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Growth Accounting:
How institutions affect Portugal's Growth

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Abstract

The main objective of this Work Project (WP) is to understand whether institutional quality has been determinant to the increase of Portugal's productivity. This WP provides a sector-wise Growth Accounting exercise and analyzes the Total Factor Productivity (TFP) growth. Secondly, it uses a cross-country approach to understand which institutional indicators influence TFP growth. This WP considers, based on GMM estimation, different models to capture the causality between productivity growth and Institutional Quality. The results obtained reveal a positive relation between TFP growth and Institutional Quality.

Keywords: Growth Accounting, TFP, Institutions, Portugal, Sector

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1 Introduction

European integration has provided an ideal context to understand the economic growth and convergence process between a group of developed countries, as its survival is dependent on real convergence. European integration focused primarily on the removal of barriers to international competition which should have led to a more competitive economy, flourishing development and innovation. The integration has risen expectations of further market integration, and of institutional and productivity convergence. The European Union defined baseline criteria to optimize the catching up process based on investment in physical capital, human capital, and monetary stabilization; where all member-states had reforms and requirements to meet in order to enter the union. In sum, the expectations of economic integration were defined as differences of factor intensity combined with factor mobility which would lead to a higher efficiency and a higher aggregated income; thus implying a convergence of production levels and income distribution[1]. However, in light of the recent European crisis doors have opened to rethink the convergence process and to identify the missing ingredient for real convergence. Portugal entered the EU (originally the European Economic Community), in 1986, in a very bad shape with serious distortions in the product and factor markets, as well as with an industrial structure in need of modernization. Portugal's external sector was based on traditional consumer goods such as clothing, textile and wood industries; all which were very sensitive to the European Business Cycle[2]. At the time, a discussion rose about the gap between real and nominal convergence (Commission, 1997) - economic policy did not seem able to support both types of convergence. Many programs were designed and funds allocated to increase competitiveness and improve production conditions in various sectors.[3] However, many economists advocate that the lack of institutional convergence is the reason behind the low growth. The insufficient real convergence of Portugal towards the EU15 can be solved through structural reforms. However, understanding which structural reforms are necessary or which incentives are needed to create a more competitive economy is the ongoing challenge.

This work project (WP) aims to understand Portugal's evolution throughout this integration

[1]Islam (2003) argues that many studies have failed to demonstrate that productivity-convergence is associated with income-convergence.

[2]Many economists, including Marques-Mendes and da Silva Lopes (1993) argue that the downturn of the growth rate was due to external factors- balance of payments and deterioration of the terms of trade

[3]The EU Commission (1997) pointed out the main lines of reform to sustain the convergence process (1) privatizations and public sector reforms, (2) reform to financial services sector, (3) 'single market' reforms (4) labor market reforms and other structural reforms.

process. The WP provides a sectoral growth accounting exercise to understand the evolution of sector-wise productivity, and analyses whether institutions are determinant to increase productivity. In spite of the importance of this subject, very little attention has been attributed to institutional quality augmenting productivity. Basically, this WP looks for evidence of the relation:

Institutional Change →Total Factor of Productivity →Economic Growth

This WP used different panel data models, such as the FE and RE, to understand how institutions are related to productivity growth. Concerns regarding reverse causality led to a more compelling approach by using GMM estimation. [4]

The remainder of this WP is divided into six sections: Section 2 -Literature review concerning all the WP; Section 3- Growth Accounting which is divided into data description and TFP growth calculations; Section 4- Institutional Framework concerning how institutions are integrated into the framework; Section 5- Model specification; Section 6-Results and finally, Section 7- Discussion.

2 Literature review

The Neoclassical growth theory considers the sources of output growth to be the junction of capital and human accumulation with exogenous technological change. However, regarding convergence processes Maddison (1996) defends that growth accounting is a better approach to explain the European catching-up process to US productivity levels, as it drops the constant elasticity assumption inherited from the neoclassical framework.

The growth accounting literature from Solow (1957) to Hall and Jones (1999) reveals that the best measure of productivity is Total Factor Productivity (TFP). Yet, the TFP or Solow residual's content or captured factors has not yet been defined with consensus among economists. Abramovitz and David (1996) define the residuals as "the measure of our ignorance" since it is an important explanatory growth factor, nonetheless disagreement persists due to the lack of data availability and diversity of methodologies. A common consensus is that TFP is the economy's capacity of converting inputs into outputs. There are two types of methods to calculate Total Factor Productivity: one deterministic and the other econometric. Growth accounting lies in the deterministic class as the residuals are "calculated"; while growth regressions are based on econometric

[4]Results are presented using the estimator xtabond2 in Stata created by Roodman (2006) as tool to control for endogeneity and reverse causality.

methods thus residuals are "estimated" through models.[5] The main advantage of the growth accounting approach is that TFP is not an estimated residual obtained through a calibration exercise. The TFP measure can use a traditional non-frontier methodology (Solow, 1957) which follows an assumption of fully efficient production implicating that the observed output equals to potential level. The Frontier models allow for inefficiencies[6]- output is not assumed to equalize the frontier output. In this WP, we will use growth accounting with maximizing profit and constant returns to scale using a non-frontier methodology.

In the growth accounting methodological approach, Islam (2003) considers three main approaches: (1) "time-series growth accounting" (developed by Jorgenson to calculate productivity growth rates[7]); (2) "a panel regression approach" (used to estimate productivity levels by Islam (2003)) and (3) "a cross-section growth accounting approach" (considered in Hall and Jones (1999) to compute levels of productivity[8]).

Economic growth has been in the limelight throughout centuries as the driver of higher welfare. Explaining wealth differences has been the foundation for the quest to find the sources and determinants that create economic growth. Hence, a vast literature regarding the determinants of economic growth,[9] where we emphasize capital accumulation, capital labor, governance, and institutional framework, has emerged. Ultimately, growth is driven by individual behavior of households, firms and research institutions whose incentives are provided by formal and informal rules. These decisions depend largely on the structure provided by the government regarding property rights, capital investments, labor utilization, capital labor, capital deepening, innovative protection and infrastructure. Institutions also play an important role in this context. North (1990) defines institutions as

> "The rules of the game in society or, more formally, are the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic."

Good institutions can avoid losses due to corruption, destruction of capital, legal procedures, en-

[5] According to Del Gatto et al. (2011) productivity measures are organized with these criteria.

[6] Data Envelope Analysis is a nonparametric frontier method that decomposes output growth into technology change, quality improvement, real cost savings and efficiency change.

[7] This approach was followed by (Timmer et al., 2007) and we have also used it. More details are available below.

[8] Hall and Jones (1999) compute the productivity levels, although it allows the capital share to vary across countries, they are restrained by the assumption of equal rate of return to capital.

[9] A summarized list may be found in Wacziarg (2002). Durlauf et al. (2005) present an extensive literature review of economic growth models and determinants.

forcement of contracts and macroeconomic stability. The public sector has a prominent role to provide a market structure to facilitate the absorption of technology and the development of competitive markets. Consequently, institutions have a direct influence on household and business decisions which ultimately influence total factor productivity. The global economy is in constant evolution forcing institutions also to evolve to accommodate changes endogenously. Despite, this evolution, institutional reforms are used to re-order priorities and maintain competitiveness. Nevertheless, institutional quality is hard to measure, and still we only have very incomplete proxies available[10].

The relation between institutions and growth has been vastly studied. Many papers[11] resort to cross-country empirical studies to understand growth differences and empirically test whether institutions are the main determinants. North's institutional framework could be integrated with the Solow growth model; Abramovitz and David (1996) highlight that the absorption of technology is constraint by "social capabilities". The rate of technical progress and efficiency is affected by institutional quality.

Hall and Jones (1999) are responsible for the turning point of considering the effect of social infrastructures as drivers of productivity [12] in a cross-country study, finding that the social structure has significant effects on long run economic performance. However, looking deeply into institutions, both formal and informal institutions are prominent in explaining incentives that could lead to an increase in productivity.

Summing-up, this WP follows the "New Growth Theory" which goes beyond neoclassical assumptions of factor accumulation, whereas the rate of technological progress is driven by internal forces to the economic system. Aghion and Howitt (1990) underlines that sustained long-term growth is achieved through a boost in technological change driven by a more efficient use of resources. Competitive firms have incentives given by policies to maintain a competitive edge by constantly innovating; altogether R&D efforts create a higher efficiency leading to technological progress. Thus, there is also a scale effect to be considered that influences the growth rate of technological progress. The New Growth Theory was empirically tested by considering the Total Factor Productivity as a proxy of technological change capturing efficiency gains; and to control

[10] The EBRD is monitoring the EU new-member convergence process to create better institutional quality indicators.

[11] Milestone references, such as Acemoglu et al. (2000), Knack and Keefer (1995), Dollar (1992) and Rodrik (2000) use proxies for institution (such as property right, risk of expropriation, contract enforceability, political systems, etc.) and use instrumental variables to capture institutional effects (settler's mortality, language, colonial origins, etc).

[12] Defined as institutions and government policies that create incentives for individuals.

for scale-effects we use country-industry level R&D stocks.

There are many studies regarding Portugal's productivity evolution. Lains (2003) has done an historical analysis of Portugal's productivity based on a econometric model considering structural changes in the industrial sector. Amador and Coimbra (2007) consider a stochastic frontier exercise using as baseline Greece, Ireland and Spain to understand what sources of growth are at larger distance from the efficiency frontier. There are also many reports with a policy driven character regarding convergence to the EU with illustrative TFP growth comparison. The IMF (2013) compares aggregate TFP growth in the US and EU15 concluding that there is an urgent need of technological improvement. The European Commission produces many reports emphasizing the catch-up and growth of member states. All these papers, in general terms, suggest structural reforms to improve institutional quality. Tavares (2004) addresses the question of which of the structural reforms actually affects growth, using different institutional indicators to understand which are more correlated with the growth of the country. This paper shows compelling evidence that institutional indicators are very correlated with growth. However, the question of whether institutional quality drives total factor productivity growth remains unanswered. Hence, is institutional quality the key to growth in a context of convergence?

3 Growth Accounting

The growth accounting exercise is a diagnostic tool that helps understand the economy's productivity throughout time. Aggregate growth accounting rules out the sectoral composition of output, following an assumption of uniform technological progress. However, differences in aggregate TFP may be explained by sectoral specialization, which would imply different policy implications. On the one hand, if productivity differences are explained by the sectoral composition, than policies should be directed towards factor mobility across sectors; on the other hand, if however this is not the case, barriers to productivity are explained through technology adoption. A relevant relationship between aggregate and industry level TFP is that the aggregate measures consider one sector that produces all GDP, whereas all intermediate goods cancel out.[13] An increase in sector-wise productivity occurs either due to improved efficiency gains at the firm level or due to a shift of production towards more efficient establishments (Schreyer, 2001). The effects of policies and

[13] This raises difficulties when deriving the aggregate to disaggregate output (or TFP) or vice-verse. Hulten (2009) focuses on both approaches.

regulation or technology change have a direct impact on relative productivity leading to relative price changes and changes in the elasticity of substitutions.

3.1 Theoretical Background

The growth accounting industry level framework applied in this WP follows the time-series panel methodology presented in the Schreyer (2001) and Timmer et al. (2007). The production function for each industry given as $Y_{j,t} = f_j(K_{j,t}, L_{j,t}, X_{j,t})$, is composed by the industry gross production output (Y), labor composition (L), index capital services flow (K), index intermediate inputs (X) and technology (A). Considering the production function as a function of time, output has a direct change over time due to impact of changes of capital, labor and intermediate goods over time. Hence, considering the production function over time t, we have that

$$\frac{dY}{dt} = \frac{\partial Y}{\partial K}\frac{dK}{dt} + \frac{\partial Y}{\partial L}\frac{dL}{dt} + \frac{\partial Y}{\partial X}\frac{dX}{dt} + \frac{\partial F}{\partial t}. \tag{1}$$

Regarding the terms of this equation, we have that $\frac{\partial Y}{\partial K}\frac{dK}{dt}$ is the capital effect on output, $\frac{\partial Y}{\partial L}\frac{dL}{dt}$ is the labor effect on output and finally, $\frac{\partial Y}{\partial X}\frac{dX}{dt}$ is the intermediate input effect. The last term, $\frac{\partial F}{\partial t}$, is the direct effect of time on output, also called productivity or technology (A_t). By dividing both parts of equation (1) by Y, we may re-write it as a function of output growth, i.e.,

$$\frac{\dot{Y}}{Y} = \frac{\frac{\partial F}{\partial t}}{Y} + \frac{\partial Y}{\partial K}\frac{K}{Y}\frac{\dot{K}}{K} + \frac{\partial Y}{\partial L}\frac{L}{Y}\frac{\dot{L}}{L} + \frac{\partial Y}{\partial X}\frac{X}{Y}\frac{\dot{X}}{X}, \tag{2}$$

which can further be represented as,

$$\frac{\dot{Y}}{Y} = \frac{\frac{\partial F}{\partial t}}{Y} + \frac{\text{MPK}}{\text{APK}}\frac{\dot{K}}{K} + \frac{\text{MPL}}{\text{APL}}\frac{\dot{L}}{L} + \frac{\text{MPX}}{\text{APX}}\frac{\dot{X}}{X} \tag{3}$$

where $\frac{\dot{Y}}{Y}$ is the growth rate of output and all other inputs follow same convention. Moreover, MPK refers to Marginal Productivity of Capital ($\frac{\partial Y}{\partial K}$), APK to the Average Product of Capital ($\frac{Y}{K}$), MPL is the Marginal Productivity of Labor ($\frac{\partial Y}{\partial L}$) and APL the Average Product of Labor ($\frac{Y}{L}$). The intermediate product follows the same convention. Furthermore, assuming constant returns to scale, capital intensity is given by $\alpha_t^K = \frac{\text{MPK}}{\text{APK}}$, labor intensity by $\alpha_t^L = \frac{\text{MPL}}{\text{APL}}$ and the intermediate product effect is $\alpha_t^X = \frac{\text{MPX}}{\text{APX}}$.

Since macroeconomic variables cannot be observed in continuous time, only in discrete time, to measure the continuous growth rate of TFP ($\frac{\dot{\text{TPF}}}{\text{TPF}}$), generally the average value of TPF $= \triangle ln\text{TPF}_t$ is considered. Moreover, under assumptions of competitive factor markets and full input utilization; and considering that firms are price-takers, it follows that,

$$\alpha_t^K = \frac{\text{MPK}}{\text{APK}} = \frac{\frac{\partial Y}{\partial K}}{\frac{Y}{K}} = \frac{R_t K_t}{P_t Y_t}, \tag{4}$$

$$\alpha_t^L = \frac{\text{MPL}}{\text{APL}} = \frac{\frac{\partial Y}{\partial L}}{\frac{Y}{L}} = \frac{W_t L_t}{P_t Y_t} \tag{5}$$

and

$$\alpha_t^X = \frac{\text{MPX}}{\text{APX}} = \frac{\frac{\partial Y}{\partial X}}{\frac{Y}{X}} = \frac{P_t^X X_t}{P_t Y_t}. \tag{6}$$

Summing-up, considering equation (2) for each sector, we have that:

$$\triangle lnY_{jt} = \alpha_X \triangle lnX_{jt} + \alpha_K \triangle lnK_{jt} + \alpha_L \triangle lnL_{jt} + \triangle ln\text{TPF}_{jt}^Y \tag{7}$$

where $\alpha_t^X + \alpha_t^K + \alpha_t^L = 1$ and the technical change A_{jt} is measured by total factor productivity ($\triangle ln\text{TPF}_{jt}^Y$). A crucial assumption is that marginal revenues are equal to marginal costs, so a weighting procedure is sufficient to ensure that the input indices reflect all the components weighted by their influence on productivity. The aggregation of Output, Labor and Capital use a Tornqvist quantity index [14].

3.2 Data

Following the literature, the database used is the *EUKLEMS Growth and Productivity Accounts* (EU KLEMS) Revised[15] 2008 as a resource of input and output series provided independently of any econometric method.

Portugal's productivity is assessed at higher depth, using as a baseline comparison average EU low (Portugal, Greece, Italy, Spain and Ireland), average EU high (Germany, France, Netherlands, Belgium, and others), Spain and Germany. We are considering the evolution of productivity in Total Industries (TOT); Agriculture, Hunting, Forestry and Fishing (AtB); Total Manufacturing

[14] Following the methodologies in Timmer et al. (2007), O'Mahony and Timmer (2009) and Schreyer (2001). Further specifications may be found in Section 9.1 of the Appendix

[15] There are a few other data-sets in WIOD or GGDC, but none were as complete and homogeneously corrected for a cross-country analysis.

(D); Finance, Insurance, Real estate and Business sector (JtK); Mining and Quarrying (C); Electricity, Gas and Water supply (E); Construction (F) and Wholesale and Retail Trade (G). Data is not available for all time periods, so our analysis only considers a sample from 1970 to 2005.

3.2.1 Output

We consider two measures of output- Value Added (VA) and Gross Output (GO). The Value Added is the production each sector provides without including purchases of intermediate goods. While the gross output is the total value of the sales including the three inputs[16]. Figure 1 illustrates how the value added growth resembles gross output growth rates.

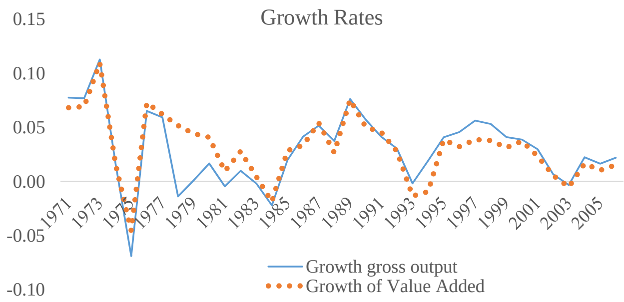


Figure 1: Growth rate of Value Added and Growth rate Gross Output

The output of growth rates are sector wise distinct displaying very significant changes within each specific sector. A higher economic integration would lead to higher factor mobility across countries following a distribution of factors according to the factor intensities of each sector. Sectors with a higher relative income of factor within the economy would attract factors needed, leading to an equalization of factor income - factor intensity equalization. Thus, sectors that are more efficient would be able to grow at a faster rate leading to higher production levels.[17] Despite the theoretical reasoning, factor mobility may react very slowly to market driven incentives. A country with rigid market conditions can be forced to enter a situation of disproportional production levels due to inefficiency of factor allocation, which creates a gap between efficient and inefficient sectors. However, in a context of economic integration, an even higher mobility between countries would be expected, as a union should converge to the same factor income in all regions. Factor abundance or scarcity are also included in the factor income variation, since these influence the factor-price component. Studying distinctively by sectors should allow for a more profound analysis to understand which sectors have flourished and which have retracted with the integration. An interesting point would also be to consider whether factor mobility across sectors was synchronized with the relative factor income across sectors.

[16] See annex section 9.1.1 for more information.
[17] Bertola (2013) provides a theoretical framework.

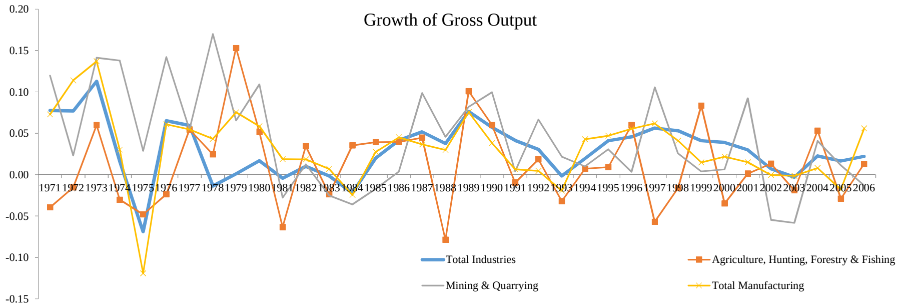


Figure 2: Value added growth rate and gross output growth rate by sector.

As expected, the overall production level growth of output should be increasing considering that there is free factor mobility, and that an increase in capital inflows contribute to the effect.

3.2.2 Intermediate goods

The database provides an aggregated index of the intermediate goods and of the inputs decomposed into energy, services and material. However, data availability of the decomposed inputs has a smaller time period than the one being considered. Using a Tornqvist index, using as weights the compensation of each intermediate index, we calculated an aggregated index. Figure 3 depicts the growth rate of both indices.

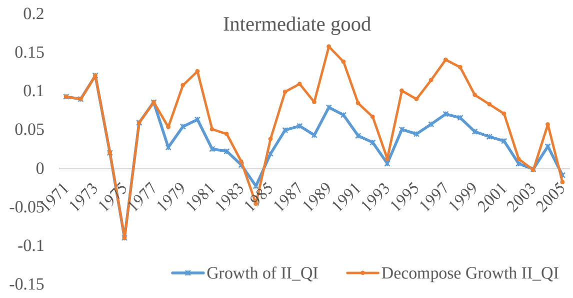


Figure 3: Growth rate of intermediate goods: (a) Aggregated intermediate goods; (b) Decomposed aggregated intermediate goods composed by energy, services and material.

3.2.3 Labor

Portugal has information regarding worked hours and number of labor engaged. When we analyze the growth rate of both variables, we conclude that both have very similar pattern.[18] In this case, we use total hours worked by persons engaged as labor input. As mentioned above, institutional quality has a direct influence on incentives of labor opportunities. Figure 4 illustrates that the employment share per sector is not evolving according to market signals of higher compensation. Ideally, sectors with higher labor compensation should attract more individuals. However, the share of workers in each sector seems quite stagnated. The mining and quarrying sector, which is

[18] In a TFP growth analysis either variables can be used.

not represented, is quite troublesome as it has a significant amount of workers, but with very low labor compensation.

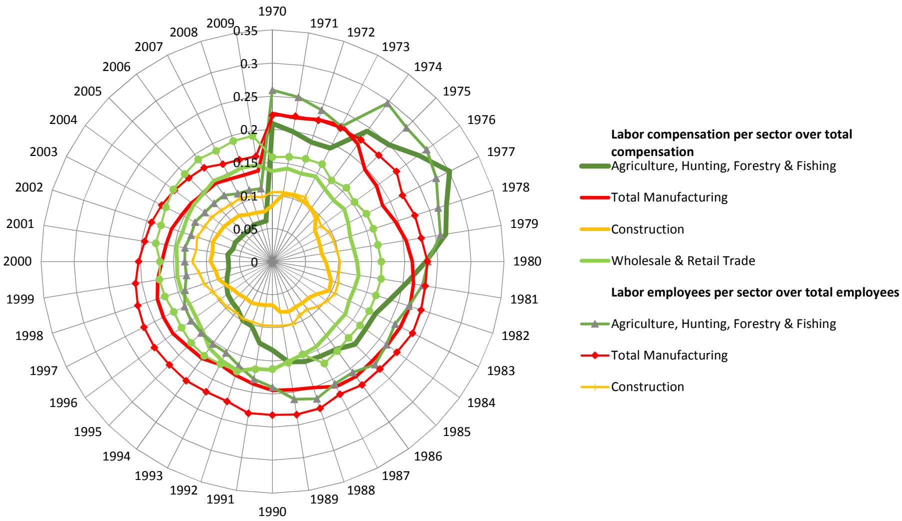


Figure 4: Relation between labor compensation and employment share in each sector.

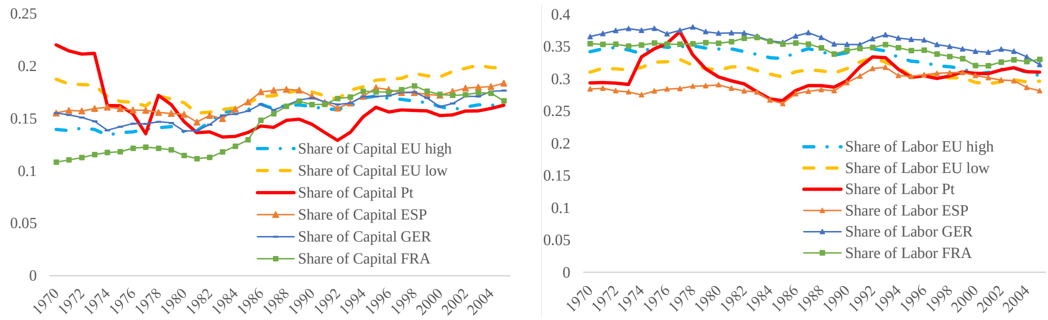
The skill composition throughout the sectors is also important to determine labor productivity within each sector. Low skill engaged personnel will induce slower labor movement towards higher skilled-demand sectors. Unfortunately, labor decomposition is only available for the period 1997-2005[19]. Due to the unavailability of data, two different measures of TFP considering both labor composition and hours worked will be considered.

3.2.4 Capital

The capital input index is composed of an aggregation of assets from land, infrastructure to computers. However, not much data is available in the KLEMS database, so input is measured by the ICT and Non-ICT capital. There is lack of detailed sector-wise information regarding capital. The capital index does not account for changes in the usage of land or differences in inventories. However, Timmer et al. (2007) describe how the capital index was set-up, the method of applying depreciation rates to different assets and the treatment of negative capital. The approach used to calculate capital compensation is not based on the exogenous cost of capital information, but rather on differentiating the value added into labor compensation and capital compensation. This process allows for an heterogeneous weighted stock of assets to be included in the index.

In the EU integration context, a common financial market would lead to higher capital flows

[19]Figure 9 of the appendix illustrates the evolution of skills



(a) The share of capital as the ratio of capital compensation and current gross output.

(b) The share of labor calculated as the ratio of labor compensation and current gross output.

Figure 5: The shares used to calculate weights of each factor in the Growth Accounting exercise.

to capital-poor countries leading to expectations of institutional and productivity integration. Despite, the theoretical reasoning, this leap could only be fostered if government authorities evolved institutions towards further integration. However, looking at Figure 12, we observe that capital based on information processing and technology had the highest advance and growth despite the fall in capital growth after 1999.

Hence, the evolution of capital and labor shares will shed more light towards the role of Capital and Labor input. Figure 5b follows the reasoning that within economic integration, expectations rose labor compensation to the level of average high income EU, despite an unreal market incentive. While capital compensation Figure 5a, which was in high supply is lower than the designated comparisons. Growth accounting uses these shares as the weights of the contribution of each component.

3.3 Total Factor Productivity

Taking all components measured earlier, Table 5 provides an average per year contribution, while Figure 13 illustrates the contribution of each factor to the TFP growth rate. As can be observed, TFP growth follows a very similar path as the output growth rate. The contribution of labor seems to be the most volatile of all components. TFP is measured as the ratio of volume of output to input. This productivity ratio has embedded many characteristics [20] that cause change, namely technological change, technical efficiency, real cost of savings and living standards. Technological change is the innovative process to transform resources into output shifting the frontier of potential production; including innovative products or scientific evolution. Technical efficiency refers to

[20] Schreyer (2001) is more descriptive regarding productivity determinants.

efficiency gains due to re-organization towards "best practices" at an individual level or concerning shifts of production at an industrial level to more efficient establishments. Real cost savings is a residual that captures all other factors not mentioned above, such as learning-by-doing or social benefits gained in certain sectors, etc.

Total Factor Productivity is very different according to the industry considered. We cannot rule out the possibility that some of the variation results from measurement errors. Below, in Figures 6 and 10, we present the differences in growth considering different levels of decomposition.

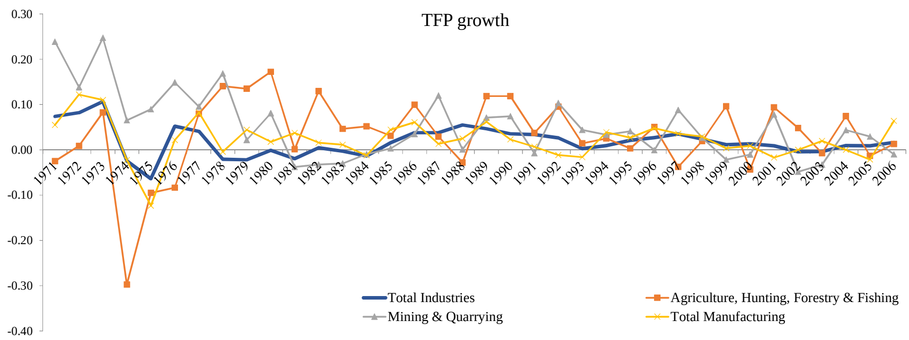


Figure 6: Total Factor Productivity growth rates using only aggregated sector-wise indices

However, due to data availability the present TFP growth does not include the desegregated labor and intermediate good decomposition presented in the formulas in the Appendix. When we allow for different decompositions the growth of TFP takes a very similar path (see Appendix Figure 11[21]).

Altogether, these differences bring forth a more skeptic look towards the calculation of growth of TFP. Looking further to the differences in growth of TFP in each sector compared to an average of EU high, EU low and baseline countries (Figure 7) hinges on the fact that they are good indicators of productivity[22].

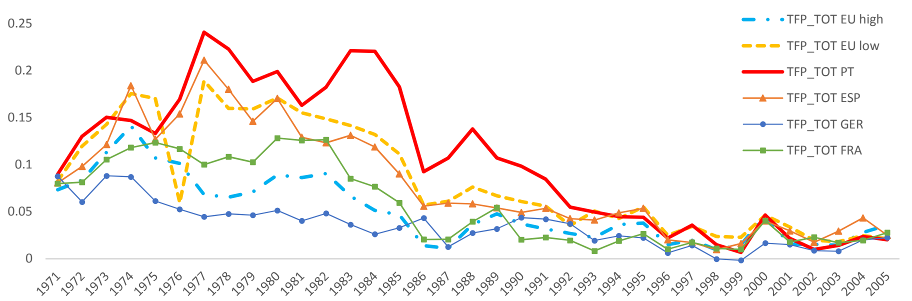


Figure 7: Total Factor Productivity growth aggregated TFP growth in comparison with EU 15

[21]The KLEMS database methodology corrected all variables to homogenize series.
[22]Figure 11 shows the decomposed TFP indicator, which is very similar from 1995 onward.

The convergence of EU countries' productivity growth is still under discussion. Stylized facts are that lower productivity countries will have higher productivity growth rates, while higher productivity countries will have low growth rates[23]. In respects to the convergence process in a market integrated setting, we will assume that productivity growth among the same sectors across countries will converge to the same growth rate, considering that there is a high diffusion of technology and free factor mobility among member-states.

4 Institutional Framework

In this WP, we consider only formal institutions to understand the casual relation with productivity[24]. Following a similar framework as Hall and Jones (1999), we consider the quantitative measure of institutional quality (IQ) as a determinant of productivity (TFP) through a structural model, i.e.,

$$log\mathrm{TFP}_{it} = \alpha + \beta_1 \mathrm{IQ}_{it} + \epsilon_{it} \tag{8}$$

$$\mathrm{IQ}_{it} = \gamma + \delta log\mathrm{TFP}_{it} + \theta X_{it} + \eta_{it} \tag{9}$$

where, IQ_{it} is institutional quality, TFP is the TFP growth rate[25]. This specification is parsimonious since it ignores many other factors that contribute to productivity, focusing mainly on the role played by institutions. However, given that there is no perfect institutional quality measure, the proxy for institutions can lead to significant measurement errors $\mathrm{IQ} = \bar{\mathrm{IQ}} + v$; where IQ is the proxy, $\bar{\mathrm{IQ}}$ is the true value and v is the measurement error. This error creates a downward bias of the OLS estimator. As empirical evidence has demonstrated (8) has an endogeneity problem between institutions and productivity.

Aron (2000) highlights many problems concerning causality between growth and institutions: (a) Reverse Causality: higher growth creates better institutions and better institutions create optimal conditions for growth. (b) Endogeneity: where institutional quality is not constant or exoge-

[23] Many papers are focusing on the question of convergence within the EU. No consensus has yet been reached, as only predictive models were constructed.

[24] Time constraints limit us of looking further into the gap between informal and formal institutions

[25] Hall and Jones (1999) emphasize the importance of TFP levels rather than growth rates. Where level analyses are more relevant to capture long run effects and also to capture welfare measured by consumption. But, their specification mainly resembles a Cobb-Douglas production function specification. Furthermore, Islam (2003) discusses different methods to calculate the TFP levels. In the context of this analysis, these methods are not yet sufficiently reliable. Consequently, we use TFP growth rates in virtue of a simplified model.

nous. It may be affected by political instability, climate shocks, trade or even austerity programs. (c) Institutions: there is no variable for institutions, considering that it represents a state that depends on many variables. Most institutional criteria are ordinal indices ranked across countries, meaning they do not quantify institutional differences, but consider a relative rank. (d) Omitted variables: is a constant concern regarding regressions; especially reverse causation combined with omitted variables were there is no assurance for the unexplained growth variance.

4.1 Institutional Indicators

There are two types of institutions: (a) Formal institutions which are an endogenous bureaucratic evolution in terms of laws, economic and political level; (b) Informal institutions are exogenous and cultural based rules and incentives. Formal institutions, in general, are based on an aggregation of hard variables; however, many indicators also aggregate a soft component. Meanwhile, informal institutions are generally based on soft indicators created through surveys data and perceptions. Generally, it is believed that institutional quality indicators have an inherit biased construction, since the weights and variables included in the indicators are left at the researchers discretion. Institutions are very hard to measure, as can be inferred from North (1990). Alonso and Garcimartín (2013) indicate that a good institutional quality indicator has to incorporate at least four properties: 1) static efficiency - ability to enhance efficient equilibrium by a technological frontier; 2) credibility- generate a framework capable of enforcing incentives and modulate individuals' behavior; 3) predictability -reduce uncertainty creating a safer environment and reducing transaction costs; and 4) Adaptability - endogenous characteristic of creating incentives to adjust agents' behavior to an anticipated social change. A description of all available indicators used in this WP can be found in Table 3 of the Appendix. This WP uses primarily, as an Institutional Quality Indicator, the Economic Freedom World (IQ_efw) built by the Fraser Institute due to its inherent characteristics and availability. The index is an aggregate of 24 components (42 different variables) into five major areas: Size of Government, Legal System and Security of Property Rights, Sound Money, Freedom to Trade Internationally and Regulation. In spite of

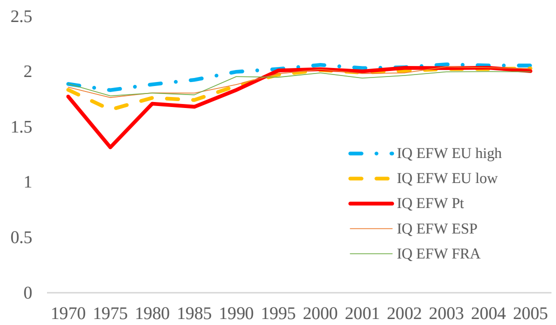


Figure 8: Institutional quality indicator based on the Economic Freedom World- Fraser Institute.

the many variables, each component and sub-component is scaled from 0 to 10 and averaged into aggregate form. This indicator is only available in intervals of 5 years during the period of 1970 to 1995, however it is available yearly in the periods afterwards. In Figure 8 there is distinctly a process of institutional catch up as is expected with economic integration, however the institutional convergence is dependent on the country's characteristics. The IQ_EFW is a hard indicator based on statistical variables to measure formal institutions.

5 Model Specification

5.1 Cross-Country Model Specifications

In order to understand how institutions affect the TFP industry-level, we use an unbalanced database of 23 countries (i=1,...,23) for 6 aggregated sectors (j=1,...,6) for the years from 1970 to 2005 (T < 35). A panel-data approach requires more attention than a cross-section study, as the standard errors of the panel estimator have to be adjusted to dependency between time periods. Wooldridge (2002) highlights that in comparison to cross-section, panel data provides more possibilities of addressing the presence of omitted variables $Cov(x, c) \neq 0$ [26].

A cross-country panel data approach opens a wide range of possibilities of different models based on the equation below:

$$\triangle ln\text{TFP}_{i,j,t} = \alpha_{j,t} + \alpha_{i,t} + \beta_1 \text{RD}_{i,j,t} + \beta_2 \text{IQ}_{i,t} + \epsilon_{i,j,t} \tag{10}$$

where R&D stock (RD) is a control for sector scale effect; $\alpha_{j,t}$ corresponds to industry-specific effects; and $\alpha_{i,t}$ is the country effect given by the time-varying institutional indicator. The institutional indicators are invariant for all sectors. Hence, the productivity growth may vary across sectors but are controlled by country institutional effects. Two different approaches can be taken into consideration resulting into different implications as shown in (11) and (12) below. Thus, the first is,

$$\triangle ln\text{TFP}_{it} = \alpha_i + \beta_1 \text{IQ}_{it} + \alpha_1 RD + \epsilon_{it}. \tag{11}$$

[26] In the cross-section we are limited to (1) appropriate proxy; (2) 2SLS method with instrumental variables for x and highly correlated with c; and finally (3) multiple indicator instrumental variables procedure.

Regression (11) considers the TFP growth rate of each sector individually. Considering the low number of countries, assumptions regarding the nature of the time series dependence are necessary as to obtain an efficient estimator. The analysis will have a panel of approximated Countries (N) x Time (T) observations. The FE models consider the individual country effects and can also control for the the time effects. The second regression is,

$$\triangle ln\text{TFP}_{jit} = \alpha_i + \beta_1 \text{IQ}_{it} + \alpha_1 RD + \epsilon_{jit} \tag{12}$$

This regression considers the TFP growth rates of all sectors controlled by sectors, following a panel with more observations for the time period. We will control for the significance of country effects, sector effects as well as time-effects; as to understand which are the most interesting. This panel will have many observations as i=1,...,29 and j=1,...,6, so we obtain 174 observations for each time period. Fixed effects and Random effects estimators will be considered to obtain adequate coefficient estimates.

Nevertheless, we can see from equation (10) that the assumption of the idiosyncratic error term $\epsilon_{i,j,t}$ being i.i.d is unlikely to hold. Additionally, the panel data model has also to be corrected for autocorrelation and heteroskedacity as it is highly likely. Besides, the model is a structural equation with a problem of reverse causality, where feedback effects are a major concern.

Arellano and Bover (1995) suggest that a system GMM estimator is highly advantageous in such cases, and is very efficient in large country/sector and short time dimensions. System GMM uses lagged regressors as instruments, thus endogenous variables are determined directly from past values ensuring that these are uncorrelated with the error term. Specifically to the system GMM estimator, a dynamic panel data model is considered, leading to the regression,

$$\triangle ln\text{TFP}_{jit} = \alpha_i + \delta \triangle ln\text{TFP}_{j,i,t-1} + \beta_1 \text{IQ}_{it} + \alpha_1 \text{RD} + \epsilon_{jit} \tag{13}$$

Bond et al. (2001) highlight the importance of using the system GMM and not the differences GMM to proceed with empirical growth estimations.

6 Results

Wooldridge (2002) discusses the advantages of a panel approach in comparison to cross-section studies to deal with endogenous components in the regressions. In this case, the panel offers attractive solutions to capture the endogenous component of institutional quality, by capturing invariant effects through time. Fixed and Random effects models give appropriate tools to hold fixed country specific idiosyncratic effects or to consider randomness among individuals - handling omitted variables. As discussed before, regressions encounter many problems derived from time-invariant country characteristics such as geography, culture and demographics that can be highly correlated with the explanatory variables. These arbitrarily distributed fixed effects remonstrate cross-section, as these ignore the effects, while in panel the variation overtime allows for identification of the parameters. This WP gathers intuition referring to different controls for fixed effects, varying from controls across individual countries, as well, as controls for effects specific to sectors or using random controls. Despite these advantages, the main problem lies on data availability through long enough panels. Unbalanced panels can originate inconsistent estimators. This WP used an unbalanced panel- however, since there is a clear selection of countries towards high-income countries with very similar characteristics; we would consider these effects mitigated. Besides, the unbalanced panel is rooted from unavailability of continuous long period institutional indicators. This WP gives a higher emphasizes to the linked chain overall score of World Economic Freedom. The index has been corrected as a linked chain through a larger time span than the other institutional indicators that were found. The indicator has as well been corrected to the fact that more components were added through time to create a more accurate institutional indicator.

Model 11 is constructed by sector, with i=1,...,22 and t=1,..,34, however, subtracting for the missing institutional data, the panel reduces to 121 observations. Anyhow, due to the unavailability of a complete database this leaves as with 22 clusters of countries and very few observations to consider the coefficients consistent. Table 4 shows the results of different fixed and random effects models. The first thing to take into consideration is the fact that the coefficients between institutions and productivity growth display a negative sign despite, being statistically significant in some of the models. As can be inferred from Hansen's test, the Random Effects model is preferred over the Fixed effects, nevertheless we are in the presence of heteroskedacity and serial correlation which questions the tests' efficiency. These results may indicate that we are in the presence of a dynamic panel bias, anyhow fixed effects in the disturbance term create endogeneity not correctable through dummies.

Altering the estimation model to equation 12 and restructuring the panel setting, to a panel with more observations as i=1,...,29 and j=1,...,6, so as to obtain 174 observations for each time period (t=1,...,34) discounting the unavailable 20 years with gaps in the institutional indicator. This constructions allows a further clustering of standard errors to sector characteristics; assuming sectors productivity has a constant variance across countries. In this case, we can opt to control for country specific fixed effects; whereas if sector effects and individual effects are correlated than the FE model makes incorrect inferences regarding the relation. Also, the RE assumes idiosyncratic effects to be uncorrelated with the predictor which allows effects to affect the error. Results for this model are basically, very similar to the results presented above.

Going back to the structural equation of productivity and institutional quality in section 4, the challenging problem to solve is the reverse causality of the institutional quality. This issue is usually solved through a fixed effects estimator corrected through two-stage least squares instrumental variable estimation. In spite of the attempts, no appropriate instrumental variables are available to differentiate between country specificity considering these very similar countries. We considered literacy, openness and other political institutional component as possibilities. On the one hand, we considered using these as time-invariant which would limit the power of the time-series approach; on the other hand, if the variables were time-varying alongside the productivity growth, there would be high correlation leading to a discussion of the weakness of the instrument. Reason why we use the Arellano and Bover (1995) system GMM estimator, which is built from stacking the data set in levels and in differences. The system GMM combines two equations: a first-differences equation with level lagged instruments and a level equation with lagged differences as instruments. The GMM assumes that past changes are uncorrelated with current errors in levels, and also uncorrelated with fixed effects. The system GMM is a dynamic panel estimator - estimating equation (13).

The system GMM estimator is quite functional for growth empirical models, (Bond et al., 2001); as we assume very similar conditions in the structural model, we expect a good fitting. The system GMM assumes mean stationary conditions for each individual, meaning that the series besides being persistent need to be stationary. The estimator allows individuals to converge to a steady state coincident to the long run fixed effects mean conditional on controls. The system

GMM allows for endogeneity, measurement errors and omitted variables, as well as, fixed effects and autocorrelation between coefficients.

We use the xtabond2 command in Stata, developed by Roodman (2006), as it has many corrections essential to the characteristics of this data-set. First-off, the estimator provides a two-step estimation of the covariance matrix, adjusting for heteroskedasticity and autocorrelation through robust and clustered standard errors. The use of instrumental variables results into a finite-sample corrected two-step covariance matrix. Secondly, it offers an option of transformation "forward orthogonal deviations", which allows for missing values, whereas the instruments (or deeper lags) are orthogonal to the error. Finally, the estimator provides distinguishable control for different effects, not only on the regressor, but also controls for the instrumental variables; the estimator allows exogenous and endogenous controls on either subset of equation. Regarding, the model fit, we considered a two-step estimation with orthogonality deviations and sector-wise standard errors clustering.

Our results using the system GMM estimator were not as brilliant as would be expected; see Tables 6 and 7. The coefficients vary from 0.017 to 0.04 considering as an exogenous Instrumental variable (IV) the years dummy, meaning that a 1% increase in the in. Undoubtedly, Table 7 illustrates the whole issue of too many controls and a small sample size problem.

The assumption of uncorrelated differences instruments and the variables used in levels with unobserved country effects, is crucial in a panel fixed effects model. Assumptions regarding the initial state or control effects play an important role to delineate the transitional path. We include all variables uncorrelated with fixed effects only in the level equation.

Nevertheless, the coefficients that are statistically significant display a positive relation with the productivity growth. In spite of inclination to use the R&D stock as to control the scale effect of each country, there seems to be a high negative correlation between the institutional quality and R&D stock variable $corr(\text{TFP\_sector}, R\&D) = -0.4680$. Whenever, one of the coefficients is positive and significant, the other is negative and insignificant. Only in one of the specifications, with no controls, and only year and sector IV, were both coefficients positive, but statistically insignificant. Nevertheless, the growth of TFP is sufficiently informative of the country effects and scale effects, to consider the model without the R&D.

Looking further into the models' outputs, we find alarming small standard errors; and weak Hansen test and Sargan-difference with p-values equal to one. Following, Roodman (2006), we identify model fitting problems that are grounded in the system GMM characteristic trade-off quest[27], i.e., include deeper lags for a better fit at the cost of inefficiency obtained from a reduced sample. Here we suspect that the model has "symptoms of instrument proliferation" which would lead to misleading apparently valid results. Roodman (2009) emphasized that these are originated from over-fitting endogenous variables and/or imprecise optimal weighting matrix. The over-fitting problem is not as relevant in this case, because as observed, in the robustness test, by collapsing the instruments into blocks, we remain with similar coefficients and smaller standard errors. With some exceptions, where the controls significantly reduce the sample, the coefficient of the collapsed estimation is very similar. We did not present the dummy coefficients, as most are dropped due to collinearity or have omitted results. As highlighted in Roodman (2009) " the bias with endogenous regressors is far worse" compared to over-fitting the endogenous variable bias. Giving a stronger power to the estimation coefficients. The second issue raised, regarding the estimates of the optimal weighting matrix, mainly bias the statistical tests, however, do not affect the parameter estimates consistency. This problem regards the distance the estimator is from the asymptotically efficient estimator due to the high number of instrumental variables. In this case, the small T periods available, after missing data count, would incline to consider that the problem faced concerns the optimal weighting matrix.

These results would seem more promising if our institutional indicator had stronger statistical power. As can be seen from the cross-correlations, Table 2, the relation is not strong. Besides, the indicators' missing gaps in the initial periods make inference weaker. The overall construction of the Institutional Quality indicator, also limits the power of this cross-country studies. It is important to question the variability of the Institutional Quality indicator, when we assume such a selected high-income group of countries. The scale of the indicator is from 0 to 10; our country sample has a minimum of 3.6 and maximum of 8.65; the mean is 7 while the variation 0.81.

However, using other available institutional indicators, has not generated more convincing results; see Table 8. In spite of statistically significant coefficients, the WGI indicator had a negative relation with productivity, while IEF has a positive but very small coefficient. As a robustness check, we also considered the five major components of the Economic Freedom Indicator independently to understand the causality between institutions 10. However, more complex estimations

[27]To avoid this problem, literature uses the first-difference GMM estimator, however, this estimators eliminates the fixed effects, which play a relevant role in this model. Additionally, the difference GMM estimator performs very badly with persistent time series and unbalanced panels eliminate even further the instrumental options.

can not be considered since, the sample size is too small to hold for more controls. As mentioned above, we also aimed to understand how each sector's productivity reacts to different institutional indicator, nevertheless, the unbalanced panel characteristics drops the sector dummies. Furthermore, different panel structures did not facilitate the process of studying sector specific productivity growth.

7 Discussion and Conclusion

Frequently the literature resorts to explaining growth differences through productivity divergence. But, as emphasized by Islam (2003), productivity growth rates and convergence are still under the microscope, and results from different growth accounting methodologies lead to very different econometric outputs. Many factors such as, e.g., scale effects, externalities, technological diffusion, culture, formal and informal institutions, or even the economic situations, contribute to the productivity growth of a country. As emphasized by Hulten (2009)'s critique, new innovations or higher technology goes beyond a shift in the production function. Methods that use microeconomic based technological assumptions to estimate the parameters eliminate scale effects and externalities ((Hall and Jones, 1999)). Extending Hulten (2009) discussion, he argues that there is a trade-off in choosing a growth accounting methodology; the productivity measure can incorporate more effects using non-parametric methods, but at the cost of accuracy.

This WP follows a non-parametric time-series approach to Growth Accounting, thereby not a very accurate approach when compared to econometric estimated approaches. Considering, that our interest lies in capturing the indirect factors that influence productivity, a less refined approach is more beneficial to the estimation process. As mentioned in the literature review, the WP follows the "New Growth Theory", where the technological progress is driven by efficiency gains originated through innovations. This raises issues when differentiating capital accumulation from technical change - The TFP growth is linked to accumulation of knowledge and innovation capability; while the source of capital accumulation is the propensity to save. Furthermore, R&D expenditures is not only a source of technical change, but also of capital formation. Here resides a feedback effect, where capital increases lead to increases in TFP as well as, increases in TFP lead to capital increases. Therefore, capital increases lead to further spillovers of TFP. This issue can explain the negative relation with the institutional quality indicator. There is clearly a very strong link between the incentives to accumulate capital and to innovate with institutional quality. These effects go beyond the scope of this WP, but we do consider that Institutional Quality is endogenous to both effects.[28]

Additionally, the growth rate of productivity eliminates the noise and appeases data volatility. Especially, since we are interested in the convergence behavior of productivity; the productivity levels would not be a stationary series, leading to explosive behaviors. By using the growth of productivity, we may further infer about technological differences across sectors and analyze different adjustment paths.

A discussion regarding the efficiency of a system GMM estimator applied to this model and database has already been provided in the Results section. To accentuate the advantages brought by the system GMM to estimate the convergence across sectors, we highlight the assumption that the estimator requires a mean stationarity condition for each individual; whereby in conjunction with persistent TFP growth is ideal to capture TFP growth rates with different initial starting points (regardless of whether it is satisfied in the model). [29] The system GMM estimator is valid as long as such a steady state is reached in the period at hand. Additional covariates establish the long run means of TFP growth conditional on the covariates. Further on, we will always consider the evidence and results of the GMM estimator.

This WP assumes that each sector has its own specific effects that will converge among countries, which are more relevant than a country effect cluster; reason why we cluster sector-wise[30]. Basically, we assume a technology diffusion across sectors implying that these should converge to the same productivity growth rate. A very criticized point raised in aggregate studies, is that Output and TFP growth, rules out sector decomposition; as by assumption they are considered as identical within productivity. This study should have shed light on the differences of TFP growth by sector, understanding which are more vulnerable to institutional change. For example, Information and Technological sector where R&D essential to innovate should be more vulnerable to financial sector institutional improvements; while the energy sector is more sensitive to the reg-

[28]Table 9 controls for the share of capital using the GMM estimator, but this has no effect on the coefficient signs. Nevertheless, a cross correlation between institutional IQ efw, TFP growth, share of labor, share of capital shows that the IQ has only has a positive high relation with the share of capital(0.4456), while the growth TFP only has a positive relation with the share of labor (0.0894). The rest are the variables are negatively related.

[29]Roodman (2009) illustrates a very interesting exercise to stress the importance of this assumption. Also, he highlights the importance of the initial conditional.

[30]Empirical application using the GMM estimator supports this assumption, as sector clusters provide more relevant regression outputs.

ulatory institutions or protective measures. This analysis would have given a higher contribution to policy implications (Del Gatto et al., 2011), whereas TFP growth differences across countries due to the sectorial composition should have policies more applied to barriers of factor mobility across sectors. Similarly, policies should consider the propensity of each sector to different aspects of the institutional framework.[31] If TFP differences are explained more on aggregate differences of TFP productivity, policies should focus on expansion and absorption of the technology. But, unfortunately, our data set was not sufficiently complete for a more comprehensive study.

To conclude, perhaps technology or innovation is not the source of the TFP differences (within or across sectors). Fabry et al. (2009) argue that the "incompatibility" between the formal and informal types of institution may be the root of wide variation in impact of institutional reforms and also responsible for the speed of institutional recombination. However, given our results, and comparing different panel structure results, we find that institutions are relevant to explain TFP growth.

In this WP, we found a statistical significant relation between institutional quality and productivity. However, due to data unavailability and unbalance panel, we were not able to make a deeper analysis regarding the productivity through sector decomposition. This model would give appropriate tools to understand very different policy implications sensitive to sector characteristics.

[31] The system GMM estimator for TFP productivity growth had a positive relation with institutional quality, when controlled by RD, however, was not statistical significant. (Table 11).

References

Abramovitz, Moses and Paul A David, ``Technological change and the rise of intangible investments: The US economy's growth-path in the twentieth century," *Employment and Growth in the Knowledge-based Economy*, 1996, pp. 35--50.

Acemoglu, Daron, Simon Johnson, and James A Robinson, ``The colonial origins of comparative development: An empirical investigation," 2000.

Aghion, Philippe and Peter Howitt, ``A model of growth through creative destruction," Technical Report, National Bureau of Economic Research 1990.

Alonso, José Antonio and Carlos Garcimartín, ``The determinants of institutional quality. More on the debate," *Journal of International Development*, 2013, *25* (2), 206--226.

Amador, João and Carlos Coimbra, ``Characteristics of the Portuguese economic growth: what has been missing?," Technical Report 2007.

Arellano, Manuel and Olympia Bover, ``Another look at the instrumental variable estimation of error-components models," *Journal of econometrics*, 1995, *68* (1), 29--51.

_ **and Stephen Bond**, ``Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *The Review of Economic Studies*, 1991, *58* (2), 277--297.

Aron, Janine, ``Growth and institutions: a review of the evidence," *The World Bank Research Observer*, 2000, *15* (1), 99--135.

Barro, Robert J and Jong-Wha Lee, ``International data on educational attainment: updates and implications," *Oxford Economic Papers*, 2001, *53* (3), 541--563.

Bertola, Giuseppe, ``Policy Coordination, Convergence, and the Rise and Crisis of Emu Imbalances," 2013.

Bond, Stephen, Anke Hoeffler, and Jonathan Temple, ``GMM estimation of empirical growth models," 2001.

Commission, European, ``The Economic and Financial Situation in Portugal in the Transition to EMU," *European Economy special reports*, 1997.

da Silva, Ester Gomes and Aurora AC Teixeira, ``In the shadow of the financial crisis: dismal structural change and productivity trends in south-western Europe over the last four decades."

Dollar, David, ``Outward-oriented developing economies really do grow more rapidly: evidence from 95 LDCs, 1976-1985," *Economic development and cultural change*, 1992, *40* (3), 523--544.

_ **and Aart Kraay**, ``Growth is Good for the Poor," *Journal of economic growth*, 2002, *7* (3), 195--225.

Durlauf, Steven N, Paul A Johnson, and Jonathan RW Temple, ``Growth econometrics," *Handbook of economic growth*, 2005, *1*, 555--677.

Fabry, Nathalie, Sylvain Zeghni et al., ``Building Institutions for growth and human development: an Economic Perspective Applied to the Transitional Countries of Europe and CIS," *Political and economic spectrum of the Soviet Union*, 2009, *24* (1), 41.

Gallup, John Luke, Jeffrey D Sachs, and Andrew D Mellinger, ``Geography and economic development,'' *International regional science review*, 1999, *22* (2), 179--232.

Gatto, Massimo Del, Adriana Di Liberto, and Carmelo Petraglia, ``Measuring productivity,'' *Journal of Economic Surveys*, 2011, *25* (5), 952--1008.

Hall, Robert E and Charles I Jones, ``Why do some countries produce so much more output per worker than others?,'' *The quarterly journal of economics*, 1999, *114* (1), 83--116.

Hulten, Charles R, ``Growth accounting,'' Technical Report, National Bureau of Economic Research 2009.

IMF, Portugal, ``Selected Issues,'' *IMF country report*, 2013, *13/19*, 103.

Islam, Nazrul, ``Productivity dynamics in a large sample of countries: a panel study,'' *Review of Income and Wealth*, 2003, *49* (2), 247--272.

Kaufmann, Daniel, Aart Kraay, and Massimo Mastruzzi, ``Governance matters VIII: aggregate and individual governance indicators, 1996-2008,'' *World bank policy research working paper*, 2009, (4978).

King, Robert G and Ross Levine, ``Finance and growth: Schumpeter might be right,'' *The quarterly journal of economics*, 1993, *108* (3), 717--737.

Knack, Stephen and Philip Keefer, ``Institutions and economic performance: cross-country tests using alternative institutional measures,'' *Economics & Politics*, 1995, *7* (3), 207--227.

Lains, Pedro, ``Catching up to the European core: Portuguese economic growth, 1910--1990,'' *Explorations in Economic History*, 2003, *40* (4), 369--386.

Maddison, Angus, ``European countries,'' *Quantitative aspects of post-war European economic growth*, 1996, *1*, 27.

Marques-Mendes, AJ and J da Silva Lopes, ``The Development of the Portuguese Economy in the Context of the EC,'' *Portugal and EC Membership Evaluated, Pinter Publishers Ltd., London, UK*, 1993, pp. 7--29.

Mileva, Elitza, ``Using Arellano-Bond dynamic panel GMM estimators in stata,'' *Economic Department, Fordhan University, July*, 2007, *9.*

North, Douglass C, *Institutions, institutional change and economic performance*, Cambridge university press, 1990.

O'Mahony, Mary and Marcel P Timmer, ``Output, input and productivity measures at the industry level: The eu klems database*,'' *The Economic Journal*, 2009, *119* (538), F374--F403.

Rodrik, Dani, ``Institutions for high-quality growth: what they are and how to acquire them,'' *Studies in Comparative International Development*, 2000, *35* (3), 3--31.

Roodman, David, ``How to do xtabond2: An introduction to difference and system GMM in Stata,'' *Center for Global Development working paper*, 2006, (103).

_ , ``A note on the theme of too many instruments*,'' *Oxford Bulletin of Economics and Statistics*, 2009, *71* (1), 135--158.

Sala-i-Martin, Xavier and Robert J Barro, *Economic growth* 1995.

Schreyer, Paul, *Measuring Productivity: Measurement of Aggregate and Industry-level Productivity Growth: OECD Manual*, Organisation for Economic Co-operation and Development, 2001.

Solow, Robert M, ``Technical change and the aggregate production function,'' *The review of Economics and Statistics*, 1957, *39* (3), 312--320.

Tavares, José, ``Institutions and economic growth in Portugal: a quantitative exploration,'' *Portuguese Economic Journal*, 2004, *3* (1), 49--79.

Timmer, Marcel, Ton van Moergastel, Edwin Stuivenwold, Gerard Ypma, Mary O'Mahony, and Mari Kangasniemi, ``EU KLEMS Growth and Productivity Accounts Version 1.0,'' *University of Groningen mimeo*, 2007.

Tornell, Aaron and Philip R Lane, ``The voracity effect,'' *American Economic Review*, 1999, pp. 22--46.

Wacziarg, Romain, ``Review of easterly's the elusive quest for growth,'' *Journal of Economic Literature*, 2002, *40* (3), 907--918.

Wooldridge, Jeffrey M, *Econometric Analysis Cross Section Panel*, MIT press, 2002.

8 Appendix I

Nominal	Variables
GO	Gross output at current basic prices (in millions EUR)
II	Intermediate inputs at current purchasers' prices (in millions EUR)
IIE	Intermediate energy inputs at current purchasers' prices (in millions EUR)
IIM	Intermediate material inputs at current purchasers' prices (in millions EUR)
IIS	Intermediate service inputs at current purchasers' prices (in millions EUR)
VA	Gross value added at current basic prices (in millions EUR)
COMP	Compensation of employees (in millions EUR)
GOS	Gross operating surplus (in millions EUR)
TXSP	Taxes minus subsidies on production (in millions EUR)
Prices	
GO_P	Gross output, price indices, 1995 = 100 I
II_P	Intermediate inputs, price indices, 1995 = 100
VA_P	Gross value added, price indices, 1995 = 100
GO_QI	Gross output, volume indices, 1995 = 100
Volumes	
II_QI	Intermediate inputs, volume indices, 1995 = 100
IIE_QI	Intermediate energy inputs, volume indices, 1995 = 100
IIM_QI	Intermediate material inputs, volume indices, 1995 = 100
IIS_QI	Intermediate service inputs, volume indices, 1995 = 100
VA_QI	Gross value added, volume indices, 1995 = 100

Table 1: KLEMS 08I Database

Variables	GO	K deep	L Prod.	I.Goods	TFP_TOT	EFW	EF	WGI
Production Growth	1.000							
Capital Deepening	0.112	1.000						
Labor Productivity	0.232	0.044	1.000					
Intermediate Goods	0.460	0.062	0.437	1.000				
TFP_TOT	0.831	-0.243	-0.149	-0.048	1.000			
World Economic Freedom	-0.513	0.128	0.178	0.121	-0.670	1.000		
Index Economic Freedom	-0.209	0.256	0.227	0.041	-0.312	0.723	1.000	
World Governance Index	-0.344	0.142	0.273	-0.137	-0.251	0.693	0.535	1.000

Table 2: Cross Correlation 1970-2005

Source	Indicators	Data range
Index Economic freedom	The Index Economic Freedom is composed by ten indicators aggregated into four categories. (1) Rule of Law (property rights, freedom from corruption);(2)Limited Government (fiscal freedom, government spending); (3) Regulatory Efficiency (business freedom, labor freedom, monetary freedom); and (4) Open Markets (trade freedom, investment freedom, financial freedom). Source: http://www.heritage.org/index/	1995-2012
World Governance Institutional Indicators	World Bank Governance Indicators were developed by \citekaufmann2009 whereas they considered six categories: (1) Voice and Accountability (VA)- accounts for political and civil rights; (2) Political stability and Absence of Violence (PV)- probability of violence or depose a goverment; (3) Control of Corruption (CC)- measures the dimension of public exerpation in prol of private gain; (4) Rule of Law (RL) - considered the enforcement of contracts and laws by courts and authorities; (5) Government Effectiveness (GE)- bureacratic measure of the goverments efficiency and service quality; (6) Regulatory Quality (RQ)- indicators that compreend the effects of market policies. Source: http://info.worldbank.org/governance/wgi/sc_country.asp	1996-2011
Fraser Institute	The Frazer Institutes provides the longest institutional Indicators, offering a correction of the older ones using a chain linked index. It scores countries from 1 (very bad) to 10 (excellent) in five categories: 1. Size of Government- extent to which goverments reduces the induals economic freedom. (goverment spending, taxes, subsidies, progressivity of taxes etc.); 2. Legal System and Property Rights- consideres rule of law, property rights and courts; 3. Access to sound money- regards monetary policy and inflationary control thus exchange rate credibility; 4.Freedom to Trade Internationally- open trade is the optimal policy to gain in economic freedom of exchange; 5. Regulation- whether market regulation prejudicial certain markets interfering through subsidies or higher taxes by creating a unbalanced market. Source: http://www.freetheworld.com/datasets_efw.html	1970-2010

Table 3: Institutional Indicators

	FE	RE	FE 1	RE 1	FE 2	RE 2	FE 3	RE 3
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
RD	0.074**	0.025	0.050	0.049	0.025	0.024	0.024	0.024
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
IQ_efw	-0.150**	-0.100**			-0.100**	-0.133*	-0.133*	-0.133*
	(0.05)	(0.04)			(0.04)	(0.06)	(0.06)	(0.06)
DIQ_efw			0.020	0.013				
			(0.06)	(0.06)				
_cons	0.332**	0.241**	0.025**	0.025**	0.241**	0.306*	0.309*	0.306*
	(0.10)	(0.08)	(0.00)	(0.00)	(0.08)	(0.12)	(0.13)	(0.12)
R-sqr	0.164			0.045		0.293		0.293
N	121	121	83	83	121	121	121	121
df	102			64		95		95
F-Stat	9.99***			1.52		4.38***		4.38***
Chi-sq		41.26***	3.409		41.26***		116.88***	
rho	0.414	0.370	0.529	0.557	0.370	0.411	0.000	0.411
Hausman			0.58		1.20			
$P\ chi2$			0.7470		0.9988			

Table 4: Comparison of Fixed Effects and Random Effect Models with different specifications: The table represents 8 models by pairs of Fixed Effects and Random Effects. The FE/RE models is a xtreg of TFP growth with R&D and institutions quality; FE1/RE1 models is same as above but instead with the growth of institutional quality; FE2/RE2 models is the same as the FE/RE models however controls for time effects; FE3/RE3 models control for both year and time effect. We have omitted the dummy variables. Hausman Chi-square test (Hausman) was to compare FE/RE models with the same specifications. Hausman Ho: coefficients estimated by FE and RE are the equal; so p-value (P>chi2) rejects the Ho if larger than 0.05. Hausman-tests that are blank are justified due to data that failed to meet the asymptotic assumptions of Hausman. legend: * p<0.05; ** p<0.01; *** p<0.001

	Output	Input	Labor	Capital	TFP	Input	TFP	Labor	TFP	TFP
	GO	II	HL	K	GTFP	II EMS	GTFPII	LD	GTFP LD	GTFP all
	Average Growth									
1971-1977	18.13%	5.38%	2.09%	-1.13%	15.12%		.	.	.	
1978-1984	21.74%	2.47%	-1.12%	5.78%	19.93%	25.87%	19.94%	.	.	
1985-1991	14.52%	5.08%	-1.37%	3.37%	11.54%	37.67%	11.55%	.	.	
1992-1998	7.04%	4.67%	-0.59%	6.29%	3.78%	30.20%	3.78%	-0.70%	3.70%	
1999-2004	4.37%	2.11%	0.85%	6.10%	2.02%	26.93%	2.01%	1.44%	1.56%	
Contribution to Gross Output growth										
1971	0.078	0.011	0.001	-0.009	0.074					
1978	-0.014	0.003	-0.006	0.010	-0.021	0.245	-0.262			
1985	0.020	0.003	-0.002	0.003	0.016	0.201	-0.181			
1993	-0.002	0.001	-0.009	0.005	0.002	0.192	0.047			
1999	0.041	0.007	0.008	0.015	0.011	-0.020	0.038	0.276	-0.256	-0.230
2004	0.023	0.004	0.003	0.006	0.009	-0.083	0.096	0.905	-0.893	-0.806
Contribution to Value Added growth										
1971	0.068		0.003	-0.017	0.082					
1978	0.052		-0.012	0.019	0.044					
1985	0.029		-0.005	0.007	0.027					
1992	-0.013		0.211	0.010	-0.018			0.592	-0.593	
1999	0.032		0.017	0.032	-0.005			0.404	-0.396	
2004	0.017		0.006	0.013	-0.003			1.914	-1.911	

Table 5: TFP Growth differences between indicators: Total Industry -- Average growth rate of volumes; Contribution of Input components; and the Total Factor of Productivity calculated using different criteria. Gross Output (GO), Aggregate intermediate input index (II), Hours worked (HL) ICT and ICT - (K), TFP with Capital decomposition (GTFP), Intermediate input decomposed into Energy, Materials and Services (II EMS), TFP with input decomposition (GTFPII), Labor Decomposition (LD), TFP with Labor decompostion (GTFPLD), TFP including all available decomposition -capital, intermediate input and labor (GTFP all). Blank spaces are unavailable data.

	GMM1 b/se	GMM1_C b/se	GMM1_R b/se	GMM2 b/se	GMM2_C b/se	GMM2_R b/se	GMM3 b/se	GMM3_C b/se	GMM3_R b/se
IQ_efw	0.018**	0.016**	0.041*	0.018**	0.018**	0.041*	0.023**	0.018**	0.041
	(0.0)	(0.0)	(0.02)	(0.00)	(0.00)	(0.02)	(0.01)	(0.00)	(0.03)
RD			-0.704			-0.704			-0.573
			(0.40)			(0.40)			(0.78)
F	5995.37***	685.28***	21383.3***	3580.97***	817.52***	12496.81***	8037.36***	147.1***	11.72***
Sargan	10.83***	33.03***	26.39***	10.83***	50.08***	26.39***	0.86***	30.41***	0.88***
N	1782	1782	1089	1782	1782	1089	1782	1782	1089
AR(2)	-0.04***	-0.01***	-1.82***	-0.04***	-0.04***	-1.82***	-0.04***	-0.04***	-1.12***
Inst	19	47	31	19	65	31	19	47	31

Table 6: GMM estimation using Year as a IV: All estimators are clustered sector-wise. GMM1 estimation using only year dummies; GMM1_C is the same model as GMM1 but with collapsed instruments; GMM1_R is the GMM1 controlled by R&D stock. GMM2 estimation using sector and year dummies; GMM2_C is the same model as GMM2 but with collapsed instruments; GMM2_R is the GMM2 controlled by R&D stock. GMM3 controls for both country and year. For all cases the L.TFP has a coefficient of zero and is not significant. Furthermore, we omit the dummy variables. Most had omitted coefficient, but in some rare cases they were significant. legend: * p<0.05; ** p<0.01; *** p<0.001

	GMM1	GMM1_C	GMM1_R	GMM2	GMM2_C	GMM2_R	GMM3	GMM4
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
IQ_efw	0.018**	0.026***	-0.000	0.022**	0.018**	0.018**	0.018***	0.046*
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.02)
RD			0.559**			0.000	0.000	
			(0.12)			(0.00)	(0.00)	
F-stat	42389.47***	3.25e+14***	6801.19***	280.33***	122.91***	135.89***	35743.13***	5685.77***
Sargan	10.83***	0.00***	26.39***	4.62***	33.00***	29.99***	29.99***	4.62***
Hansen	0.00***	77.65***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
AR(2)	-0.04***	-0.58***	-1.57***	-0.03***	-0.19***	-0.94***	-0.94***	-0.03***
N	1782	1782	1089	1782	1782	1089	1089	1782
Instrument	27	21	39	38	66	47	55	46

Table 7: GMM estimation with different combinations of controls and instruments: All estimators are clustered sector-wise. GMM1 TFP is controlled by year and sector, while the IV level is controlled for year and sector effects ; GMM1_C is the same model as GMM1 but with collapsed instruments; GMM1_R is the GMM1 controlled by R&D stock. GMM2: TFP is controlled by year and sector, while the IV level is controlled for year and country effects; GMM2_C is the same model as GMM2 but with collapsed instruments; GMM2_R is the GMM2 controlled by R&D stock. GMM3 and GMM4 controls for country and sector effects, however, IV level is controlled for sector, country and year effects. For all cases the L.TFP has a coefficient of zero and is not significant. Furthermore, we omit the dummy variables. Most had omitted coefficient, but in some rare cases they were significant. legend: * p<0.05; ** p<0.01; *** p<0.001

	GMM_efw b/se	GMM_efw_R b/se	GMM_wgi b/se	GMM_wgi_R b/se	GMM_ief b/se	GMM_ief_R b/se
L.TFP_sec	0.0	0.0	-24.28	0.0	0.0	0.00
	(0.00)	(0.00)	(40.47)	(0.00)	(0.00)	(0.00)
IQ_efw	0.018**	0.041*				
	(0.00)	(0.02)				
IQ_wgi			-3.245	-0.117***		
			(5.21)	(0.02)		
IQ_ief					0.008**	0.015***
					(0.00)	(0.00)
RD		-0.704		0.325**		0.0
		(0.40)		(0.07)		(0.00)
F-stat	5995.37***	21383.30***	37.12***	37.86***	5390.95***	1510.70***
Sargan	10.83***	26.39***	10.87***	13.26***	18.46***	15.49***
Hansen	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
AR(2)	-0.04***	-1.82***	.***	0.31***	-2.06***	-2.09***
N	1782	1089	1233	1008	1584	1233
Instru.	19	31	15	15	20	20

Table 8: The GMM estimation using different Institutional Quality Indicators: Using the System GMM with clustered standard errors by sector, twostep, orthogonal, small sample estimation controlling for time effects. The first columns use the Economic Freedom Indicator; column 3 and 4 estimates are the world governance indicator built by the World Bank; and the last columns use the indicator of Economic Freedom. legend: * p<0.05; ** p<0.01; *** p<0.001

	GMM	IQ	IQ_KL	IQ_K	IQ_R_KL
	b/se	b/se	b/se	b/se	b/se
IQ_efw	0.018**	0.041*	0.020***	0.041*	0.046*
	(0.00)	(0.02)	(0.00)	(0.01)	(0.02)
RD		-0.704		-0.704	-0.858
		(0.40)		(0.38)	(0.49)
F-stat	5995.37***	21383.30***	1888.72***	41280.05***	22142.85***
Sargan	10.83***	26.39***	53.66***	38.24***	53.81***
Hansen	0.00***	0.00***	0.00***	0.00***	0.00***
AR(2)	-0.04***	-1.82***	-0.04***	-1.87***	-1.99***
N	1782	1089	1782	1089	1089
instru.	19	31	61	46	61

Table 9: The GMM estimation controlling for capital share or/and labor share: Using the System GMM with clustered standard errors by sector, two-step, orthogonal, small sample estimation controlling for time effects. We control for either capital share, R&D stock and/or Labor share. In this case, the coefficients of the shares of capital and labor are equal to zero. For all cases the L.TFP has a coefficient of zero and is not significant. Furthermore, we omit the dummy variables. Most had omitted coefficient, but in some rare cases they were significant. legend: * p<0.05; ** p<0.01; *** p<0.001

	GMM1	GMM2	GMM3	GMM4	GMM4_R	GMM5	GMM6
	b	b	b	b	b	b	b
L.TFP_sector	0.00	0.00	0.00	-0.44	0.00	0.00	0.00
RD			0.00		0.00	0.00	0.00
govsize_efw	0.00	0.00					
law_efw	0.02*	0.02*					0.00
money_efw			0.02**	0.55*	-0.21**	0.01**	0.13**
trade_efw			0.00				
creditmkt_efw			0.00				
labor_efw				0.65*	0.18*	0.00	0.13*
business_efw				0.00	0.10	0.00	0.00
AR(2)	-0.04***	-0.04***	-0.94***	-1.67***	-1.19***	-0.94***	-1.35***
N	1773	1773	1089	1170	999	999	999
Instrument	38	38	47	15	28	44	11

Table 10: GMM estimation for different components of the EFW indicator: All estimators are clustered sector-wise. For GMM1 and GMM2 controlling for R&D stocks give similar results. For all cases the L.TFP has a coefficient of zero and is not significant. Furthermore, we omit the dummy variables, they show no coefficient. legend: * p<0.05; ** p<0.01; *** p<0.001

	GMM_TOT	GMM_AtB	GMM_C	GMM_E	GMM_F	GMM_G	GMM_H	GMM_I	GMM_JtK
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
IQ_efw	0.011	0.039	-12.170	0.058	-0.545	-2.600	-0.014	0.009	-0.399
	(0.02)	(0.29)	(6.79)	(0.05)	.	(5.11)	(0.03)	(0.01)	(0.87)
RD	-0.098								
	(0.65)								
RD_AtB		0.058							
		(0.05)							
RD_C			0.262*						
			(0.11)						
RD_E				-0.045					
				(0.04)					
RD_F					0.052				
					.				
RD_G						-0.008			
						(0.08)			
RD_H							0.161		
							(0.18)		
RD_I								-0.005	
								(0.02)	
RD_JtK									-0.065
									(0.10)
F-stat	391470.18***	25048.01***	0.73	1964.36***	0.00	0.17	8.63*	0.90	10.51***
Sargan	21.35***	53.01***	24.52	29.03***	13.92	27.06	16.00*	10.64	36.51***
Hansen	0.00***	0.00***	0.30	0.00***	0.08	1.59	0.00*	3.36	0.00***
AR(2)	-0.98***	-1.50***	-0.90	-1.45***	-0.76	1.12	-4.62*	-1.83	0.45***
N	121	94	100	108	106	93	22	107	91
instru.	47	44	46	46	46	43	23	47	44

Table 11: GMM estimation for different sector TFP growth: All estimators are clustered country-wise. The TFP for each of the sectors controlled for year and country effects. For all cases the L.TFP has a coefficient of zero and is not significant. Furthermore, we omit the dummy variables. Most had omitted coefficient, but in some rare cases they were significant. legend: * p<0.05; ** p<0.01; *** p<0.001

8.1 Data Description

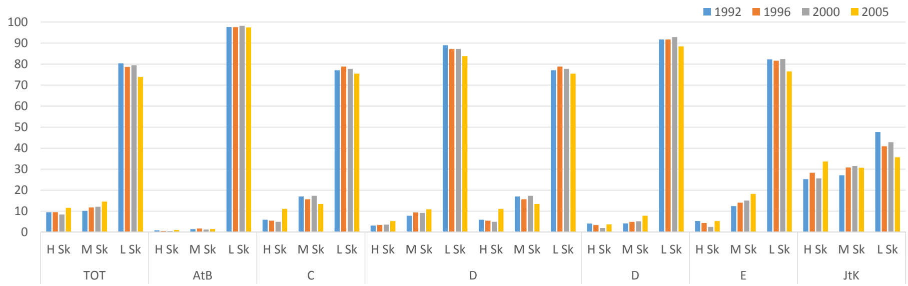


Figure 9: Evolution of labor skill hours in each sector.

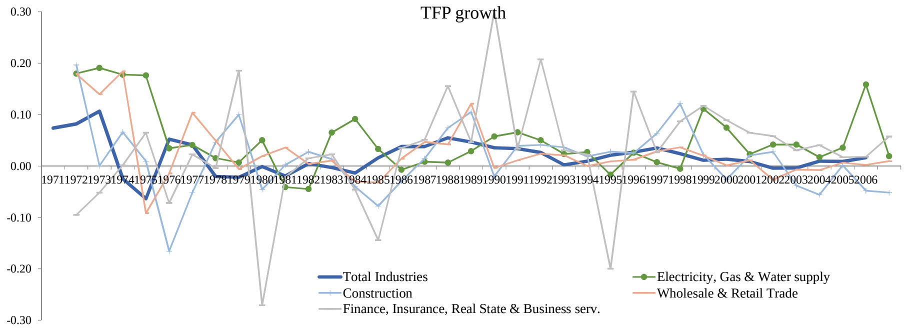


Figure 10: Total Factor Productivity growth rates using only aggregated indexes sector-wise

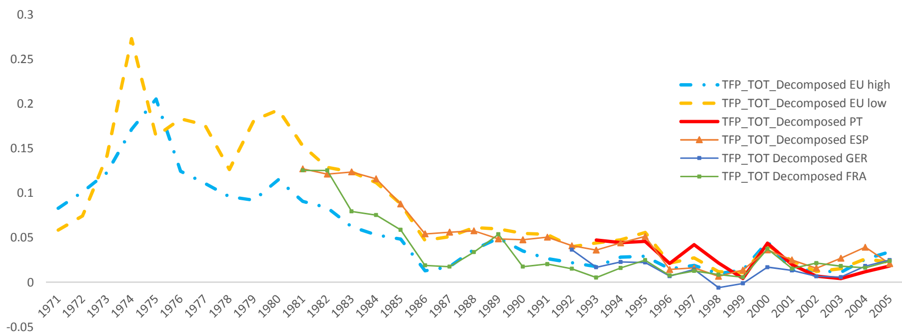


Figure 11: Total Factor Productivity growth decomposed TFP growth in comparison with EU 15

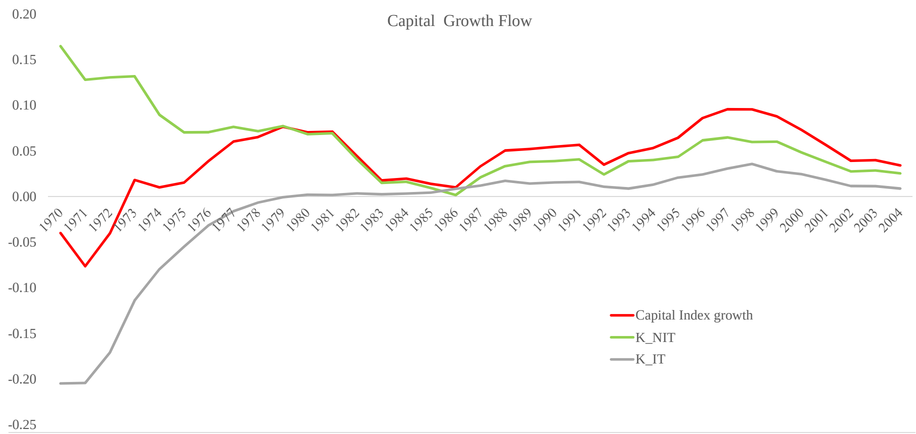


Figure 12: Growth rate of Capital flows

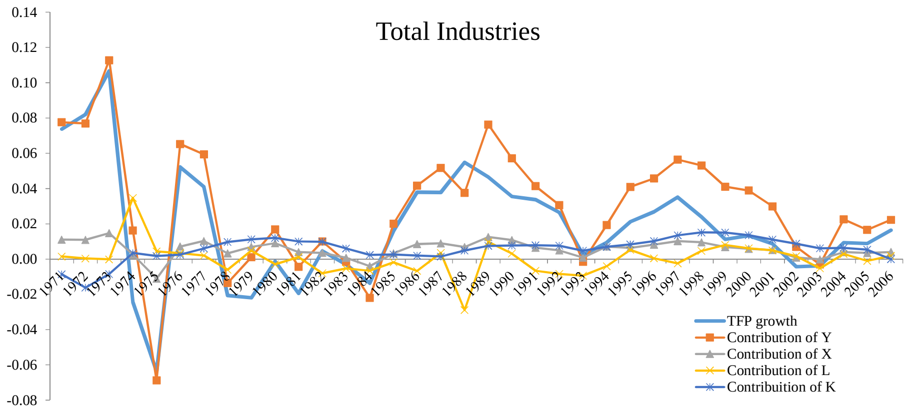


Figure 13: Contribution of the different components to the TFP growth

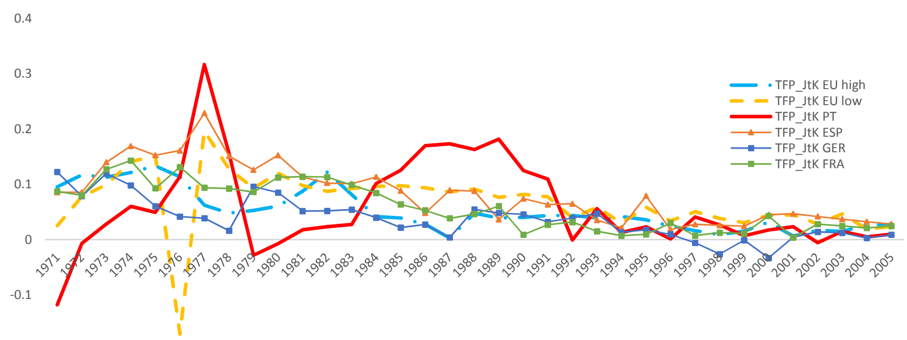


Figure 14: Total Factor Productivity growth aggregated TFP growth sector JtK

9 Appendix II

9.1 Methodology: link Growth Accounting and Data

Applying the available data to the model is always a complicated part of the growth accounting process. The GGDC's KLEMS database for Portugal is very incomplete compared to other countries, despite still being the most advantageous, complete and homogeneous database to use for this exercise. Recalling the equation from above, under assumptions of CRS, profit maximizing behavior, competitive markets where factors are valued by their marginal product, we have:

9.1.1 Relation between Value Added and Output

Following the Timmer et al. (2007) methodology, we will measure the TFP Growth using both output and value add share. Econonomists still haven't reached a consensus regarding which of the methods is a better indicator of sectoral productivity.

$$\triangle lnY_{jt} = \alpha_X \triangle lnX_{jt} + \alpha_K \triangle lnK_{jt} + \alpha_L \triangle lnL_{jt} + \triangle lnTFP^Y_{jt} \iff \tag{14}$$

$$\triangle lnTFP^Y_{jt} = \triangle lnY_{jt} - \alpha_X \triangle lnX_{jt} - \alpha_K \triangle lnK_{jt} - \alpha_L \triangle lnL_{jt} \tag{15}$$

The TFP based on output doesn't consider intra industry production. While the value added focus on the value added each industry adds total production- a higher level of aggregation. Below you can find the relation between output and vale added measures:

$$\triangle Y_{jt} = (1 - \bar{v}^V_{jt})\triangle X_{jt} + \bar{v}^V_{jt} \triangle lnV_{jt} \iff \triangle lnV_{jt} = \frac{1}{\bar{v}^V_{jt}}(\triangle Y_{jt} - \big(1 - \bar{v}^V_{jt} \triangle X_{jt}\big) \tag{16}$$

$$\triangle lnV_{jt} = \bar{\alpha^K_{jt}} \triangle lnK_{jt} + \bar{\alpha^L_{jt}} \triangle lnL_{jt} + \triangle lnA^V_{jt} \tag{17}$$

Hence, the relation between the TFP growth measured through both methods is:

$$\triangle lnA_j t^V = \frac{1}{\bar{C}^V_{jt}} \triangle A^Y_{jt} \tag{18}$$

9.1.2 Labor

Labor has a component of Labor Services, which calculates the contribution of labor education on the productivity. Here, we have considered the TPF using two processes:

(a) Labor is not differentiated considering skills (series with longer periods).

$$\triangle lnL_t = \bar{\alpha}_j \triangle lnH_j \tag{19}$$

(b) Productivity considering the labor composition effect where different types of skilled labor: low, medium and high skilled labor will have different degrees of productivity.

The labor composition effect is the difference existent due to skill types where the same hour worked will have different productivity levels. Labor is differentiated according to the employees' skills and hours worked; and weighted using the compensation of each skill type. Whereas, i is the index of individual types, t is each year and j for each sector activity.

The flow of labor services is composed by the proportional of hours worked by labor type weighted by the value of labor compensation for each skill. $\bar{\alpha}_{i,j} = \frac{1}{2}[\alpha_{i,t} + \alpha_{i,t-1}]$ thus $\alpha_{i,t} = (\sum_l p_i t^L H_{it})^{-1} p_i t^L H_{it}$ is in practical implementation equal to the share of labor compensation.

9.1.3 Capital

In this case, the calculations follows the KLEMS methodology.

$$\triangle lnK_t = \sum_k \bar{\alpha_{k,t}} \triangle A_{k,t} \tag{20}$$

$\delta_{kt} = \frac{A^k_{t-1} + I^k_t - A^k_t}{A^k_{t-1}}$ where, each industry j and applied to three asset subgroups: nonresidential structures, non-ICT equipment and transport equipment. Hereby, a different depreciation rate is consider per sector. This series is in generally, the most challenging to treat and actually reflect to be a good proxy for capital formation.

10 Time-Series Analysis

Dependent on the organization of the panel data and the different regressions considered, the panel data may present time dependence problems of spurious correlations. In this case, we apply a panel unit-root test for unbalanced panels Fisher-type tests for augmented Dickey-Fuller (1979) and Phillips-Perron (1988). The unit root tests have given evidence that the TFP growth and R&D are stationary variables, the null of all panels contain unit roots was always rejected. In terms of the Institutional Quality it doesn't make sense to test for the unit root considering that it is a qualitative variable scaled 1 to 10. As demonstrated in the figure 8 the variable is stationary.[32]

[32]The unit test failed due to the gaps between years. As the test gave more relevance to the zero values recorded.