PPP constant international US$ in the year 2000). Data on net capital stock (public and private) and public education expenditure are taken from Kamps (2006)[5] and OECD Education at a Glance, respectively, and expressed in the same terms than the rest of variables[6].

A summary of the frontier estimates is presented both for the aggregate of the economies -showing differences among the European countries- and for the main sectors of private activity. Table 1 provides the estimates for the relative efficiency levels while Table 2 shows the estimates of TFP growth, which in turn are decomposed into changes in efficiency and technological progress.

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[2] Data Envelopment Analysis is one of the most commonly used techniques among non-parametric approaches. The advantage of the latter is their greater flexibility since they neither require a particular functional form to be specified for the technology nor any assumption to be made about the distribution of the inefficiency term. A complete survey of DEA techniques can be found in Charnes *et al*. (1994).

[3] For a detailed description and formal presentation of the Malmquist indices, see Färe *et al*. (1994).

[4] Luxembourg is excluded from the analysis because of the absence of capital data. Moreover, works including this country in the estimation of the EU frontier show that the presence of Luxembourg exacerbates the drop in efficiency (Fare and Grosskopf, 2006).

[5] Based on Kamps´ estimates of net capital stock, the series of public and private capital have been extended to 2002 by using the growth rate of investment.

[6] To measure the change in the public and human capital there are two possible alternatives: directly calculating the change rates of the capital stocks or the rate of annual change in public investment and spending on education. The difference between these two alternatives relies on correcting the values of investment and spending on education by the depreciation rate of these respective capitals. Given the available data, in this study we follow the second option.

The average efficiency level estimated for the European countries in the period 1980-2002 stands at 87.1%. Nevertheless, one observes significant differences among countries, with Ireland being on the frontier all along the period -and Belgium and France showing efficiency levels above 95%- whereas countries such as Greece and Finland get indices below 80%. It is also worth noting the negative evolution of the levels of efficiency in most of the European countries, mainly since the mid 1990s. As shown in Table 2, the European countries suffer an average decline of 1% in efficiency in the period 1980-2002, although the fall in efficiency is around 2.6% during the period 1996-2002. In spite of this, technical progress compensated for the negative change in efficiency, with an average rate of 2.4% which made possible TFP growth. Thus, the joint effect of efficiency change and technical progress gives an average TFP growth rate of 1.3% per year. At the sector level, the best performance in terms of TFP growth is shown in the construction (1.7%), services (1.7%) and industry (1.5%) sectors, with agriculture (0.6%) lagging behind. The negative evolution of efficiency pointed above is common to all sectors (with the exception of agriculture since the mid 1990s). Regarding to technical progress, however, the agriculture sector present, on average, a lower growth rate than the other sectors, being the higher rates of technical progress in industry, construction and services the driving force of TFP growth in these sectors.

Table 1. Relative efficiency Levels

Country	1980-2002	1980-1985	1986-1990	1991-1995	1996-2002
Austria	**0.811**	0.864	0.818	0.805	0.764
Belgium	**0.988**	1.000	1.000	1.000	0.962
Denmark	**0.838**	0.874	0.840	0.839	0.804
Finland	**0.782**	0.763	0.775	0.783	0.802
France	**0.971**	0.991	0.973	0.982	0.945
Germany	**0.928**	1.000	1.000	0.874	0.854
Greece	**0.690**	0.753	0.689	0.673	0.647
Ireland	**1.000**	1.000	1.000	1.000	1.000
Italy	**0.911**	0.883	0.910	0.949	0.908
Netherlands	**0.880**	0.918	0.877	0.908	0.828
Portugal	**0.872**	0.860	0.970	0.937	0.768
Spain	**0.847**	0.902	0.892	0.877	0.748
Sweden	**0.812**	0.858	0.840	0.812	0.752
United Kingdom	**0.861**	0.952	0.955	0.840	0.730
Total	**0.871**	0.901	0.896	0.877	0.822
Sector					
Agriculture	**0.728**	0.779	0.737	0.662	0.724
Industry	**0.770**	0.838	0.843	0.832	0.616
Construction	**0.829**	0.872	0.835	0.792	0.815
Services	**0.898**	0.915	0.901	0.898	0.881

Table 2. Total Factor Productivity Decomposition

	Efficiency Change					Technical Change					Total Factor Productivity Change				
Country	**1980-2002**	**1980-1985**	**1986-1990**	**1991-1995**	**1996-2002**	**1980-2002**	**1980-1985**	**1986-1990**	**1991-1995**	**1996-2002**	**1980-2002**	**1980-1985**	**1986-1990**	**1991-1995**	**1996-2002**
Austria	**0.989**	0.987	0.993	0.996	0.982	**1.028**	1.015	1.024	1.016	1.049	**1.016**	1.001	1.017	1.011	1.029
Belgium	**0.992**	1.000	1.000	1.000	0.975	**1.022**	1.013	1.022	1.008	1.040	**1.014**	1.013	1.022	1.008	1.013
Denmark	**0.992**	1.007	0.981	1.010	0.975	**1.022**	1.012	1.020	1.005	1.043	**1.013**	1.019	1.000	1.015	1.016
Finland	**0.998**	1.002	1.002	1.016	0.978	**1.022**	1.010	1.020	1.009	1.042	**1.019**	1.012	1.021	1.025	1.018
France	**0.991**	0.994	1.001	1.003	0.974	**1.020**	1.009	1.019	1.003	1.040	**1.010**	1.003	1.020	1.006	1.012
Germany	**0.988**	1.000	1.000	0.980	0.975	**1.024**	1.016	1.022	1.010	1.040	**1.011**	1.016	1.022	0.990	1.013
Greece	**0.988**	0.980	0.983	0.997	0.993	**1.024**	1.009	1.020	1.010	1.048	**1.012**	0.988	1.003	1.006	1.039
Ireland	**1.000**	1.000	1.000	1.000	1.000	**1.026**	0.999	1.024	1.022	1.049	**1.026**	0.999	1.024	1.022	1.049
Italy	**0.993**	0.993	1.011	1.014	0.965	**1.025**	1.015	1.026	1.013	1.040	**1.017**	1.009	1.036	1.027	1.003
Netherlands	**0.987**	0.992	1.000	1.000	0.965	**1.025**	1.018	1.022	1.009	1.043	**1.011**	1.010	1.022	1.009	1.006
Portugal	**0.990**	1.008	1.021	0.978	0.964	**1.016**	0.983	1.021	1.018	1.036	**1.006**	0.990	1.041	0.995	0.999
Spain	**0.985**	0.997	0.994	0.995	0.962	**1.025**	1.010	1.023	1.010	1.049	**1.009**	1.007	1.017	1.004	1.008
Sweden	**0.989**	1.003	0.984	1.007	0.970	**1.029**	1.016	1.025	1.014	1.051	**1.016**	1.018	1.008	1.020	1.018
United Kingdom	**0.980**	0.998	0.981	0.991	0.960	**1.030**	1.009	1.021	1.019	1.059	**1.009**	1.007	1.001	1.010	1.016
Total	**0.990**	0.997	0.996	0.999	0.974	**1.024**	1.010	1.022	1.012	1.045	**1.013**	1.007	1.018	1.011	1.017
Sector															
Agriculture	**1.001**	1.003	0.982	0.966	1.038	**1.011**	1.003	1.046	1.043	0.967	**1.006**	1.005	1.025	1.000	0.997
Industry	**0.974**	0.997	1.007	0.984	0.928	**1.045**	1.012	1.012	1.033	1.100	**1.015**	1.008	1.017	1.016	1.017
Construction	**0.998**	1.003	0.982	1.005	1.001	**1.020**	1.024	1.031	1.016	1.010	**1.017**	1.026	1.012	1.022	1.009
Services	**0.998**	1.003	0.990	1.004	0.996	**1.019**	1.009	1.034	1.010	1.022	**1.017**	1.012	1.023	1.014	1.018

3. Explaining sectoral productivity growth in EU: A dynamic panel data approach

Once TFP indices were estimated for the productive sectors of the European economies, we will explore the sources of TFP growth. The above estimates allow us to study what economic characteristics could lie behind productivity growth and whether their influence appears via technological progress or efficiency gains. To test the significance of different variables in explaining sectoral productivity growh, we estimate the following equation:

$$TFP_{it} = \beta_0 + \beta_1 TFP_{it-1} + \beta_2 \Delta H_{it} + \beta_3 \Delta G_{it} + \beta_4 K/L_{it} + \beta_5 G/K_{it} \beta_6 PS\% + \beta_7 S/I_{IT} + \\ + \beta_8 EX_{it} + \beta_9 RE_{it} + u_{it} \quad (1)$$

where *i* refers to each of the European countries and *t* is the time period: 1980-2002. This equation follows a standard dynamic model where the lagged dependent variable is included among the regressors (TFP_{it-1}). It seems reasonable in our analysis to consider that the dependent variable is partly explained by its past value. We are also interested in assessing the effects of changes in human and public capital as they are frequently pointed out in the literature as crucial factor underlying TFP growth. Thus, the effects of investment in public infrastructure (ΔG) and education expenditure (ΔH) are estimated, distinguishing the effects of these variables via efficiency gains and technological progress.

Other parameter that could condition TFP growth is an economy´s private capital endowment. Therefore, a variable referring to the capital-labour ratio (K/L) is introduced under the hypothesis that countries with greater endowment of capital per worker will present greater productivity growth both because of a more efficient use of the productive inputs and from the adoption technological advances. We also consider how capital endowment is distributed between public and private capital (G/K). With respect to the relative endowments of public to private capital, one might expect that countries with greater relative shares of public capital would present higher productivity growth rates because of the “free” use that private factors can make of public goods. The crowding-out effect on private investment, however, or the effect of the saturation of public infrastructure for a given level of private capital, could lead to a negative relationship between this ratio and TFP growth, reflecting in this case a relative scarcity of private capital.

Two variables designed to take into account the private sector structure and the relative importance of different activity sectors are also introduced in the analysis. One is the relative weight of the private sector in the economy as a whole (PS%) and the other is the weight of services relative to the industrial sector (S/I). Te reason for including these variables is that the sector structure may condition the rate of adoption of new productive techniques or the efficient use of existing technology.

Finally, we are interested in providing evidence on the role played by asymmetries in the EU economic cycle. Since for the EU economies it is possible to be neither perfectly in concert with nor independent of each other, differences in productivity responses to cyclical fluctuations should be analysed. In particular, countries with higher growth rates are likely to exhibit tendencies for adoption of technical innovations, while countries with low or even declining growth may reveal difficulties in improving efficiency. In this sense, we construct two dummy variables designed to reflect the asymmetries in the countries´ response to EU economic cycle, so that if a country´s growth in GVA is greater -lower- than one standard deviation from the mean EU growth rate, the expansion (EX) -recession (RE)- variable takes a value of one.

The estimation of this model involves some econometric problems. The first one results from the dynamic nature of the data, which can introduce some correlation between the error term and the explanatory variables. In this context, the use of static estimation methods would lead to biased estimates with dynamic panel data. The second issue results from the potential endogenity of the explanatory variables. This could be the case of the public and human capital variables since the causal relation between these variables and GVA growth can run in both directions. Therefore, an instrumental variable estimation is to be used to avoid any potential biased induced by simultaneity. Finally, time invariant variables, which vary across sectors but are not expected to change very much in a short period of time, are often difficult to obtain. We then use a one-way error component model for the disturbance term: $u_{it} = \alpha_{it} + \nu_{it}$, where α_i denotes the unobservable individual specific effects that are independent and identically distributed (iid) over the sectors with variance σ_α^2, and ν_{it} denotes the remainder disturbance iid over the whole sample with variance σ_v^2.

Taking into account these questions (dynamic nature of the model, endogeneity of some explanatory variables and potential unobserved sector heterogeneity), the system Generalized Method of Moments (GMM) developed by Arellano and Bover (1995) and Blundell and Bond (1998) is used in this study. This estimator bases on an augmented system that includes the regression in differences in addition to the regression in levels with lagged differences as instruments. The second part of the system requires the additional assumption of no correlation between the variables in differences and the unobserved sector effects, although there may be correlation between the levels of the explanatory variables and the fixed effects. The consistency of the GMM estimator depends on the validity of the instruments, which is examined by means of the Sargan Test. The Sargan statistic of over-identifying restrictions tests the hypothesis that the instruments are not correlated with the residuals. The validity of the instruments also requires the lack of second-order serial correlation in the first-differenced error term whereas, by construction, first-order correlation is expected even with an uncorrelated original error term. An additional test is therefore included to examine the null hypothesis of no second-order correlation in the residuals.

Next, the results of the estimates at the aggregate and sector levels are presented. In all cases, one cannot reject the null hypothesis of no second-order serial correlation and the validity of the instruments used in the estimation is not rejected by the Sargan test. In addition, the Wald test statistics show that the explanatory variables introduced in the analysis are conjointly significant. Table 3 gives the estimates obtained for the aggregate economy and Tables 4-7 the estimates for each of the private sectors considered. In each case, column 1 offers the results from considering the effects of the explanatory variables on TFP growth, column 2 on technological change and column 3 on efficiency change. These estimates show the importance of the analysed variables in expalining TFP growth and the via by which these variables contribute to productivity growth. The positive and significant coefficient of the lagged dependent variable indicates that TFP growth, technical change and efficiency change, in each case, is partly explained by its past results.

With regard to the role of public productive investment and human capital change on TFP growth the results show the greater impact (and significance) of these variables both at the aggregate and at industry and services sectors, being the positive effects of these variables also apparent through their contribution to technical and efficiency changes. In the agriculture sector, however, only public capital investment is found to be significant whereas in the construction sector we only find evidence of the influence of the human capital variable via technological change.

Greater relative endowments of private capital seem to contribute positively to productivity growth. A significant positive effect of the stock of private capital per employee is observed at the aggregate level, although it is difficult to separate the via by which this variable contribute to productivity growth in the sector-by sector analysis. Despite this, an outcome to consider is the negative effect of the stock of private capital per employee on the efficiency of the construction and industry sector. This result is consistent with those obtained for the European manufacturing in Angeriz, et al., 2006. The ratio public-private capital is also positively related to TFP growth, technological change and efficiency change for the aggregate of the economy. This would indicate that there is no deficit of public capital in the European countries, a result which is in accordance with other works on these economies (Kamps, 2005). Our regression results indicate that the rate at which technical innovation, efficiency and overall productivity advance is higher in countries with greater relative weight of the ratio public to private capital. This may be partly due to the important public investment effort made in the EU during the sample period.

The sector structure also contributes to explain productivity growth. We find evidence that TFP growth, efficiency change and technical progress are positively influenced by a higher private sector share of GVA, for the aggregate of the economy and at the sector level. In this sense, the stock of private capital not only conditions the level of production by participating in the productive process as a production input, but simultaneously favours the processes of technical change and efficiency gains, thereby contributing to TFP growth. The weight of services relative to the industry sector also contributes to explain technical change, although the influence on efficiency gains is negative for the aggregate of the economy. This is the main reason why the effects of this variable are not found to be significant in explaining TFP growth.. Clearly therefore, the importance of the decomposition is evident. The results inicated that the rate at which efficiency advance is lower in countries with service sectors that are large relative to manufacturing. This may be due, in part, to the specialization in activities in the services sector less efficient.

Lastly, for the expansion variable the coefficients are not significant in most of the estimations. This gives support to the existence of a rise in cross-country busines cycle correlation (Barrios and de Lucio, 2003). Despite this, the recession variable is negatively significant, showing that countries with lower growth rates are less productive and become less efficient in the use of the private factors of production. This is to be expected given idle capital and labor hoarding during an economic downturn. In this sense, it is worth noting that negative coefficients do not necessarily imply a decrease in productive capacity, but a decrease in the use of the productive factors or in the rate of technical innovation since, during recession, sectors exhibit diminished propensity to adopt new technology.

Table 3. Estimation results for the aggregate economy.
Dynamic Panel Regression Analysis. GMM-IV System Estimator

Aggregate economy	*TFP growth*	*Technical change*	*Efficiency change*
Lag	0.4022 (3.6198)**	0.4425 (6.5654)**	0.5236 (5.4107)**
Δ H	0.0038 (3.4410)**	0.0044 (2.7216)**	0.0041 (2.3943)**
Δ G	0.0042 (3.9687)**	0.0030(2.7552)**	0.0044 (3.7739)**
K/L	0.0002 (1.9095)**	0.0002 (1.2516)	0.0001 (1.2651)
G/K	0.0012 (1.8943)**	0.0011 (1.4422)**	0.0010 (1.4781)**
Private Sector (%)	0.4756 (3.9498)**	0.4025 (3.4606)**	0.3577 (3.0878)**
Services/Industry	-0.0058 (-0.8807)	0.0194 (2.2878)**	-0.0227 (-3.1880)**
Expansion	0.0023 (0.4195)	0.0030 (0.7233)	-0.0013 (-0.1538)
Recession	-0.0193 (-4.2594)**	-0.0063 (-1.2651)	-0.0108 (-1.5008)*
Test (p-values)			
WALD	157771.20 [0.0000]	194710.93 [0.0000]	65562.76 [0.0000]
AR(1)	-2.4737 [0.0134]	-3.5845 [0.0003]	-3.2029 [0.0014]
AR(2)	0.6663 [0.5052]	1.3352 [0.1818]	-0.3706 [0.7109]
SARGAN TEST	354.2478 [0.0540]	464.759 [0.0000]	366.0365 [0.0208]
Observation (N)	294	294	294

Notes: One-step robust standard errors in brackets; statiscally significant * at 10% and ** at 5%.
AR(1) and AR (2) are tests of first and second order serial correlation.

Table 4. Estimation results for the agriculture sector.

Dynamic Panel Regression Analysis. GMM-IV System Estimator

Agriculture	*TFP growth*	*Technical change*	*Efficiency change*
Lag	-0.0066 (-0.0730)	0.1696 (2.4210)**	0.0717 (1.2516)
Δ H	0.0034 (0.8504)	0.0064 (1.2642)	0.0012 (0.2659)
Δ G	0.0065 (1.9108)**	0.0048 (1.1413)	0.0086 (1.7562)**
K/L	0.0006 (2.6846)**	0.0004 (1.5800)*	0.0007 (2.3870)**
G/K	0.0024 (0.9753)	0.0026 (1.6177)*	0.0013 (0.4668)
Private Sector (%)	0.9334 (5.7576)**	0.7063 (4.7354)**	0.7840 (4.2426)
Services/Industry	-0.0338 (-2.3055)**	-0.0415 (-2.3144)**	0.0066 (0.5509)
Expansion	-0.0009 (-0.0500)	0.0236 (1.0677)	-0.0131 (-0.7874)
Recession	-0.0229 (-2.0663)**	-0.0696 (-6.2299)**	0.0319 (1.4182)*
Test (p-values)			
WALD	18497.96 [0.0000]	26863.37 [0.0000]	24253.79 [0.0000]
AR(1)	-3.3012 [0.0010]	-3.1913 [0.0014]	-3.3816 [0.0007]
AR(2)	-0.4603 [0.6453]	-3.0363 [0.0024]	-2.5530 [0.0107]
SARGAN TEST	309.0555 [0.5524]	389.6482 [0.0021]	354.5734 [0.0527]
Observation (N)	294	294	294

Notes: One-step robust standard errors in bracktes; statiscally significant * at 10% and ** at 5%. AR(1) and AR (2) are tests of first and second order serial correlation.

Table 5. Estimation results for the construction sector.

Dynamic Panel Regression Analysis. GMM-IV System Estimator

Construction	*TFP growth*	*Technical change*	*Efficiency change*
lag	-0.0784 (-2.3964)**	-0.2451 (-4.2448)**	0.1441 (3.0475)**
Δ H	0.0149 (2.1088)**	0.0185 (2.7178)**	0.0006 (0.1600)
Δ G	0.0029 (0.6391)	0.0007 (0.1434)	0.0092 (2.9797)**
K/L	-0.0030 (-1.1195)	-0.0024 (-1.2279)	-0.0014 (-1.3361)*
G/K	0.0016 (0.7403)	0.0014 (0.7187)	0.0022 (1.1264)
Private Sector (%)	0.9700 (5.9041)**	1.1356 (5.1222)**	0.7150 (4.2207)**
Services/Industry	0.0051 (0.2127)	-0.0101 (-0.5411)	0.0268 (2.8364)**
Expansion	-0.0100 (-0.5265)	-0.0092 (-0.6341)	0.0096 (0.6467)
Recession	-0.0448 (-1.1944)	-0.0487 (-2.0384)**	0.0190 (1.6752)*
Test (p-values)			
WALD	51717.71 [0.0000]	7911.91 [0.0000]	11340.10 [0.0000]
AR(1)	-1.5755 [0.1151]	-1.4926 [0.1355]	-2.2859 [0.0223]
AR(2)	-0.9896 [0.3224]	-0.7644 [0.4446]	-0.5969 [0.5506]
SARGAN TEST	418.5866 [0.0001]	367.1002 [0.0190]	343.5009 [0.1135]
Observation (N)	294	294	294

Notes: One-step robust standard errors in brackets; statiscally significant * at 10% and ** at 5%. AR(1) and AR (2) are tests of first and second order serial correlation.

Table 6. Estimation results for the industry sector.

Dynamic Panel Regression Analysis. GMM-IV System Estimator

Industry	*TFP growth*	*Technical change*	*Efficiency change*
Lag	0.1332 (1.7790)**	0.2251 (3.5328)**	0.1775 (1.7005)**
Δ H	0.0045 (2.1470)**	0.0052 (1.8602)**	0.0069 (2.5036)**
Δ G	0.0064 (2.8972)**	0.0016 (0.8327)	0.0082 (3.8770)**
K/L	0.0002 (1.0400)	0.0005 (2.5835)**	-0.0003 (-1.8590)**
G/K	0.0011 (1.1720)	0.0017 (1.6170)*	0.0013 (1.3206)*
Private Sector (%)	0.7252 (4.5628)**	0.5901 (4.1108)**	0.6627 (6.2219)**
Services/Industry	-0.0015 (-0.1116)	0.0487 (3.0230)**	-0.0435 (-2.7600)**
Expansion	-0.0150 (-1.1901)	-0.0081 (-1.0406)	-0.0106 (-0.8347)
Recession	0.0199 (1.3352)*	-0.0084 (-0.5758)	0.0261 (0.8308)
Test (p-values)			
WALD	33140.80 [0.0000]	19647.59 [0.0000]	39952.02 [0.0000]
AR(1)	-2.8538 [0.0043]	-3.3559 [0.0008]	-2.3604 [0.0183]
AR(2)	0.2251 [0.8219]	-3.6533 [0.0003]	-1.6952 [0.0900]
SARGAN TEST	368.8243 [0.0163]	502.2584 [0.0000]	403.2944 [0.0004]
Observation (N)	294	294	294

Notes: One-step robust standard errors in brackets; statiscally significant * at 10% and ** at 5%.
AR(1) and AR (2) are tests of first and second order serial correlation.

Table 7. Estimation results for the services sector.

Dynamic Panel Regression Analysis. GMM-IV System Estimator

Services	*TFP growth*	*Technical change*	*Efficiency change*
Lag	0.3807 (5.4310)**	0.4586 (12.0222)**	0.2820 (3.0473)**
Δ H	0.0044 (2.7663)**	0.0045 (1.8756)**	0.0067 (3.3067)**
Δ G	0.0038 (2.8748)**	0.0052 (3.4198)**	0.0027 (1.3073)*
K/L	0.0002 (2.4002)**	0.0000 (-0.0938)	0.0000 (0.0111)
G/K	0.0013 (1.7465)**	0.0012 (1.5322)**	0.0014 (1.4138)*
Private Sector (%)	0.4671 (4.1413)**	0.3917 (4.8863)**	0.5885 (4.7854)**
Services/Industry	-0.0017 (-0.2514)	-0.0031 (-0.6692)	0.0005 (0.0613)
Expansion	0.0049 (0.5546)	-0.0007 (-0.0793)	0.0048 (0.3490)
Recession	-0.0177 (-1.9961)**	-0.0099 (-1.4442)*	-0.0088 (-0.6558)
Test (p-values)			
WALD	100317.47 [0.0000]	34711.41 [0.0000]	88068.38 [0.0000]
AR(1)	-3.1258 [0.0018]	-3.0914 [0.0020]	-2.9619 [0.0031]
AR(2)	1.6438 [0.1002]	2.2478 [0.0246]	1.6139 [0.1066]
SARGAN TEST	326.5337 [0.2878]	371.9404 [0.0123]	334.9715 [0.1881]
Observation (N)	294	294	294

Notes: One-step robust standard errors in brackets; statiscally significant * at 10% and ** at 5%.
AR(1) and AR (2) are tests of first and second order serial correlation.

4. Conclusions

In this study, we employed DEA methods to measure efficiency change, technical progress and TFP growth, using sectoral level data for the EU economies in the period 1980-2002. The Malmquist productivity index was used to measure changes in TFP and its components. The results indicate that technical change plays a main role in contributing to TFP growth in the EU economies at the aggregate level and for the main private sectors of activity. At the same time, a poor record of efficiency has proved detrimental in pushing EU productivity growth. The unfavorable performance of efficiency detected at the aggregate level and for the major private sectors seems to constitute a structural problem for the European economies.

In order to anchor this analysis in the context of ongoing policy debates, we attempted to provide additional insights into the factors that could lie behind differences in productivity growth and whether the contribution of these variables manifest through either changes in efficiency or technological progress. To this end, we used the system-GMM approach proposed by Blundell and Bond (1998). Overall, our results are consistent with the widely-accepted idea in policy research that infrastructures and education play an important role in promoting growth, as well as with the viewpoint that a higher private sector share has a positive influence on TFP growth. However, the analysis does not allow to fully explain the poor results achieved in terms of efficiency change at the European level. The evidence reached shows that the higher weight of services relative to the industry sector negatively conditioned the efficiency growth in this period and that, during recessions, productivity decreased as a result of diminished efficiency. The interest in understanding these behaviors makes it necessary to continue this line of research to identify the reasons behind relative low levels of efficiency in the EU countries and economic policies that could reverse this trend.

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