Productivity Convergence between Greece and Germany, What is the Role for Trade and R&D[i]

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Abstract

The principal aim of the policies formulated within the EU is to promote economic integration among state members. European integration implies that states comprise of the periphery of EU follow a catch up process towards more technologically advanced countries. The present study investigates the sources of Total Factor Productivity (TFP) in Greek Manufacturing sector under a convergence framework considering the German Manufacturing sector as the technological leader. In such a framework, standard determinants of TFP growth are autonomous technological transfer, R&D, trade and human capital. The study provides new insights adding two variables that represent the level of rigidity in the labour market and the degree of concentration in the product market. A wide set of robustness checks in the econometric analysis confirm that Greek industries in the period under study experience substantial convergence identifying the important role of technological transfer as a source of TFP growth. Results also highlight the importance of trade-based and human-based technology transfer and the negative impact of labour market rigidities on TFP growth.

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4.1. Introduction

In the field of development economics a large amount of studies have attempted to understand the sources of economic growth. Solow's influential study (1957)[1] for instance, which develops the concept of the residual in an aggregate production function, is a case in point. Solow's approach exemplifies that the real sources of technical change are disembodied from inputs of production, implying that technological progress is not included in the flows of labour and capital. Accordingly, in Solow's terminology, the real sources of technical change are exogenous.

In a standard production function $Q_t = A_t F(K_t, L_t)$, any shift in the Hicks- neutral technical parameter is "costless" highlighting the feature of a disembodied technical change. This is why parameter *A* is referred to as the "Manna of Heaven". In a more realistic setting, the above formulation gives the opportunity to estimate econometrically the contribution of the other factors to shift technology over time. Hulten (2000) provides a short biography of the formulation and many standard issues involved in modeling the productivity parameter *A* derived from the Solow benchmark model.

The "new" growth theory also known as the endogenous growth theory provides us with some new insights in our effort to understanding the sources of economic growth. As implied from its name, this theory relies on the assumption that the determinants of growth are endogenous considering that technological advancements are embodied in the inputs of production. One of the differences between the neoclassical and the endogenous growth theories refers to a different assumption about the behaviour of the capital input. In the neoclassical setting, capital is subject to diminishing returns and along with the assumption of identical technology and preferences across countries then poor countries tend to grow faster relative to rich ones. Baumol (1986) fails to find evidence of convergence between poor and rich countries attributing this failure to the mis-specified assumption about the behavior of capital as suggested by the neoclassical growth theory. Romer (1986, 1990), one of the most important contributors of the endogenous growth theory, neglects the assumption of diminishing returns to capital specifying a linear relationship between investment and output.

The endogenous growth theory gives particular emphasis to investment associating it with a bigger variety of capital goods. A key feature of the endogenous growth model is the role of knowledge accumulation as a source of economic growth. In an endogenous growth model, the technical change – the parameter *A* in the Solow production function- is not a measure of our ignorance; instead, it is embodied in the factors of production and it is subject to an interplay between the structure of the economic system and the production process.

Neoclassical and endogenous growth theories are not contradictory with each other. Both demonstrate convincingly the importance of studying technology (Sharpe (2002)) but endogenous growth theory provides a more insightful and systematic analysis of the sources that influence technological progress. Along with the accumulation of capital (both physical and human), some new concepts have been added in the agenda of economic growth, with the most prominent those of trade and innovation. Greater trade openness leads to competition that encourages the adoption of new technologies resulting greater productivity. Trade can also serve as a transmitter of new ideas and information that can be reflected in higher rates of productivity growth. Furthermore, innovative activity can generate new inventions and processes contributing to a more efficient use of the existing resources and hence to higher productivity. These theoretical arguments are not always supported by the empirical evidence stimulating further research in the field of economic growth (Romer and Frankel (1999)). A main focus of this research agenda is to identify the mechanisms through which trade and innovative activities can meaningfully affect the rates of productivity growth.

The main aim of the present chapter is to investigate the sources of productivity growth in Greek manufacturing industries. To do so, the analysis uses as a departure point some key propositions of the endogenous growth theory. However, the novelty of the present chapter is that it analyses the sources of total factor productivity (henceforth TFP) growth using a framework of convergence[2] between a non-frontier country, which is Greece, and a frontier country, which is Germany. The aim of using this methodology is to assess the importance of technology transfer as a source of productivity growth for a country, which does not always act as a technology leader.

The potential of convergence as a source of productivity growth is initially developed by Bernard and Jones (1996a, 1996b) specifying a model that carries some similar characteristics with the traditional convergence literature. Redding et al. (2005) adopt this model to explain the sources of TFP growth in UK manufacturing considering as a frontier country US. Other important contributions to the empirical validity of this productivity convergence model made by Griffith et al. (2004) for a group of OECD countries, Cameron (2005) for Japan and US and Khan (2006) for France and US. The main feature of these studies is that the frontier country is mainly US while the non-frontier countries are developed countries that their productivity falls behind only compared to US. There is no empirical evidence in the productivity convergence literature from an application of this

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[2] Technology transfer at the industry level is measured by a relative index of TFP between Greece and Germany. The present concept of convergence is not identical to the classical idea of β and σ convergence as used in the cross-country growth literature (Barro and Sala-i-Martin (1995)). The difference is that β convergence, for example, is concerned with the relationship between a country's growth rate and its initial per capita income, while in the present study convergence refers to industry's TFP growth and its initial distance from the frontier. Redding et.al (2005) provide a detailed discussion regarding the similarities of the present concept of convergence with the classical ideas of σ and β convergence.

model in less developed non-frontier countries such as Greece. The pair of countries considered in the present study differs considerably from the pair of countries used in the existing literature. Germany is a developed and productivity-leader European country while Greece is a country belongs to the peripheral spectrum of the European Union.

Despite the small number of studies that analyse TFP convergence, the latter issue is of special interest from a policy-making point of view, especially for the ongoing process of European economic integration. A number of structural changes have taken place in the European Union within the last fifteen years, such as the removal of trade barriers, the use of a common currency, and the establishment of a common economic policy for a number of issues[3]. The main objective of the above set of policies is to accelerate economic integration across European member states. A coherent and integrated Europe without commercial constraints minimizes transaction costs, risks and uncertainties providing a great opportunity to less developed countries to converge in a more rapid pace towards the economic level of more developed EU countries.

The present study has three main goals. Firstly, it seeks to enrich the literature of TFP convergence using a lengthy panel from 1980-2003 quantifying the speed of convergence for a traditionally non-frontier economy like Greece. Secondly, it provides evidence for the impact of factors indicated by the endogenous growth theory (i.e. such as R&D investment, trade and human capital) on TFP growth of Greek manufacturing industries. Thirdly, the present study introduces some variables, as potential sources of productivity growth that have attracted little attention in the productivity convergence literature. These variables are labour market rigidities and product market concentration that mainly reflect the condition of the domestic market and its impact on productivity growth.

[3] This set of changes includes the harmonization of the fiscal policy rules and the existence of a common monetary authority.

The chapter is organized as follows: section 4.2 discusses in more detail the sources of productivity growth and provides a brief review of the important contributions made in the lengthy literature of productivity growth. Section 4.3 presents the analytical framework of the convergence scenario and discusses the measurement of TFP. Section 4.4 presents the econometric specification of the analysis and the main results. Section 4.5 provides a sensitivity analysis checking for the robustness of the principal findings and section 4.6 provides a conclusion of the main points discussed in the core analysis.

4.2 Sources of Productivity Growth: Review of the Theoretical Literature and the Empirical Evidence

A body of empirical work has examined the relationship between R&D-the principal source of innovation- and productivity growth. Studies that confirm a positive effect of R&D investment on productivity growth include Griliches (1980) and Griliches and Lichtenberg (1984) among many others. These studies use evidence either from a firm or from a country level data to highlight the fact that domestic investment can act as a conduit for productivity improvements and cost reductions.[4] Helpman and Grossman (1991) and Helpman and Coe (1995) address the issue whether R&D investment initially conducted abroad can serve as a source of productivity growth in other countries. Evidence provided by the above papers verifies that gains from R&D are multifaceted. A country can gain from its own R&D effort but can also exploit positive spillovers by imitating R&D

[4] Linking this argument with stylized facts at the industry level, Spence (1984) assumes that a firm's R&D investment provides positive spillovers in the performance of rival firms within the industry, leading to an increase in industry's overall performance. Simultaneously, spillovers generate free-rider problems affecting negatively the decision of a firm to invest in R&D. This feature of diminishing returns of R&D is more systematically explored in the sensitivity analysis of the empirical section later in this chapter.

outcomes of other countries. The debatable issue in the literature regarding the influence of R&D on productivity growth refers to the accurate mechanism through which gains from R&D initially conducted abroad are transmitted across countries.

One of the most prominent scenarios is that foreign R&D is diffused to other countries via trade. When a trade partner devotes substantial resources in R&D activities then the importing country can have multiple benefits from trade. The first set of gains stresses the importance of static gains derived from specialisation and the improvements in the economic welfare of the importing country. The second set comprises of dynamic gains derived from imitation of new technology, which is incorporated in the imported commodities. For the dynamic effect to occur, trade should take place in raw intermediate inputs rather than in final goods. The above effects are summarised to the learning-by-importing hypothesis.

Exports can also generate some important positive spillovers. The static benefit of exporting is the exploitation of economies of scale due to market expansion. In a more dynamic perspective, exporting offers domestic producers the opportunity to have contacts with international best practices (i.e. this effect is known in the corresponding literature as the learning-by-exporting effect). The set of dynamic gains carries many similar characteristics with gains acquired from pure exercises of learning- by- doing.

As far as the empirical evidence of the above hypotheses is concerned, Keller (1998) provides robust evidence for the learning-by-importing hypothesis. Additionally, evidence from Keller (2000) reveals that the composition of the imported commodities also matters for productivity growth. The evidence of this study indicates that imports facilitate the outcomes of R&D activity undertaken in the foreign country, which are also beneficial for the domestic market of the receiving country. The empirical evidence of the learning-by-exporting hypothesis is vague. Clerides et al. (1998) and, Bernard and Jensen (1999) reveal that higher export involvement does not increase firm's productivity. A similar result is found in Xu (1996) with the use of country level data[5]. A possible reason for the lack of evidence concerning the learning-by-exporting hypothesis could be the causal nature of the two variables. The current research agenda addresses the question whether exporting improves productivity; while, the true causality might run from productivity to exporting and not vice versa. Empirical support for the hypothesis that productivity leads to exporting is found in Clerides et al. (1998) and Bernard and Jensen (1999), who view it as an evidence in favour of the self-selection hypothesis. Accordingly, good firms (in terms of productivity) are those that become exporters.[6]

In the discussion so far, special emphasis has been given to the role of trade as a technology transmitter of foreign innovation (i.e. innovation that is initially developed abroad). But, the scenario regarding the contribution of R&D to productivity growth is incomplete if one ignores the multifaceted role of domestic innovation. The standard impact of domestic R&D is to accelerate the growth of productivity but, even if this direct effect is weak, domestic innovation is essential since it guarantees that the economy has the minimum level of technical expertise and technological "know-how" to absorb technological advancements from abroad. Cohen and Levinthal (1989) suggest that R&D enhances the firm's ability to assimilate and exploit existing information. Acemoglu and

[5] Evidence for the learning-by-exporting hypothesis at the industry level is rather limited. Some recent studies that they have analysed the issues using industry data are Anderson (2001) and Fu (2004). Findings appear to be rather contradictory; the former study finds positive exporting effects of productivity growth for Swedish manufacturing industries while the latter finds no evidence for Chinese industries.

[6] Certainly, there are studies in which the results indicate that the causality runs from exporting to productivity (see Kraay (1999) and Castellani (2002)). To estimate the real direction of the exporting-productivity causation is a complex econometric issue, which requires panel data sets with very long time spans. The fulfillment of this requirement is very crucial if one seeks to obtain a clear view for whether exporting Granger-causes productivity improvements or vice versa. The fact that many studies do not accomplish this characteristic explains somehow why there is divergence in the existing empirical findings. Apart from the pure econometric technicalities, the lack of evidence for the learning-by-exporting hypothesis is attributed to the different nature of the case studies used in the analysis. For instance, in a highly industrialised country, which is very close to the international frontier there is little scope for knowledge spillovers, while in less developed countries, (which are distant from the frontier) the margin for substantial knowledge spillovers is bigger.

Zillibotti (2001) stress a similar role of complementarity between technological transfer and human capital on stimulating productivity growth. Griffith et al. (2004) systematically address the multi-faceted role of domestic R&D is in a panel of OECD countries showing that domestic R&D improves substantially the absorptive capacity of the domestic economy.

The literature regards that the above stylized facts are some of the key sources of TFP growth. Certainly, the sources of productivity growth are not limited only to the variables of innovation and trade. The present study extends the analysis to include some factors that reflect structural conditions of the domestic market, namely labour market rigidities and concentration within industries. Obviously, it is not claimed that the impact of these variable on TFP growth has not been stressed in other studies, but the present study addresses the impact of these variables within a framework of productivity convergence.

A flexible labour market allows resources to move easily and costless within the economy thus promoting efficient allocation of resources, which might be a crucial engine for positive productivity shifts. In the literature, there are various measures regarding the regulation of labour markets. Scarpetta et al. (2000) provide a summary of indices used to measure regulation in the product and labour markets. These measures are particularly useful in a cross-country context since they reflect differences across countries, while in the present study any change in the labour market regulation is likely to affect all industries in the same direction. The present study uses the ratio of minimum to median wage to capture the effect of high labour costs. This variable represents conditions of the institutional environment that are of particular importance for productivity. For instance, an over-protective labour legislation concerning workers reduces the annual speed of adjustment to productivity shocks (OECD (2005)). A relatively stringent labour market with high costs of recruitment and dismissal prevents firms from organizing their resources optimally.

Greece, typically considered to have heavily regulated markets in which trade unions have strong bargaining power in negotiating the collective wage agreements both at the national and at the sectoral level. The ratio of minimum to median wage can partially reflect the impact of labour market conditions on productivity. To the extent, that high minimum labour costs indicate labour payments above the equilibrium level then financial resources for R&D and similar innovative activities are radically reduced (Scarpetta and Tressel (2004))[7].

Another domestic factor that affects the growth of productivity is the degree of competition in the domestic market. A fundamental argument in economics is that perfect competition is the ideal type of market structure because it ensures an efficient allocation of resources and maximises the surplus of both consumers and producers. This argument is widely highlighted to support the positive link between competition and productivity performance. Furthermore, Vickers (1995) points out that innovation is generally promoted more effectively in competitive markets since a share of the efficiency gains are devoted to innovative activity. Nonetheless, the productivity-competition relationship should be treated with special care since its empirical confirmation is not always clear due to the endogeneity nature of the two variables. Nickell (1996) argues that if a firm is initially productive then it gains a larger share of the market in the long-run. However, the evidence from his study suggests that market power generates a reduced level of productivity and, more importantly, that an increased degree of competition is associated with higher rates of TFP growth. Tsekouras and Daskalopoulou (2006) provide evidence for Greek

[7] The fact that the current proxy does not reflect accurately all the effects of labour market rigidities on growth, it should be kept in mind when one interprets the results presented in the following sections.

manufacturing industries, which does not confirm Nickell's findings. Precisely, Tsekouras and Daskalopoulou's study proves that higher degree of concentration in the market does not necessarily lead to more slack, confirming Caves's (1987) argument that efficiency in the market is independent from the degree of concentration. Which of the above arguments is consistent with the current data set is an issue examined in the empirical section together with a more detailed description of the variable used to measure market concentration.

4.3 Analytical Framework

This section presents the theoretical framework from which an econometric specification is derived. The present framework replicates the main settings of prior models in the productivity convergence literature (Bernard and Jones (1996a, 1996b) and Redding et al.(2005)). Consider a world with only two countries $j \in \{G, F\}$, producing an output in industry i at time t. Production is characterised by constant returns to scale and takes the form of a Cobb-Douglas production function:

$$Y_{j,i,t} = A_{j,i,t} f(K_{j,i,t} L_{j,i,t}) \quad (4.1)$$

Y measures value added and the inputs include capital stock K, labour L. Parameter A represents a measure of technical efficiency as in Solow's study, and differs across countries and industries. In the empirical analysis, the efficiency parameter is approximated by an index of Total Factor Productivity (TFP). The above production function is homogenous of degree one and exhibits diminishing marginal returns to the production inputs.

For the purposes of the present analysis, at a given point in time *t*, one of the countries *j* will have a higher level of TFP and thus this country is specified as the "technological frontier" economy (Redding et al.(2005)) indexed by *F*, in the present empirical model this country is Germany and the follower economy is Greece denoted by *j*. The sensitivity analysis of the chapter proves that choosing a different definition of the frontier economy does not change the picture of the empirical results.

In Bernard and Jones (1996a, 1996b), $A_{j,i,t}$ is primarily modeled as a function of either domestic innovation or technology transfer from the frontier country. Therefore, a general formulation of the efficiency parameter *A* or equivalently the total factor productivity growth (TFP) in industry *i* of country *j* is:

$$\Delta \ln A_{i,j,t} = \gamma_{i,j,t} + \lambda_{i,j} \ln\left(\frac{A_{i,F,t-1}}{A_{i,j,t-1}}\right) \tag{4.2}$$

In equation (4.2) parameter γ represents the rate of innovation, which depends on industry-specific factors while parameter λ denotes the change in TFP with respect to technology transfer from the frontier. As it stands, the ratio in the right-hand side - $\left(\frac{A_{i,F,t-1}}{A_{i,j,t-1}}\right)$ -indicates that the higher is the gap in industry *i* from the frontier economy the greater is the potential for productivity growth through technological transfer. For the frontier economy, productivity growth depends only on domestic innovation and thus the second term in the right-hand side of equation (4.2) is zero for the frontier economy

$$\Delta A_{i,F,t} = \gamma_{i,F,t} \tag{4.3}$$

Subtracting equation (4.3) from (4.2) yields the following relationship:

$$\Delta \ln\left(\frac{A_{i,j,t}}{A_{i,F,t}}\right) = (\gamma_{i,j} - \gamma_{i,F}) - \lambda_{i,j} \ln\left(\frac{A_{i,j,t-1}}{A_{i,F,t-1}}\right) \tag{4.4}$$

Equation (4.4) can be viewed as an equilibrium correction model (ECM) with a long-run steady state relative TFP. Assuming that in the long-run, $\Delta \ln\left(\frac{A_{i,j,t}}{A_{i,F,t}}\right) = 0$, the steady state equilibrium is given by:

$$\Delta \ln\left(\frac{\bar{A}_{i,j}}{\bar{A}_{i,F}}\right) = \frac{\gamma_{i,j} - \gamma_{i,F}}{\lambda_{i,j}} \tag{4.5}$$

Equation (4.5) states that in the steady state equilibrium, relative TFP depends on the rates of innovation in the non-frontier economy *j*, in the frontier economy *F* and on the speed of technological convergence λ occurs between the two economies.

Another inference that can be made from equation (4.5) is that country *j* remains technologically behind in steady state equilibrium, that is, $\ln\left(\frac{\bar{A}_{i,j}}{\bar{A}_{i,F}}\right) < 0$ when $\gamma_{i,j} < \gamma_{i,F}$. In other words, these inequalities describe that in the steady state equilibrium technological frontier country *F* remains as such as long as the rate of innovation in that country is higher than the rate of innovation in country *j*. Finally, according to the propositions of the endogenous growth theory, the other factors affecting $\gamma_{i,j,t}$ and $\lambda_{i,j,t}$ in (4.2) are R&D, trade, human capital, rigidities in labour market and domestic market concentration. Appendix C4.1 provides a discussion about the data sources while Appendix C4.2 shows summary statistics of the variables used in the econometric analysis. The next section is devoted to define the measure of productivity, which is the key variable of the chapter.

4.4 Measuring Total Factor Productivity

As mentioned before, the measure of productivity used in the present study is total factor productivity (TFP). The calculation of this index is based on Divisia number initially developed by Caves et al. (1982). The TFP index can be directly derived by a flexible translog production function and it is superlative since it is a close approximation of an arbitrary, twice differentiable production function with constant returns to scale. From the Divisia approach, the TFP growth in industry *i* is defined as:

$$\ln\left(\frac{A_{i,j,t}}{A_{i,j,t-1}}\right) = \ln\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right) - a_L \ln\left(\frac{L_{i,j,t}}{L_{i,j,t-1}}\right) - (1-a_L)\ln\left(\frac{K_{i,j,t}}{K_{i,j,t-1}}\right) \tag{4.6}$$

The notation remains the same as in the previous section, where *j* and *t* refers to country and time, respectively. Output *Y* is measured by value added, *L* is a measure of labour input and *K* denotes capital stock constructed by accumulating investment flows in capital assets. The input measures in equation (4.6) are weighted by their shares in value added under the assumption of constant returns to scale. The labour share is defined as: $a_L = \frac{a_{i,j,t} + a_{i,j,t-1}}{2}$.

The main data provider for the calculation of TFP is OECD-STAN.

A crucial issue in comparing industry's TFP across countries is to express output and inputs in a common currency. O' Mahoney (1996) presents that relative TFP levels differ substantially according to the conversion method used. A common methodology is to use an aggregate Purchasing Power Parity (PPP) exchange rate based on prices of final expenditure. However, this aggregate method of conversion does not reflect differences in retail prices across industries as well as it does not provide information for the distribution of output across industries (van Aark and Trimmer (2001)). An industry specific conversion factor seems more suitable to the present exercise but the only database (i.e. GGDC-International comparison of productivity program (ICOP) with industry conversion factors reports data only for 1997. Consequently, the standard aggregate method is followed applying the GDP-PPP conversion factor that expresses national currency per international USD. The latter data are obtained from World Bank indicators under the International Comparison Project (ICP). After converting data to a common currency, sector-specific deflators are utilised to correct for price changes. OECD-STAN provides specific deflator indices for value added and investment in capital assets[8]. Therefore, the output and input values appeared in (4.6) are expressed in constant prices of 1995.

[8] Data for gross fixed capital formation, capital deflator, number of employees and value added deflator for years prior to 1995 are taken from KLEMS database; an appendix provides a detailed summary of data sources.

As stated in equations (4.2) and (4.4) of the previous section, apart from industry *i*'s TFP growth, another index is necessary to represent industry *i*'s TFP in Greece relative to industry *i*'s in Germany. The relative index of TFP level is defined as:

$$\ln\left(\frac{A_{i,j,t-1}}{A_{i,F,t-1}}\right) = \ln\left(\frac{Y_{i,j,t-1}}{Y_{i,F,t-1}}\right) - a_L \ln\left(\frac{L_{i,j,t-1}}{L_{i,F,t-1}}\right) - (1-a_L)\ln\left(\frac{K_{i,j,t-1}}{K_{i,F,t-1}}\right) \qquad (4.7)$$

where *j* and *F* are Greece and Germany, respectively and the labour share is now defined as: $a_L = \frac{a_{i,j,t-1} + a_{i,F,t-1}}{2}$.

The construction of capital stock is based on a perpetual inventory formula given by the following equation: $K_{i,j,t} = (1-\delta)K_{i,j,t-1} + I_{i,j,t-1}$, where the Greek letter δ denotes the capital depreciation rate, defined at the 10% for all industries and *I* stands for the investment in gross fixed capital assets. The initial capital stock is computed from the following formula: $K_{i,j,1980} = \frac{I_{i,j,1980}}{g_i + \delta}$, where *g* is the average growth rate of industry *i*'s investment over the whole period and year 1980 denotes the first year with available data in gross capital investment.

A consistent measurement of TFP requires to control for a series of issues that reflect some particular characteristics of productivity. The first issue refers to the cyclical character of productivity indicating that the productivity residual as specified in the aggregate Solow model tends to follow the movements of the business cycle; in periods of expansion productivity is unusually large while in periods of recession it is low or even negative (Hall (1990)). To control for the cyclicality nature of productivity, the input of capital stock is adjusted for fluctuations in capacity utilisation. A second adjustment is to express the labour input in equations (4.6) an (4.7) in hours worked rather than in number of employees. Therefore, the number of employees is multiplied by the annual number of hours worked per employee in each industry[9]. A last issue concerning a consistent measurement of TFP is to adjust TFP for quality differences in the labour input. This requires information about the number of skilled and unskilled workers as well as information about their wages. Unfortunately, these data do not exist for Greek manufacturing industries for the whole period under study and thus labour is measured as a homogenous input. After the adjustments discussed above the final TFP growth index takes the following form:

$$\ln\left(\frac{A_{i,j,t}}{A_{i,j,t-1}}\right)=\ln\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)-a_L\ln\left(\frac{\tilde{L}_{i,j,t}}{\tilde{L}_{i,j,t-1}}\right)-(1-a_L)\ln\left(\frac{\tilde{K}_{i,j,t}}{\tilde{K}_{i,j,t-1}}\right) \tag{4.8}$$

$\tilde{L}_{i,j,t}=h_{i,j,t}L_{i,j,t}$ and $\tilde{K}_{i,j,t}=u_{j,t}K_{i,j,t}$

where h denotes the average annual hours worked and u denotes the percentage of capacity utilization[10]. No industry-specific information is available for the rate of capacity utilization, thus data for the whole manufacturing sector are used. The use of an aggregate capacity utilisation measure presupposes that the business cycle effect is fixed across industries. Such an assumption is not necessarily true taking into account that the size of

[9] Data for hours worked per employee in each industry are taken from the Groningen Growth and Development Centre (GGDC)-60 Industry database.

[10] Capacity utilisation data are obtained from OECD-Main Economic Indicators and are provided on a quarterly basis.

the business cycle effect is proportionate to industry's capital –labor ratio and the level of technology[11].

Annual TFP growth rates of the aggregate manufacturing sector for both Greece and Germany are shown in table (4.1) along with the relative TFP level between the two countries. In order to ensure that the above figures are not driven by outliers, a test is implemented to detect for extreme values[12]. After dropping outliers, the results show that the Greek manufacturing sector has grown on average by 16.84% over the sample period while the German manufacturing has clearly experienced a lower rate of productivity growth equal to 1.86%. This preliminary evidence indicates that the non-frontier country grows faster confirming the core proposition of the neoclassical theory of convergence. The last column of table (4.1) verifies that Germany is correctly taken as the "technological frontier" country since the TFP level in German industries is always higher. Figures in the last column can be interpreted in the following manner: Greek manufacturing was only 2.81% percent as productive as that of Germany in 1980, while in the last year of the sample the Greek TFP level is something more than the half of the German one (i.e. 56.24%).

[11] The fact that the current TFP measure does not control for industry –specific rate of capacity utilisation and different composition of labour skills might cause important difference in the measure of TFP across countries. A similar argument is appeared in Andersson (2001) and Redding et al. (2005). However, these problems cannot bias the econometric results since they can be effectively tackled in a fixed effects econometric specification.

[12] The test for outliers is undertaken in STATA 9 under the command `hadimvo`. The total number of observations dropped is eighteen.

Table 4.1 Growth Values and Relative Levels of TFP

Year	$TFPG_{Germany}$	$TFPG_{Greece}$	RTFP
1980			2.81%
1981	-4.70%	25.38%	3.16%
1982	1.29%	32.43%	3.68%
1983	3.23%	30.26%	5.46%
1984	0.82%	28.99%	7.70%
1985	2.75%	27.57%	10.08%
1986	6.29%	22.29%	9.79%
1987	1.18%	12.35%	9.76%
1988	2.56%	32.17%	13.26%
1989	1.34%	23.23%	15.32%
1990	5.84%	18.07%	17.35%
1991	4.52%	26.19%	25.93%
1992	-0.14%	13.07%	25.11%
1993	3.04%	22.45%	37.92%
1994	2.39%	12.56%	36.33%
1995	1.07%	7.79%	39.67%
1996	4.24%	8.64%	40.27%
1997	1.26%	2.36%	40.37%
1998	1.29%	12.22%	44.58%
1999	1.98%	0.90%	44.33%
2000	-0.60%	9.03%	48.51%
2001	1.36%	7.05%	48.07%
2002	4.12%	6.34%	48.97%
2003	-5.82%	11.36%	56.24%
Mean	1.86%	16.84%	26.12%

Notes: TFPG is an index of TFP growth adjusted for capacity utilization and hours worked
RTFP is an index of Relative TFP level between Greece and Germany; figures displayed are the exponential values of equation (4.8)

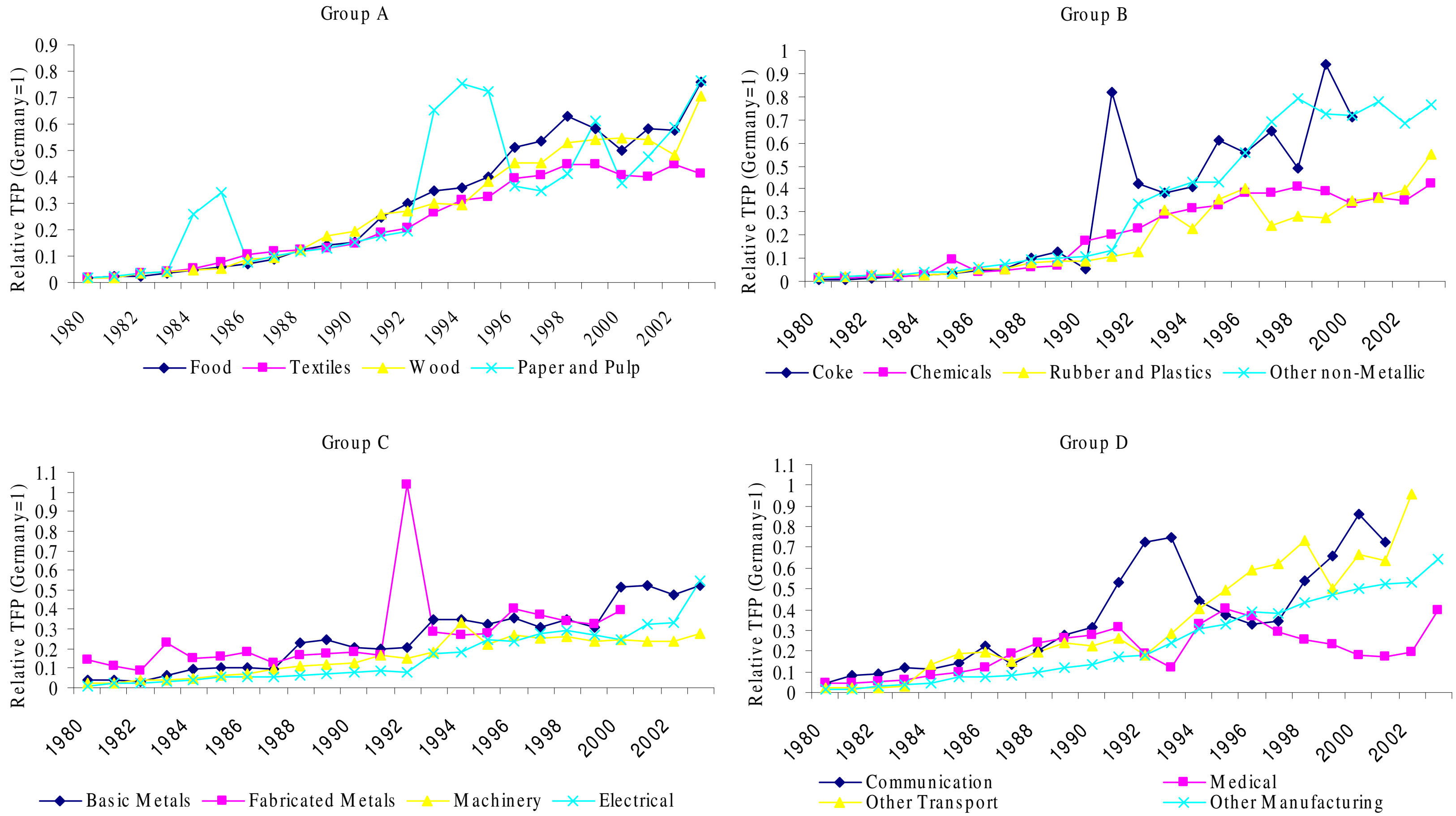
Table 4.2 reports the values of relative TFP at the first and the last year of the sample. Similar evidence is shown in figure (4.1), which shows the time trends of relative TFP of all industries included in the study. The first remark that should be done from this evidence is that Germany maintains a clear technological leadership in all industries both in the beginning and at the end of the period. Nonetheless, the figures reported indicate a clear evidence of convergence. In 1980, the Greek manufacturing industries had less than 10% of the TFP of their German counterparts. At the end of the period, this productivity gap has closed substantially and in six out of the seventeen industries, Greece is more than 70% as productive as Germany (i.e. food, pulp paper, rubber and plastics, electrical machinery, motor vehicles and other manufacturing). A particular characteristic of Figure (4.1) is that

Group A that include low-technology industries tend to converge faster that any other group of industries of the sample. Yet, there are industries in which Greece needs to accelerate the speed of catch up since the relative TFP remains below 50% even at the end of the period (i.e. textiles, coke, basic metals, fabricated metals and communication equipment). The fact that some industries tend to catch up faster than some other domestic counterparts reflects somehow that existence of different structural patterns across industries. For instance, in the period under study, one of the largest firms in the coke industry belongs to the state highlighting the monopolistic nature of the industry and the strong potential for slack that possibly slows down the rate of productivity growth. In contrast, in the food industry many structural reforms have been undertaken in the period under study stimulating faster rates of productivity growth. The econometric analysis of the next section systematically investigates, among others, the importance of technological transfer as a source of productivity growth.

Table 4.2 Relative TFP in 1980 and 2003

Industry	1980	2003
Food products, beverages and tobacco	2.38%	76.11%
Textiles, textile products, leather and footwear	3.37%	40.95%
Wood and products of wood and cork	3.44%	70.61%
Pulp, paper, paper products, printing and publishing	3.61%	76.34%
Coke, refined petroleum products and nuclear fuel	1.21%	42.08%
Chemicals and chemical products	1.74%	54.86%
Rubber and plastics products	2.94%	76.34%
Other nonmetallic mineral products	2.43%	51.86%
Basic metals	3.44%	39.71%
Fabricated metal products, except machinery and equipment	8.88%	27.60%
Machinery and equipment, n.e.c.	3.63%	54.28%
Electrical machinery and apparatus, nec	2.59%	72.59%
Radio, television and communication equipment	9.12%	39.83%
Medical, precision and optical instruments, watches and clocks	5.13%	64.20%
Motor Vehicles	2.00%	76.11%
Other transport equipment	2.26%	40.95%
Manufacturing nec	2.72%	70.61%

Figure 4.1 Relative TFP of Greek Manufacturing, (Germany=1)



4.5 Econometric Model and Results

The present section specifies the econometric model applied to estimate the sources of productivity growth in Greek manufacturing industries. The econometric model is based on the theoretical concepts already presented giving emphasis to the catch-up process between industries across countries. Following Bernard and Jones (1996a), the empirical convergence equation is an equilibrium correction model (ECM) represented by an ADL (1,1) process,[13] in which the level of productivity in industry *i* is co-integrated with productivity in the frontier country *F* as follows:

$$\ln A_{i,j,t} = \beta_0 + \beta_1 \ln A_{i,j,t-1} + \beta_2 \ln A_{i,F,t} + \beta_3 \ln A_{i,F,t-1} + \omega_{i,j,t} \tag{4.9}$$

where ω stands for all the observed and unobserved effects that may influence $A_{i,j,t}$ (i.e. TFP in the non-frontier country) and it is further decomposed as:

$$\omega_{i,j,t} = \sum_k \gamma_k Z_{i,j,t-1} + \rho_i + d_t + e_{i,j,t} \tag{4.10}$$

The summation in the right-hand side of (4.10) includes all the observed factors affecting TFP while ρ and d stand for industry and year specific effects, respectively.

[13] Further details about estimation issues of an ADL (1, 1) model can be found in Pesaran and Shin (1997) and Hendy (1995).

Assuming that the long-run homogeneity $(1-\beta_1=\beta_2+\beta_3)$ holds in (4.9), then its transformation gives:

$$\ln \Delta A_{i,j,t} = \beta_0 + \beta_2 \ln \Delta A_{i,F,t} + (1-\beta_1)(\ln A_{i,F,t-1} - \ln A_{i,j,t-1}) + \omega_{i,j,t} \qquad (4.11)$$

The dependent variable in equation (4.11) is industry *i*'s TFP growth in Greece- the non-frontier economy- including in the right hand-side the industry *i*'s TFP growth in Germany -the frontier economy- and a term of technological gap in industry *i* between Germany and Greece. The substitution of (4.10) into (4.11) yields a specification in which R&D, trade and human capital influence the rate of TFP growth in the non-frontier economy both directly and through the rate of absorptive capacity. After these considerations, the estimatable equation takes the following form:

$$\ln \Delta A_{i,j,t} = \rho_{i,j} + \alpha \ln \Delta A_{i,F,t} + \gamma Z_{i,j,t-1} + \lambda \left(\ln \frac{A_{i,F,t-1}}{A_{i,j,t-1}} \right) + \mu Z_{i,j,t-1} \left(\ln \frac{A_{i,F,t-1}}{A_{i,j,t-1}} \right) + e_{i,j,t}$$

(4.12)

In (4.12), $\rho_{i,j}$ controls for industry's individual heterogeneity, α captures the impact of TFP growth in the frontier economy on the non- frontier economy, λ indicates the speed of technology transfer, Z includes other factors that have a direct effect on TFP growth such as: R&D, trade, human capital, labour market rigidities and market concentration and μ measures the responsiveness of TFP growth after changes in the level of absorptive capacity. The latter variable is represented by the interacted term between variables included in Z and TFP gap.

Equation (4.12) is a fixed effects specification; the term $\rho_{i,j}$ stands for time-invariant industry dummies. A possible method to estimate (4.12) is to use a least squares dummy variable approach (LSDV), which is an OLS, with a set of dummy variables. A potential problem regarding the LSDV approach is that industry fixed effects might be correlated with other covariates of the right hand-side leading to biased estimates. A Within-Group Fixed Effects (FE) estimator eliminates $\rho_{i,j}$ by expressing all variables as deviations from their industry means. According to Nickell (1981), the order of the bias emerged from the use of the FE estimator is of order $1/T$, where T is the number of years. Therefore, in panels with relatively large number of time series the bias tends to be zero. Evidence from Monte Carlo experiments (Judson and Owen (1999)) shows that if $T>N$, where N is the number of cross-sections then a FE estimator performs better than the instrumental variable (IV)-GMM estimator. In the current sample, after missing two years required for the construction of some variables, the panel consists of 22 years and 17 industries indicating that the FE within group estimator is a better choice than GMM[14].

Table (4.3) presents results from a FE estimator, the dependent variable is the growth rate of total factor productivity (i.e. $\Delta \ln A_{i,j,t}$) in Greek manufacturing industries and the right-hand side in each specification includes four explanatory variables.[15] This

[14] The crucial dilemma faced by the researcher in estimating a dynamic panel data model as this specified in (4.12) is to assess the cost of reducing the correlation bias emerged between the lagged dependent variable and the fixed effects. Judson and Owen (1999) consider three different alternatives to correct this bias. Their results prove that with a $T\approx 30$ then a fixed effects estimator is the best alternative giving the smallest root mean square error (RMSE). The GMM estimator can more effectively correct bias in panels with smaller number of $T(<10)$ (a characteristic more usually met in micro data sets) while if $10<T<20$ then an Anderson Hsiao (1981) estimator should be chosen.

[15] Summary statistics of the explanatory variables are shown in the Appendix.

table reports a set of standard specification tests concerning the behaviour of the error-term $e_{i,j,t}$. Firstly, the modified Wald test refers to whether the error term has a constant variance across industries, $Var(e_{i,t}) = \sigma_i^2$. Secondly, the Pesaran (2004) test is reported for cross-sectional dependence of the residuals, $Cor(e_{i,t}e_{k,t}) \neq 0$ for any industry *i≠k*. These tests indicate that heteroscedasticity and cross-sectional correlation are present in the current sample. Finally, two alternative tests for first order serial correlation, $Cor(e_{i,t}e_{i,t-1}) \neq 0$ are implemented based on Wooldridge (2002) and Baltagi-Li (1995). According to the latter tests, the null hypothesis of no first order serial correlation is accepted at high statistical levels of significance.

Table 4.3 Diagnostic Tests

COEFFICIENT Period	FE 1982-2003 (1)	FE 1982-2003 (2)	FE 1982-2003 (3)
$\Delta \log TFP_{i,F,t}$	0.350**	0.342**	0.371***
	(2.44)	(2.36)	(2.60)
TFPgap	0.0706***	0.0777***	0.0504***
	(5.57)	(6.27)	(3.17)
$\log(Trade / X)_{i,t-1}$	-0.0415		
	(1.46)		
$(Trade / X)_{i,t-1}$*$TFPgap$	0.0143*		
	(1.66)		
$\log(IMP / X)_{i,t-1}$		-0.0153	
		(-0.69)	
$(IMP / X)_{i,t-1}*TFPgap$		0.00929	
		(1.08)	
$\log(EXP / X)_{i,t-1}$			-0.0864**
			(2.47)
$(EXP / X)_{i,t-1}*TFPgap$			0.189**
			(2.44)
Observations	276	276	276
Diagnostic Tests			
R-squared	0.35	0.34	0.36
Modified Wald Test for Heteroscedasticity	chi2(17) =240.06 (0.000)	chi2 (17) = 262.15 (0.000)	chi2 (17) =279.28 (0.000)
Pesaran Test for Cross-sectional Dependence	8.460 (0.000)	8.904 (0.000)	7.815 (0.000)
Wooldridge Test for Serial Correlation	F(1, 11) =0.006 (0.9408)	F(1, 11) =0.001 (0.9798)	F(1, 11) = 0.020 (0.8898)
Baltagi-Li Test	LM(rho=0)=0.06 (0.8121)	LM(rho=0)=0.00 (0.9548)	LM(rho=0)= 0.01 (0.9416)

NOTES:

A. t statistics in brackets with correspondence *** p<0.01, ** p<0.05, * p<0.1

B. $(Trade / X)$ =Imports plus Exports to output ratio

(IMP / X) = Imports to output ratio

(EXP / X) =Exports to output ratio

C. The null hypothesis of the Modified Wald test is $H_0 : \sigma_i^2 = \sigma$

The null hypothesis of the Pesaran test is $H_0 : E(e_{i,t} e_{k,t}) = \sigma_{i,k}$

The null hypothesis of the Wooldridge test is no serial correlation after allowing for an AR(1) process of the residuals. Under the null the parameter of the lagged residual rho is equal to 0.5. The Baltagi-Li test is an LM test for first order serial correlation implemented after specifying a model of random effects. The null hypothesis is that the rho parameter of the AR(1) process of the residuals is equal to zero.

D. The implementation of the Pesaran cross-sectional dependence test and the Baltagi-Li test are only available with balanced panels, so observations are dropped when they do not have full series across years.

The estimator used to correct for group wise heteroscedasticity and cross-sectional correlation is the Feasible Generalized Least Squared (FGLS) [16]. Since industries are quite different in size, each observation is weighted by the industry's share in total manufacturing value added in the first year of the sample, as suggested by Redding et al. (2005). The implementation of the FGLS estimator is only available with balanced panels hence those industries without a full series of variables across years are dropped. After this data modification the new dimensionality of the panel is 22 years and 12 industries.

Results from the FGLS estimator are reported in table (4.4), the first three columns of this table replicate specifications of table (4.3) using an FGLS estimator. In column (1), the dependent variable is regressed on the contemporaneous TFP growth in German manufacturing industry *i*, the TFP distance (i.e. $TFPgap = \log(\frac{A_{i,F,t-1}}{A_{i,j,t-1}})$) between Greece

[16] The software package used to estimate regressions throughout the paper is STATA 9. The specific command used to fit an FGLS model in STATA is `xtgls`. Beck and Katz (1995) develop an alternative estimator that corrects for panel heteroscedasticity and cross-sectional correlation. The estimator of Beck and Katz (1995) carries many similarities with the FGLS currently used and results are not affected much from the estimation method selected.

and Germany at year *t-1* in industry *i*, a trade variable and, an interacted term of trade with TFP gap.

Table 4.4 FGLS Estimator for the Sources of TFP Growth: Basic Results

Period	**1981-2003 (1)**	**1981-2003 (2)**	**1981-2003 (3)**	**1981-2003 (4)**	**1982-2003 (5)**
$\Delta \log TFP_{i,F,t}$	0.265***	0.267***	0.257***	0.290***	0.313***
	(3.45)	(3.24)	(3.56)	(3.91)	(4.62)
$TFPgap$	0.0970***	0.096***	0.112***	0.210***	0.037***
	(10.9)	(9.46)	(9.87)	(3.06)	(3.82)
$\log(Trade/X)_{i,t-1}$	-0.071***				
	(7.07)				
$(Trade/X)_{i,t-1}*TFPgap$	0.027***				
	(4.96)				
$(IMP/X)_{i,t-1}$		-0.045***			
		(4.86)			
$(IMP/X)_{i,t-1}*TFPgap$		0.016***			
		(3.56)			
$\log(EXP/X)_{i,t-1}$			-0.049***		
			(6.54)		
$(EXP/X)_{i,t-1}*TFPgap$			0.016***		
			(4.52)		
$\log(R\&D/VA)_{i,t-1}$					0.023***
					(6.62)
$(R\&D/VA)_{i,t-1}*TFPgap$					-0.009***
					(6.23)
$\log(HCshare)_{i,t-1}$				-0.074*	
				(1.68)	
$HCshare_t*TFPgap$				0.043*	

				(1.94)	
Observations	276	276	276	276	252
Number of sectors	12	12	12	12	12
Number of years	23	23	23	23	22
	Chi(4)=161.	Chi(4)=	Chi(4)=172.	Chi(4)=	Chi(4)=
Wald Test	13	145.04	93	168.57	328.72
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LL test	375.3746	366.8694	376.2834	364.373	365.7395

Notes: Absolute *t*-statistics in parentheses represent * significant at 10%; ** significant at 5%;*** significant at 1%. All observations are weighted by industry's value added in manufacturing at the first year of the sample available; Estimates are based on a Feasible Generalized Least Squared method that corrects for heteroscedasticity and cross-sectional correlation of the residuals. The R&D series starts from 1981 hence the sample period of estimation starts from 1982 given that the variable of R&D share enters the model lagged by one year.

The positive and statistically significant coefficient of the technological gap variable indicates that the more an industry lies behind the frontier, the faster is the rate of total productivity growth. The contemporaneous term of the TFP growth in the frontier economy has a positive and statistically significant sign throughout all the specifications of the table. Regarding the trade variable, the revealed pattern is very interesting. The level variable carries a negative and statistically significant coefficient while the interacted term of trade with the TFP gap suggests that trade plays an important role on technology transfer. The sign of the trade variables is different from each other and remain as such even if the trade variable is decomposed into exports and imports. Colum (4) examines the influence of human capital ($logHCshare_{t-1}$) measured by the share of workers with tertiary education in total labour force and its interacted term ($HCshare_{t-1}*TFPgap$). Results from this specification do not differ from the pattern obtained from the trade variables. This means that the level of human capital that interacts with the productivity gap can increase the rate of catch-up.

Column (5) controls for the impact of R&D on the growth of total factor productivity. The level term of R&D share appears with a positive coefficient and statistically significant at the 1% percent level while the interacted term is negative. The results emerged suggests that the dominant effect of R&D is on innovation rates and not on improving the industry's absorptive capacity. In other words, industries with a higher share of R&D expenditures tend to grow faster but this characteristic does not improve their ability to imitate more effectively the technological advancements of the "technological frontier" country. In these benchmark specifications, except for R&D the remaining variables have only an indirect effect on productivity growth. In the forthcoming analysis, a number of additional specifications will test the robustness of this pattern.

Table (4.5) presents results from a specification in which trade and R&D variables along with their associated terms are included in the same specifications. After including the whole set of productivity growth drivers, the findings do not differ substantially from what we obtain in table (4.4). The autonomous technology transfer as measured by the relative TFP variable is positive and statistically significant at high confidence levels, confirming once again that a country, which falls far behind the frontier, tends to grow faster. The level term of trade still has a negative sign while its interacted term with the TFP gap is positive. The R&D level continues to be positive as table (4.4) shows and the R&D interacted term remains negative at high statistical levels. There is only a minor difference in the sign of the level term of human capital, which is now positive and thus consistent with the economic priors, but this is likely to reflect only a marginal change since the estimated coefficient is not statistically different from zero.

In column (2), the variable of interest is the minimum to median wage representing the role of labour market rigidities on TFP growth. As discussed earlier, stringency in the labour market can be an obstacle for productivity upgrading from many different aspects. But the definition of the present variable allows us to assess only the impact of labour cost adjustments on productivity growth. On that basis, column (2) of table (4.5) certifies that labour market rigidities have a negative influence on productivity growth, as the ratio of minimum to median wage has a negative coefficient and statistically significant at the 5% (absolute t-value is 2.06).

Column 3 presents results from a specification that includes a measure of domestic market concentration. Note that data for this variable are only available from 1993 onwards and thus the length of the panel is reduced by twelve years. The estimated coefficient of the variable of domestic concentration proved to be positive at the 1% statistical level (t-value is 3.87) supporting the argument that industries with high degree of concentration operate in a higher scale of production increasing the overall productivity. Estimating the TFP growth equation for the reduced sample causes only a radical difference in the estimate of the level variable of R&D share. The latter variable is now negative with a statistically significant coefficient. This negative pattern indicates a particular characteristic of R&D activity. In a relatively long panel as in columns (1) an (2) of table (4.5), there is enough time to implement the R&D effort to productivity gains. In shorter periods, innovative activity through R&D expenditure increases the cost of production without ensuring a successful research outcome.

Table 4.5 FGLS and IV Estimations for the Sources of TFP Growth: Further Specifications

COEFFICIENT Period	1982-2003 (1) FGLS	1982-2003 (2) FGLS	1994-2003 (3) FGLS	1982-2003 (4) IV- FE	1994-2003 (5) IV-FE
$\Delta \log TFP_{i,F,t}$	0.277***	0.280***	0.189***	0.339**	0.0224
	(5.38)	(4.76)	(3.36)	(2.03)	(0.069)
log TFPgap	0.186***	0.150**	0.334***	0.0945*	0.52
	(3.14)	(2.45)	(2.67)	(1.97)	(0.93)
$\log(Trade/X)_{i,t-1}$	-0.114***	-0.107***	-0.197***	-0.134**	0.648
	(10.6)	(9.17)	(9.83)	(2.32)	(1.64)
$(Trade/X)_{i,t-1}*TFPgap$	0.039***	0.036***	0.058***	0.073***	-0.115
	(6.27)	(5.46)	(7.20)	(2.82)	(-0.50)
$\log(R\&D/VA)_{i,t-1}$	0.038***	0.035***	-0.050***	0.0265	0.024
	(11.8)	(10.2)	(6.98)	(1.31)	(0.39)
$(R\&D/VA)_{i,t-1}$ *TFPgap	-0.015***	-0.014***	-0.039	-0.0151	-0.0157

	(10.3)	(8.64)	(0.62)	(1.33)	(-0.32)
$\log(HCshare)_{i,t-1}$	0.031	0.062	0.144***	0.0842	
	(0.86)	(1.38)	(2.71)	(1.36)	
$HCshare_t * TFPgap$	0.040**	0.032	0.058***		
	(2.02)	(1.59)	(7.20)		
(Min Wage/Median Wage)$_{i,t-1}$		-0.082**	-0.064	-0.056	-0.440**
		(2.06)	(1.39)	(0.87)	(-2.39)
$\log CR_{i,t-1}$			0.021***		-0.248
			(3.87)		(-0.86)
Observations	264	264	120	240	96
Industry Fixed Effects	Yes	Yes	Yes	No	No
Number of sectors	12	12	12	12	12
Number of years	22	22	10	20	8
R-squared				0.34	0.06
Wald Test/F Test	Chi(8) =697.1 (0.00)	Chi(9) =519.4 (0.00)	Chi2(10) =469.9 (0.00)	F(20,220) =14.28 (0.00)	F(21,75) =2.11 (0.03)
Log-likelihood	380.8224	381.7314	581.6265		
Sargan Test				3.767 (0.4385)	11.827 (0.032)

Notes:
Absolute *t*-statistics in parentheses represent * significant at 10%; ** significant at 5%;*** significant at 1%. All observations are weighted by industry's value added in manufacturing sector at the first year of the sample available. Estimates in columns (1), (2), (3) are based on a Feasible Generalized Least Squared estimator that corrects for heteroscedasticity and cross-sectional correlation of the residuals. Specifications in columns (4) and (5) report results from IV–FE estimators. The endogenous variables in columns (4) and (5), are TFPgap, $\log(Trade/X)_{i,t-1}$, $(Trade/X)_{i,t-1}$*$TFPgap$, $(R\&D/VA)_{i,t-1}$*TFPgap and $\log CR_{i,t-1}$. The instruments used are their lagged values dated *t*-2 and *t*-3. The Wald and F-test refers to whether coefficients are jointly zero. The Sargan test refers to the validity of instruments following the Chi-squared distribution; the null hypothesis is that the set of instruments is valid.

4.5.1 Results from an Instrumental Variable (IV) Approach

A further concern regarding the econometric analysis of the present chapter is the existence of substantial measurement errors. The present measurement of TFP controls for some standard corrections suggested in the literature of TFP measurement, such as hours worked and capacity utilization[17]. Apart from the standard measurement errors that might exist in the TFP variable, another issue that arises in the econometric estimation and needs special treatment is the potential endogeneity between the left-hand side variable and the right hand side variables in equation (4.12). Note that the growth of TFP in the left hand side is measured as $\ln\left(\frac{A_{i,j,t}}{A_{i,j,t-1}}\right)$ whereas the right hand side relative TFP level is $\ln\left(\frac{A_{i,F,t-1}}{A_{i,j,t-1}}\right)$, this indicates that shocks in the level of TFP in country *j* at year *t*-1 affect both growth of TFP and the initial distance from the frontier. This realization enhances an endogeneity problem between the variables of TFP growth and TFP gap. To control for this endogeneity problem as well as to correct for any potential measurement bias already embodied in TFP, the instrumental variable (IV) estimator is applied.

In the present chapter, one of the central aims is to investigate whether there is substantial evidence for the trade-led growth hypothesis. Nevertheless, the neoclassical trade theory identifies as determinants of trade flows differences in the level of productivity across countries; this proposition implies that the link of trade with productivity might run in the opposite direction[18]. Therefore, there is a clear indication for the potential endogeneity between TFP growth and trade.

A crucial issue concerning the use of an IV estimator is to construct valid instruments for the endogenous variables. Generally speaking, this criterion is fulfilled if

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[17] Regularly TFP is corrected for different types of workers and for the existence of price mark ups. Some of them are addressed in the present work due to lack of data, this is the case especially for different types of labour. In the next section, we provided a test for the bias captured from double-checking in the construction of TFP. The problem of double checking refers to the fact that R&D inputs, especially R&D personnel are sometimes double counted in the standard measure of labour input. After extracting R&D personnel from the total number of employees in the TFP calculation, the TFP figures are almost unchanged.

[18] This proportion has been the central focus of chapters 2 and 3 of the present thesis.

the instruments are strongly related to the endogenous variables and uncorrelated with the error term of the TFP growth equation (4.12). A choice that fits closely the above criteria is to consider as instruments the higher order lags of the endogenous variables. In order for the lagged values of the endogenous variable to be uncorrelated with the residuals of (4.12), the latter must be serially uncorrelated. The Baltagi-Li and Wooldridge tests reported in the previous subsection indicate that residuals do not present first order serial correlation permitting us to believe that the higher order lags of the endogenous variables can act as valid instruments.

The Sargan test appeared in the last row of the table is an additional diagnostic test that informs us about the validity of the instruments. This test computes a statistic for an over-identifying restriction in which the number of regressors is smaller than the number of instruments. Under the null hypothesis, the equation is correctly specified and the set of instruments is valid. The reported probabilistic value of the Sargan test in column (4) is 0.4 indicating the acceptance of the null hypothesis.

The results produced in columns (4) and (5) of table (4.5) rely on a two-stage instrumental variable estimator. Comparing the results between the IV-FE (column 4) and the FGLS estimator (column 2), there are not considerable differences. The values of t-statistics in the IV estimation are now relatively lower but this is an expected trade-off after controlling for potential measurement errors and endogeneity bias. Apart from the estimates of R&D (both the level and the interacted term) and the labour market, the remaining coefficients are statistically significant at conventional levels. The fact that IV estimation does not change fundamentally the results indicates that the findings derived from the FGLS estimation are not driven by measurement errors. Similarly, any underlying problem with endogenous variables does not affect the qualitative picture of the results. In the specification of Column (5), where market concentration is included as a control variable on TFP growth, the IV estimation provides statistically insignificant coefficients. This is mainly resulted from the fact that the size of the panel has been substantially reduced.

4.5.2 Summarising Results from Benchmark Specifications

The results from both the FGLS and the IV-FE estimators suggest that the role of the autonomous technological transfer is of particular importance on the movements of TFP growth. The coefficient of the autonomous transfer variable is 15% in the FGLS specification (column (2)) and 9% in the IV specification (column (4)). These magnitudes mean that each year a typical Greek manufacturing industry covers 15% or 9% percent of the productivity gap that has with its German counterpart. From these figures, the solution of the steady –state equilibrium condition (4.5) implies that the autonomous technology transfer takes 3.3 or 5.5 years to close half of the gap in technical efficiency between the Greek and the German industry. These figures refer to the estimated TFP gap coefficients of the FGLS and IV-FE methods, respectively. The appendix C4.3 provides a formal unit root test for stationarity testing whether the model specified in (4.10) is a good approximation of an equilibrium correction model (ECM). The coefficients of autonomous technological transfer of the present study imply that the catch up process in Greek industries is rapid. A similar speed of adjustment is found in Redding et al. (2005) in which the estimated coefficient of technology transfer between UK and US is 14%.

Nonetheless, other studies reveal different speed of technological convergence across countries. For, example, in a very similar specification as in table (4.5), Cameron (2005) finds that the speed of adjustment in Japanese industries towards their US counterparts is 6.3%, while, Khan (2006) reveals a speed of adjustment of French industries towards US counterparts in the order of 6.5%. Prescott (1997) suggests that TFP growth reflects changes in organizational practices realized at the firm or at the industry level. From a similar point of view, institutional reforms can accelerate the process of productivity convergence. Given that the present study does not control explicitly for these factors, the relatively high speed of catch-up in the present study is likely to reflect successful organisational and institutional reforms that allow Greek manufacturers to adopt more quickly and effectively the technological developments of the frontier country.

The systematic economic forces determining the speed of adjustment towards a steady –state equilibrium include, among other characteristics, trade, R&D and human capital. These characteristics can interact with the autonomous technological transfer accelerating or slowing down the speed of catch-up. This scenario is explored with the use of various interacted terms (see equation (4.12)). Results from both FGLS and IV-FE estimations suggest that trade openness is a negative determinant of productivity growth. Nonetheless, the interacted term of trade with TFP gap indicates that trade openness contributes to a faster implementation of technological techniques initially developed in the frontier economy. Evidence from trade-based technological transfer is consistent with both industry (Redding et al. (2005)) and country level studies (Prescott (1994) that assess through which channels the speed of technology diffusion is faster. According to the present results, the absorptive capacity of Greek manufacturing industries is improved only through trade and not through R&D activity. The interacted term of R&D with TFP gap is negative throughout all the specification in table (4.5) implying that the second face of R&D as suggested by many recent studies (see Griffith et al. (2004)) is not present in the current sample. In contrast, R&D has a direct role on stimulating productivity growth through innovation. The latter result confirms the well-established impact of innovation on output growth documented mainly in firm level studies (Griliches (1970) and Griliches and Regev (1995)).

The present study reveals a multifaceted role for human capital. The number of workers with at least a degree from tertiary education as a share of total number of workers proved to have a positive influence on TFP growth. Additionally, a higher level of human capital allows for some externalities since the interacted term of human capital with the variable of TFP gap is always a positive determinant of TFP growth. In the present study, human-based and trade-based technological transfer are the two main channels though which a fast and effective implementation of foreign technology takes place.

Finally, rigidities in labour markets have a negative impact on TFP growth, which is present even if the IV estimation is applied. As already commented, the current study cannot perfectly define a variable that captures all the institutional factors that determine the level of stringency in the labour market. The present measure is the ratio of minimum to median wage, which is a close proxy for labour cost adjustments that somehow reflects the bargaining power of the trade unions. With these considerations in mind, powerful trade unions have a negative influence in TFP growth. This means that collective wage agreements determine an actual wage that in some industries lies far above the competitive level of marginal product of labour. In this context, a powerful trade union can also be connected to a protective employment legislation that has negative effects on the skill upgrading of labour force. From this point of view, when firms wish to achieve a high level of dynamic efficiency they should recruit personnel that can adopt the new technological standards. If legislation is too strict, firms do not recruit easily people from the external market. Instead, they need to re-train the existing personnel to acquire the necessary skills, but with wages already above the competitive level, additional training of personnel causes further increases in labour costs and thus firms are unable to follow the new technological developments (Scarpetta et al. (2006)). The empirical evidence of the present chapter cannot directly support the above mechanisms but the negative relationship between the minimum to median wage ratio and TFP growth is likely to be attributed to a similar process.

4.6 Sensitivity Analysis

Several issues remain regarding the analysis presented in the previous section. After controlling for potential endogeneity in key variables, the main inference remains unchanged since the IV- results are very similar. Apart from measurement and endogeneity bias, some results obtained above contradict the theoretical expectations and therefore some further analysis is required to check whether the findings of the previous section yield a particular structural pattern or simply reflect a problem in the definition of specific variables. The present section conducts some sensitivity tests seeking to test for the robustness of the results presented in table (4.5).

Table (4.5) does not reveal any significant impact of trade on TFP growth. This finding is in opposition to propositions of endogenous growth theory but it also diverges from findings in other empirical studies. To analyse this result further, two points should be taken into account; first, more emphasis is given to the idea discussed in the introduction regarding the strong similarity between the concepts of learning-by-doing and learning-by-exporting. If these two processes have many common features then learning-by-exporting might be described more accurately by a non-linear relationship. Going back to the seminal work of Arrow (1962), the key point suggested is that learning-by-doing is an accumulated product of experience and as such, it is subject to diminishing returns to scale. Accepting that dynamic gains from exporting are at work but they are non infinite implies that after a critical threshold further increase of export activity is unable to provide significant benefits[19]. Second, models developed by Young (1991) and Chaung (1998) emphasize the bounded nature of learning induced by trade. The latter studies suggest that learning-by- trading is critically determined by the pattern of trade (i.e. the types of goods traded) and the identity of the trade partner.

Appendix C4.4 replicates the specification of column (2) in table (4.5) after controlling for a non-linear relationship between trade and TFP growth as well as for a

[19] Similarly, the argument can be at work from the reverse side, exposure in international markets does ensure automatically learning benefits; instead, exporters need to reach a crucial threshold after which they can start experiencing substantial knowledge gains from exporting.

bounded nature of trade. Specification (1) presents results from a quadratic term of both trade share and the interacted term. The negative sign of the trade share is not eliminated while the interacted term now appears with a negative impact. However, these estimates cannot be viewed as informative since coefficients are far from statistically significant levels. Estimates from an IV specification remain statistically insignificant[20]. Specifications (3) to (6) refer to estimates when trade only with G7 countries is considered. The ratio used is the sum of imports (exports) to G7 over the total amount of imports (exports). The rationale of this specification is based on the idea that these countries are clearly more technologically advanced than Greece and thus increases in trade involvement of Greek industries with them can facilitate significant knowledge spillovers. The only robust effect from these specifications is that import-based technological transfer is important for productivity growth when imports from the G7 countries are considered. The technological content of these imports is usually high fostering receiving country's absorptive capacity and thus accelerating productivity growth. Overall, table in the Appendix_ shows weak evidence for a non-linear relationship between trade and productivity growth, as well as for the hypothesis that learning effects depend on the identity of trade partners.

A further check of robustness involves the measurement of R&D. The previous section relies on a flow measure of R&D; however, it seems reasonable to assume that knowledge is an accumulated process rather than a one – off effect. Therefore, R&D is also measured as a stock variable obtained by the standard inventory equation:

[20] Results (not shown) here from quadratic terms of imports and exports are very similar to the specifications displayed in Appendix C4.4.

$$RDstock_{it} = (1-\delta)RDstock_{it-1} + RDexpenditure_{it}$$

Here, $RDstock_{i,t-1}$ describes the accumulated stock up to period $t-1$ and $RDexpenditure_{i,t-1}$ denotes the expenditure on R&D conducted by industry i at the current year. The initial R&D stock in industry i is calculated using a benchmark equation proposed by Griliches (1981), which is identical to the formula applied to calculate benchmark physical capital stock previously. A standard dilemma encountered in the calculation of the above equation is a plausible assumption about the depreciation of the R&D stock. The present measure assumes a rate of 5%, admittedly this assumption seems arbitrary; although, it makes no difference to the qualitative picture of the econometric results if it is assumed a rate of 10 or 2.5%. The econometric results of the previous section reveal that R&D share has a positive impact on TFP growth. Nevertheless, R&D activity does not contribute to improvements in country's absorptive capacity. Griffith et al. (2004) note that countries lying far behind the frontier initially conduct little R&D and thus the marginal productivity of R&D at the early stages is quite high. Although, this argument cannot explain why the interacted term of R&D in the main econometric results is negative implies clearly that R&D activity might be subject to a non-linear process[21].

Appendix C4.5 replicates specifications (2) and (4) of table (4.5) checking for a non-linear relationship between R&D and TFP growth. In the same table, a stock measure of R&D is used to provide a means of comparison with the results obtained from the

[21] If this argument holds then a country like Greece, which is not R&D intensive, should have a high marginal productivity of R&D at the early stages. On this basis, the interacted R&D term should have been positive.

measure of R&D flow. The pattern revealed from a stock measure of R&D indicates no change compared to results produced from a flow measure of R&D. In the FGLS estimation, the level variable of R&D is positive and significant highlighting the role of innovation on promoting TFP growth while the R&D stock interacted term is negative. Controlling for endogeneity the previous estimates appeared to be insignificant at conventional levels. Indicating that estimates of table (4.5) in the previous section are robust to alternative measures of R&D. After controlling for a quadratic term of R&D share in columns (3) and (4), radical changes occur in the impact of R&D activity on TFP growth. The pattern revealed from a squared term of R&D suggests the existence of decreasing returns to R&D expenditure. Given that the liner term of R&D is positive, the negative sign of the quadratic term implies that the marginal productivity of R&D decreases as R&D expenditure increases. In such a pattern, industry's absorptive capacity is a positive function of R&D. The message emerged from column (3) in the Appendix C4.5 is that even if investment in R&D becomes of no importance after a certain point in affecting productivity growth, it improves industry's ability to assimilate and exploit exiting information or technological achievements developed externally. Controlling for endogeneity in column (4), both estimates become insignificant.

The last test of robustness refers to the measure of the frontier. The econometric results so far explore the sources of TFP growth considering as "technological frontier" country Germany. However, one can pose the crucial question to whether the existing results are sensitive to a different definition of the "technological frontier". To address this issue, the specifications (2) - (5) of table (4.5) are re-estimated using French manufacturing sector as the “technological frontier”.

There are not substantial differences after considering France as the “technological frontier” country (Appendix C4.6). The main forces driving TFP growth in Greek manufacturing industries have the same sign as in table (4.5). One of the main messages emerged after using France as the “technological frontier” country is that trade–based technological transfer remains a principal source or productivity growth (i.e. the interacted term of trade is positive and statistical significance in both FGLS and IV estimations). Similarly, the variable that reflects the conditions of labour market has a negative sign confirming once more the negative impact of labour market rigidities on TFP growth. There are only minor changes in the statistical significance of the variables. The coefficient of the autonomous technological transfer is not significant after controlling for potential endogeneity. R&D share is positive and statistical significance and remains so even after controlling for endogeneity (t-statistic is 1.81). This result highlights the role of innovation as a driver of productivity growth but the interaction of the linear R&D term with the relative productivity gap does not support the hypothesis that R&D improves absorptive capacity. Note that this evidence should be explored further since R&D might be subject to a non-linear relationship as already indicated from the estimates of the Appendix C4.6.

4.7 Conclusions

It is widely acceptable that the economic welfare of a country is strongly associated with its productivity records. The new theoretical developments of the endogenous growth theory suggest that the factors driving productivity growth are mainly determined by the decisions taken from the economic agents. These decisions refer to activities such as investment in innovation, the degree of trade openness and investment in human capital. The aforementioned activities can act as explicit or implicit channels of productivity growth. The puzzle about the factor affecting productivity growth is completed taken into account the importance of technology transfer as a conduit of productivity improvements. The present chapter investigates the sources of productivity growth under the general theme of productivity convergence, which pays particular attention to the potential of technology transfer between a frontier and a non-frontier economy.

The current study contributes to the productivity convergence literature providing evidence from Greece (i.e. the non-frontier country) and Germany (the frontier country). The empirical exercise focuses exclusively on two European countries offering a new aspect in the respective literature, which focuses only on a group of developed non-frontier countries and the United States. In a more general view, this pure intra-European comparison constitutes a central issue of the agenda of the European economic integration, given that many policies seek to narrow the gap between the core and peripheral countries within the EU. Consequently, it is useful for the policy maker to be aware of the factors that stimulate productivity growth and thus to design the appropriate policy devices in order to promote productivity over time.

Although, the results obtained from the present study regarding the determinants affecting productivity growth refer exclusively to Greek manufacturing industries, a number of general lessons can be drawn with regard to other European countries, especially those that carry similar economic features with Greece. The first finding of the study is that there is a convergence process at work during the sample period, which occurs at a rapid rate. The speed of catch-up process between Greek and German industries is higher than the speed of convergence documented for other pair of countries in the literature. This finding along with the result that the autonomous technological transfer is an important contributor to TFP growth confirm the argument of the traditional convergence literature that countries fall behind tend to grow faster.

As pointed out, the present chapter pays special attention to the role of trade, R&D and human capital as key drivers of productivity growth. The chapter also explore whether the above variables have an indirect impact on TFP growth. Recent literature proves that R&D has a dual role, the first one is to promote innovation and the second one is to improve absorptive capacity. The first role highlights the private rate of return to R&D expenditure while the latter indicates a more social aspect of R&D. The social return to R&D implies that research activity might not be effective in producing a new product but improves industry's ability to imitate effectively the existing technological information. In a similar line of argument, trade and human capital may have both direct and indirect effects on growth. The present study does not find evidence for the second role of R&D, instead confirms that R&D promotes innovation, which is a principal channel of productivity growth. Although, the statistical magnitude of the above result is robust, the nature of R&D activity maintains many unexplored characteristics. For example, the sensitivity analysis reveals that R&D effort is subject to diminishing returns, thus gains from R&D research are realised up to a certain threshold. Beyond this, R&D does not promote innovation, instead improves industry's absorptive capacity. Therefore, further research should be undertaken to provide a more overwhelming evidence for the precise relationship between R&D and growth. On this basis, a more systematic framework is required to reveal which are the factors that drive industries to invest in R&D.

The chapter provides clear and robust evidence for trade-based technological transfer. The interacted term of trade with the productivity gap variable is significant and positive throughout a big number of different specifications indicating that trade exposure helps Greek industries to close faster the gap with their German counterparts. The preliminary specifications of the chapter reveal that both importing and exporting are important engines of technology transfer. Most of the specifications consistently reveal a negative coefficient of trade share contradicting the propositions of the endogenous growth theory. A sensitivity analysis does not support the hypothesis that the relationship between trade and productivity is non-linear as well as it does confirm the proposition that the identity of trading partners matter. This set of empirical findings tends to support that trade induced gains are indirect and occur mainly through accelerating the rate at which the productivity convergence occurs.

Two new variables are also added to the analysis to reflect the impact of domestic market conditions on TFP growth. The ratio of minimum wage to median wage is consistently negative and in almost all the specifications is significant. The concentration index is insignificant but estimating the model using an instrumental variable, the coefficient of the concentration index becomes insignificant. The positive coefficient produced from the FGLS estimation is compatible with the view that monopolistic power in the market is not an obstacle for efficiency since the dominant firms can exploit economies of scale and hence an industry's productivity growth can be positively affected.

From a policy-making standpoint, results regarding the variable of labour market rigidities can provide interesting insights. Before stating strong conclusions, one might think that other types of variables might be more adequate to describe the degree of stringency in the labour market. For instance, variables that refer to the number of missing hours due to strikes can reflect more precisely the power of trade unions. Although, one can easily find data for the number of strikes for the aggregate economy is rather difficult to find this piece of information for disaggregate manufacturing industries. Similarly, to the best of our knowledge there is no data for the Greek manufacturing sector regarding the share of workers that covered by a collective wage agreement or any information that represents the share of trade union workers.. As far as the present measure is concerned, its negative impact on TFP growth indicates that trade unions experience strong bargaining power achieving collective wage agreements that in some industries correspond to wages above the competitive level. Certainly, this practice diverts financial resources from other activities concerning training of personnel, adjustment and use of new technological techniques etc. The negative impact of the labour market variable might refer to a very strict employment legislation, which does not allow employers to adjust their work force effectively and quickly. On this basis, inefficient firms remain as such for a long period, simply because the existing legitimate regime does provide an appropriate frame that always ensures an efficient reallocation of resources.

After all, the crucial question posed is what constitutes an appropriate policy reform within the labour marker in order to stimulate productivity growth? An insightful discussion of this issue is beyond the scope of this chapter but easing the stringency in Greek labour markets will certainly have a positive impact on TFP growth as already suggested in Scarpetta and Tressel (2002). In order to do so, legislation should give firms the ability to hire the personnel needed from the external market relaxing the various strong rigidities that already exist. Similarly, some structural changes should be promoted ensuring that the current salary schemes keep in pace with the levels of labour productivity.

Some issues that remain unexplored and definitely need further investigation. Two paths for further research that are strongly related to the current work are to quantify the direct impact of foreign R&D on domestic TFP (Coe and Helpman (1995) and Kneller (2000)) and to asses whether the pattern (i.e. type of goods traded) of trade really matters for TFP growth. In addition to these, future research should address the issue whether

FDI and firm dynamics have an impact on TFP growth. The presence of multinational companies in the domestic market is a channel that can diffuse new effective techniques and ideas boosting the rate of TFP growth. Simultaneously, entries (exits) in (from) the market as well as factors that drive this type of movements constitute core issues of the current pr

Appendix C4

Appendix C4.1

Total Factor Productivity

The main source of data used in calculating TFP is OECD-STAN. Variables used are Value added (VALU), Value added Volume (VALUK), Labour compensation of Employees (LABR),Employees (EMPE), Gross Foxed Capital Formation (GFCF), Gross fixed capital formation volume (GFCFK). Full data series for Greek industries are available only for the period 1995-2003. Prior to this period STAN reports data only for value added and labour compensation. Data for the remaining variable for the period 1980-1994 are taken by EU KLEMS project run by Groningen Growth and Development Centre (GGDC). Data for hours worked on each manufacturing sector are taken by GGDC 60-Industry database. OECD-STAN provided a full data series for Germany during the whole period, for years before 1990 data refer to West Germany. Missing values in GFCF and GFCFK for German industries for 2003 are filled with values taken from EU KLEMS- GGDC database.

Trade

Values of imports and exports for Greek manufacturing industries between 1995-2033 are provided by OECD-STAN (release 05), while date for the period 1980-1994 are taken by OECD-STAN (release 01). Trade share is the sum of imports an export over production in nominal values. Trade data are not deflated into real values due to lack of appropriate deflators.

Research and Development

Data for R&D expenditures and R&D personnel are taken from OECD (Main Science and Technology Indicators, releases: 13r2-13r3 and 16&17r2-16&17r3). Data series for both variables starts from 1981 and they have many missing within year intervals. To fill in missing values, the STATA routine interpolation function is used. This considers that

R&D expenditure is a positive function of time. Raw data are in current Euro prices. Nominal values are deflated by an R&D price index, which is defined as: $PR = 0.5(VAI + WAI)$, where VAI is a value added industry specific deflator and WAI is a nominal manufacturing wage index, taken by International labour Organization (ILO). The above definition of R&D deflator is given by Coe and Helpman (1995) and implies that half R&D expenditures are labour costs. The level measure of R&D is a share of real R&D expenditure to real value added while a complementary measure is also considered referring to R&D stock since the main text for more details. Data on are obtained by

Human Capital

It is measured as the share of workers with tertiary education over the entire labour force. Data for educational enrolment by level and for labour force are taken by UNESCO.

Concentration Ratio

An ideal measure for industry's concentration is the Herfindahl-Hirschman index; however, its calculation requires specific information for the whole number of individual firms in each industry and such a dis-aggregate data set is very difficult to be obtained for Greek manufacturing firms. Following a methodology y proposed by Schmalensee (1977) the concentration index is computed as:

$$CR = \frac{(AS_1 - AS_2)^2 (n_1^2 - 1)}{3n_1} + h\,; \quad h = n_1 (AS_1)^2 + (n - n_1)(AS_2)^2$$

where AS_1 and AS_2 are the average market shares of the five largest firms and the remaining firms of the industry, respectively. Using n and n_1 to denote firm population and group of largest firms in the industry (i.e. in the current case this is five) the above index is easily computable. Schmalensee (1977) considers Herfindahl-Hirschman index as the ideal measure and after comparing twelve possible surrogates concludes that, the above index is the second best alternative. Market Share of the top five firms in each industry is calculated using information of total assets in monetary values provided by ICAP. The latter is a private Business Information and Consulting company that reports financial data for Greek manufacturing firms. Data used in the present study are reported from the annual financial directory of Greek manufacturing Sector and they are only available from 1993 and onwards.

Appendix C4.2

To obtain a more formal test of convergence for each industry the methodology of Bernard and Durlauf (1995) and Bernard and Jones (1996 a) is followed. In the present framework a Greek industry *i* is said to converge towards its German counterpart *i* if the TFP gap (i.e. $TFPgap = \ln(A_{i,F,t}) - \ln(A_{i,j,t})$, i=1,...,$N$) variable is stationary. A test of stationarity is developed by Kwiatkowski et al.(1992) or KPSS for brevity. This test differs from the standard Dickey-Fuller and Perron unit root tests by having a direct null hypothesis of stationarity. The null hypothesis of the KPSS test is implemented for both trend and level stationarity. As it is appeared in both columns of the table below the null hypothesis of stationarity is accepted in all industries. Equivalently, this suggests that for all industries in the sample convergence is at work. The fact that it is possible to accept the null hypothesis in all industries indicates that data of the current study support the formulation of an equilibrium correction model (ECM) as specified in (10). The economic content of the observation is that for industries where TFP gap is not stationary, the long-run average productivity growth would be different (Bernard and Jones 19996a).

Unit Root Tests

Industry	Trend	Level
Food products, beverages and tobacco	0.154	0.391
Textiles, textile products, leather and footwear	0.157	0.391
Wood and products of wood and cork	0.148	0.394
Pulp, paper, paper products, printing and publishing	0.143	0.395
Coke, refined petroleum products and nuclear fuel	0.143	0.391
Chemicals and chemical products	0.15	0.386
Rubber and plastics products	0.148	0.392
Other nonmetallic mineral products	0.136	0.419
Basic metals	0.148	0.402
Fabricated metal products, except machinery and equipment	0.139	0.379
Machinery and equipment, n.e.c.	0.145	0.369
Electrical machinery and apparatus, nec	0.157	0.387
Radio, television and communication equipment	0.15	0.4
Medical, precision and optical instruments, watches and clocks	0.144	0.154
Other transport equipment	0.2	0.395
Manufacturing nec	0.158	0.396

Notes: Null Hypothesis in both columns is that TFP gap is stationary or equivalently that each industry converges
Critical Values are taken by KPSS (1992) for trend stationarity are: 2.5%:0.176;1%:0.216
Critical Values for Level stationarity are: 2.5%:0.574; 1%:0.739
The maximum lag order of the test is derived by a rule provided by Schwert (1989). The Schwert criterion for the current test chooses 8 as maximum lags for all industries.

Appendix C4.3 TFP Growth and Bounded Learning

	1982-2003 (1)	1982-2003 (2)	1982-2003 (3)	1982-2003 (4)	1982-2003 (5)	1982-2003 (6)
Estimation	FGLS	IV	FGLS	FGLS	IV	IV
$\Delta \log TFP_{i,F,t}$	0.248***	0.310*	0.223***	0.214***	0.171	0.162
	(3.61)	(1.85)	(2.93)	(2.75)	(0.87)	(0.81)
log TFPgap	0.0222*	0.131**	0.0827***	0.0364*	0.337**	0.283
	(1.92)	(2.16)	(5.00)	(1.83)	(2.02)	(1.56)
$\log\left(Trade/X\right)^2_{i,t-1}$	-0.00474	-0.0124				
	(-0.98)	(0.76)				
$\log\left(Trade/X\right)_{i,t-1} * TFPgap$	-0.00356	0.014				
	(0.89)	(1.49)				
$\log(R\&D/VA)_{i,t-1}$	0.0191***	-0.00902	0.0253***	0.00482	-0.0251	-0.0246
	(4.82)	(0.45)	(5.20)	(0.66)	(0.52)	(0.65)
$(R\&D/VA)_{i,t-1} * TFPgap$	-0.00757***	0.00844	-0.00839**	0.00125	0.0336	0.0299
	(4.17)	(0.77)	(2.44)	(0.27)	(0.87)	(0.95)
$\log\left(\frac{MinWage}{MedianWage}\right)_{t-1}$	-0.0974***	-0.0883	-0.145***	-0.215***	-0.142**	-0.142**
	(3.29)	(1.53)	(3.84)	(5.10)	(2.02)	(2.06)
$(IMPG7/X)_{i,t-1}$			-0.0708***		-0.0298	
			(6.94)		(0.36)	
$(IMPG7/X)_{i,t-1} * TFPgap$			0.0306***		0.0396	
			(4.24)		(0.76)	
$(EXPG7/X)_{i,t-1}$				-0.00856		0.0174
				(0.91)		(0.23)
$(EXPG7/X)_{i,t-1} * TFPgap$				-0.00855		0.00954
				(1.19)		(0.29)
R-squared	0.2039	0.22	0.05	0.215	0.09	0.26
Observations	264	240	180	180	156	156
Number of sectors	12	12	12	12	12	12
Wald test, F- test; P-value	262.68 (0.00)	486.92 (0.00)	205.76 (0.00)	138.83 (0.00)	173.53 (0.00)	170.63 (0.00)
Sargan Test; P-value		1.739 (0.7836)			11.403 (0.04)	5.684 (0.338)

Notes: Absolute *t*-statistics in parentheses represent * significant at 10%; ** significant at 5%;*** significant at 1%.All variables are weighted by industry's value added in manufacturing sector at the first year available. The FGLS estimator corrects for heteroscedasticity and cross-sectional correlation. In IV specifications, the endogenous variables are trade, import and export shares and its associated interacted terms and the R&D interacted term. The instruments used are their lagged values dated *t*-2 and *t*-3. The wald test refers to the hypothesis that the estimated coefficients are jointly zero in the FGLS estimation while the F-test tests the same hypothesis after the IV estimation. For an interpretation of the Sargan test, see table 4.5 and the main text.

Appendix C4.4 TFP Growth and Alternative Measures of R&D

	1982-2003 (1) FGLS	1982-2003 (2) IV	1982-2003 (3) FGLS	1982-2003 (4) IV
$\Delta \log TFP_{i,F,t}$	0.264***	0.319*	0.241***	0.323*
	(3.81)	(1.92)	(3.54)	(1.93)
log TFPgap	0.058***	0.128***	0.066***	0.113
	(4.98)	(3.10)	(6.68)	(1.59)
$\log(Trade/X)_{i,t-1}$	-0.089***	-0.039	-0.085***	-0.0814
	(7.71)	(0.61)	(7.01)	(0.75)
$(Trade/X)_{i,t-1}*TFPgap$	0.032***	0.027	0.031***	0.0491
	(4.72)	(0.93)	(4.47)	(0.97)
$\log(R\&Dstock/VA)_{i,t-1}$	0.023***	-0.024		
	(5.31)	(-0.55)		
$(R\&Dstock/VA)_{i,t-1}*TFPgap$	-0.007***	0.011		
	(4.98)	(0.70)		
$\log(R\&D/VA)^2_{i,t-1}$			-0.0025***	-0.0005
			(6.35)	(0.090)
$(R\&D/VA)^2_{i,t-1}*TFPgap$			0.0009***	0.0002
			(5.49)	(0.040)
(Min Wage/Median Wage)$_{t-1}$	-0.104***	-0.078	-0.0596**	-0.0551
	(3.75)	(1.26)	(2.04)	(0.64)
R-squared		0.3349		0.3418
Observations	264	240	264	240
Number of sectors	12	12	12	12
Wald Statistic, F- test; P-value	321.08 (0.00)	491.08 (0.00)	315.94 (0.00)	497.37 (0.00)
Sargan Test for the validity of Instruments; P-value		2.639 (0.61)		1.594 (0.809)

NOTES: Absolute *t*-statistics in parentheses represent * significant at 10%; ** significant at 5%;*** significant at 1%. All variables are weighted by industry's value added in manufacturing sector at the first year available. The FGLS estimator corrects for heteroscedasticity and cross-sectional correlation. In IV specifications, the endogenous variables are log TFPgap, $\log(Trade/X)_{i,t-1}$, $(Trade/X)_{i,t-1}*TFPgap$ and $(R\&D/VA)^2_{i,t-1}*TFPgap$. The instruments used are their lagged values dated *t*-2 and *t*-3. The wald test refers to the hypothesis that the estimated coefficients are jointly zero in the FGLS estimation while the F-test tests the same hypothesis after the IV estimation. For an interpretation of the Sargan test, see table 4.5 and the main text.

Appendix C4.5 Sources of TFP Growth with France as a Frontier Economy

	1982-2003 (1) FGLS	1982-2003 (2) IV
$\Delta \log TFP_{i,F,t}$	0.314***	0.344**
	(4.58)	(2.28)
log TFPgap	0.297***	0.0146
	(4.13)	(0.42)
$\log(Trade/X)_{i,t-1}$	-0.0962***	-0.116***
	(8.32)	(2.60)
$(Trade/X)_{i,t-1}$*$TFPgap$	0.0322***	0.0535***
	(5.60)	(2.91)
$\log(R\&D/VA)_{i,t-1}$	0.0254***	0.0368*
	(5.47)	(1.81)
$(R\&D/VA)_{i,t-1}$ *TFPgap	-0.0103***	-0.0233**
	(5.29)	(2.27)
(Min Wage/Median Wage)$_{t-1}$	-0.0935**	-0.0964
	(2.07)	(1.55)
R-squared	0.1520	0.4397
Observations	242	220
Number of sectors	11	11
Wald test, F-test; P-value	328.98 (0.00)	19.56 (0.00)
Sargan Test ; P-value		1.275 (0.8656)

NOTES: Absolute *t*-statistics in parentheses represent * significant at 10%; ** significant at 5%;*** significant at 1%. All variables are weighted by industry's value added in manufacturing sector at the first year available. The FGLS estimator corrects for heteroscedasticity and cross-sectional correlation. In IV specifications, the endogenous variables are log TFPgap, $\log(Trade/X)_{i,t-1}$, $(Trade/X)_{i,t-1}$*$TFPgap$ and $(R\&D/VA)^2{}_{i,t-1}$*$TFPgap$. The instruments used are their lagged values dated *t*-2 and *t*-3. The Wald test refers to the hypothesis that the estimated coefficients are jointly zero in the FGLS estimation while the F-test tests the same hypothesis after the IV estimation. For an interpretation of the Sargan test, see table 4.5 and the main text.

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