Does Greece learn from Germany? Technological Catch-Up and the Channels of Productivity Growth in the Greek Manufacturing Sector

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Abstract

The paper examines the determinants of productivity growth in Greece; a country that falls behind the international technological frontier. We set as a benchmark technological leader, the German manufacturing sector, posing the question whether technological transfer from Germany to Greece can generate productivity gains in the latter country. Within this framework, technological transfer can boost productivity growth autonomously but it can also interact with other certain factors such as trade and R&D in improving laggard country's absorptive capacity. The puzzle of productivity growth in the Greek Manufacturing sector is completed with the consideration of factors related to the general business and institutional environment of the country.

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1. Introduction

In both neoclassical and endogenous growth theories, the role of technology as a source of economic growth is well acknowledged (Sharpe, 2002). According to the neoclassical setting, technological progress is taken as exogenous to factors of production and thus any technical change is regarded as disembodied (i.e. the so-called *manna from heaven*) while according to the endogenous growth model, the factors of production play a more active role whereby technological improvements are embodied in the purchase of inputs to production.

To conceptualise technology in the growth process indicates mainly countries' ability to imitate or transfer technological developments already invented somewhere else. Abramovitz (1986) notes that the main target of industrialised countries during the second half of the last century was to incorporate unexploited technology used in advanced countries into their production processes. In conformity with this view, the successful adoption of foreign technology can be a convincing explanation itself for the successful productivity catch-up. Needless to say, the role of technology diffusion is yet more important for countries that fall behind technologically. Accordingly, the economic research agenda is driven by our need to understand either the factors that contribute to a faster technology transfer (Cameron et al. (2005)) or the barriers that slow down the adoption process, enlarging productivity disparities around the world (Parente and Prescott (1994)).

The present paper seeks to offer an analytical narrative contributing to the productivity convergence debate. As the title of the paper implies, we focus on a traditionally laggard country, (i.e. Greece), investigating whether there is potential of knowledge transfer from a leader country (i.e. Germany). The main objective of our study is to explore the sources of productivity growth in a group of 17 Greek manufacturing industries over the period 1980-2003 accrediting special focus on the role of technological catching-up. The theoretical proposition that is derived from the standard convergence literature suggests that the further Greece's productivity falls behind, the higher the potential for technology transfer from Germany; hence the faster the pace of productivity growth. When convergence is implemented at later stages of the development path, the productivity growth of the "follower" country slows down while the potential for further technology transfer is limited.[2]

The selection of Greece and Germany for our empirical exercise is based on two criteria. First, Germany is technological leader in the global economy and second, Greece has traditionally strong bilateral trade relationships with Germany. It is mainly the second criterion that helps us to investigate the importance of technological transfer through the conduit of trade. Within this framework, attention is given to the dual character of standard productivity drivers. This is that we estimate the direct role of R&D in accelerating the rate of innovation but we also investigate whether R&D can improve the country's absorptive capacity by adopting promptly and effectively the technological developments from abroad.

To explore the sources of productivity growth becomes a misleading task if one ignores the conditions of the domestic market environment. There is an ongoing conception in the literature that the different degree of stringency in both product and labour market is a substantial source of productivity differentials across countries. Countries that are in favor of more flexible labour market policies are more capable to reallocate resources across economic activities, so in the event of an external shock the reaction is always more effective. Traditionally, many countries in Europe, including Greece, have adopted an over protective labour market legislation maintaining many chronic rigidities while US operates in a less rigid institutional frame without heavy regulation, creating an ideal business environment for the stimulation of dynamic

[2] This implies pretty much that as a country closes the technology gap with the frontier then productivity growth is further stimulated from country's own efforts, such as domestic innovative activity, capital deepening and so forth. The analytical framework of the next section provides a more formal representation of this argument.

efficiency.[3] The above considerations convince us to shed some light on the impact of the domestic market conditions on productivity growth. More precisely, we include proxies for the degree of labour market rigidity and market concentration.

The structure of the paper is the following: section 2 seeks to familiarize the reader with the distortions in the Greek labour over the period 1980-2003. In this discussion, we attempt to link how chronic institutional rigidities affect productivity performance. The reader can find an overview of the productivity growth literature Bournakis (2009). Sections 3 and 4 present the productivity convergence framework as well as issues related to TFP measurement. Section 5 presents the econometric results and section 6 concludes.

2. Labour Market Distortions in Greece and their Effect on Productivity

Scarpetta et al. (1999) is a standard reference in the literature of labour and product market distortions. Although these indices are informative, they are time invariant within a country making their application misleading within a cross-country context. Alternatively, we can measure the effect of labour market distortions on productivity growth through the implementation of minimum wage. This measure is rather attractive in our case as it captures the fact that during 1980s approximately 15-20 % of the Greek labour force was in receipt of the minimum wage while at the same period the same figure in USA and France was 5% and 12%, respectively (Koutsogeorgopoulou (1994)).

During 1980s, the ratio of minimum to average wage in Greece was the highest within the OECD countries (Table 1, Neumark and Wascher (2004)). More recently, this ratio has been

[3] The facts that wage determination is subject to a negotiation procedure with the trade unions but independent from the efficiency level as well as the burden of high labour costs due to heavy regulation (i.e. high fire costs) imply the devotion of additional financial resources that otherwise could have been used for the adoption of production techniques necessary for the stimulation of dynamic efficiency. As firms fail to upgrade the degree of dynamic efficiency, productivity growth is affected negatively in the long run.

very close to the OECD average. Two factors need highlighting for the existence of a high minimum to average wage ratio in Greece at that period. First, the presence of powerful trade unions in many industries led the commonly agreed minimum wage to be much greater than the perfectly competitive wage. Second, during 1980s there was a welfare program at work seeking to narrow income and wage inequalities that had existed in Greece previously. A major component of this policy agenda was the introduction of a minimum wage indexation, which made automatic pay adjustments (known as ATA[4]) compensating low income earners for erosion in wages due to inflation. ATA operated in a gradual manner compensating those on low income with the highest payment while workers in the upper income scale received almost no compensation. Although the ATA system was abolished in 1991, trade unions have maintained a strong bargaining power in the minimum wage determination.

The realisation of a minimum wage policy enhances a standard trade off; on the one hand the insiders of the labour market are better off from the reduction of wage differentials while on the other hand, outsiders are negatively affected due to an increase in the unemployment rate. Regulating the market through a minimum wage policy implicitly means productivity losses but many empirical studies are silent about this effect (Siebert (1997)).[5]

Within a group of OECD countries, France and Greece have the highest minimum to median wage ratio as shown in Table 1. It is commonly accepted that minimum wage is often resulted in from powerful trade unions, which also happens to be a representative case in the Greek labour market. In the econometric section, we address the issue whether an increase in unit labour costs due to minimum wage regulation surpasses productivity growth.

[Insert Table 1 Here]

[4] ATA stands for the Greek acronyms of the Automatic Price Adjustment.
[5] In the likely case, that minimum wage slows down productivity this is reflected into higher levels of unemployment.

Market structure affects productivity performance but so far the empirical evidence is far from being conclusive. According to the Schumpeterian notion, a competitive market ensures the reduction of slack and the promotion of innovation that leads to high levels of dynamic efficiency.[6] For the Greek case, the empirical evidence on the competition-productivity nexus is rather poor. A key stylized fact that is derived from the existing studies suggests that the level of concentration in the Greek manufacturing sector has increased after the accession to EU (Anagnostaki and Louri (1995)). This finding indicates that the participation in an integrated European market has created severe competition that makes many small and medium sized enterprises to shut down. Fotopoulos and Spence (1997) confirm a similar pattern acknowledging as a source of market concentration the existence of significant barriers to entry. Nonetheless, Tsekouras and Daskalopoulou (2006), while admit the importance of a highly competitive environment, reveal that a highly concentrated market is not a *de facto* fatal disease. Although in our empirical analysis we use a different framework, we seek to contribute to the same concentration-efficiency debate as the above studies.

3. Theoretical Underpinnings and Model Specification

Following previous models in the productivity convergence literature (Bernard and Jones, 1996a, 1996b; Cameron et al., 2005) we consider that Greece's (*GRC*) production function in industry *i* is under constant returns to scale and is written as:

$$Y_{GRC,i,t} = A_{GRC,i,t} f(K_{GRC,i,t} L_{GRC,i,t}) \tag{1}$$

Y, *K* and *L* represent value added capital and labour, respectively while subscript *t* indexes time. Parameter *A* stands for a measure of technical efficiency in a Solow manner whose empirical approximation is an index of Total Factor Productivity (TFP). The exact form of production function (1)

[6] See Vickers (1995), Nickell (1996), Caves (1987) and Jovanovic's (1982) for the most important contributions in this area.

is a homogenous Cobb-Douglas of degree one exhibiting diminishing marginal returns to the production inputs. Although we do not show here the production function in German industry *i* at year *t*, it has exactly the same settings as (1).

For our empirical framework, we assume that at a given point in time Germany (*GER*) has a higher level of TFP than Greece (*GRC*) allowing us to specify *GER* as the "technological frontier" economy (Cameron et al., 2005). Consequently, Greece (*GRC*) is the technologically laggard country throughout the analysis. Bernard and Jones (1996a, 1996b) suggest that technological parameter *A* for the laggard country should be modeled as a function of domestic innovation and technology transfer from the frontier country. Therefore, the efficiency parameter *A* or equivalently Greece's (*GRC*) TFP growth in industry *i* is given by:

$$\Delta \ln A_{i,GRC,t} = \gamma_{i,GRC,t} + \lambda_{i,GRC} \ln\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right) \qquad (2)$$

In equation (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. The ratio $\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right)$ represents the variable of technology transfer from *GER* to *GRC* indicating that the higher the gap between Greece and Germany in industry *i*, the greater the potential for productivity growth through technology transfer. Since *GER* is the frontier economy its productivity growth depends only on domestic innovation implying that the second term in equation (2) is abolished, hence Germany's TFP growth in industry *i* is given by:

$$\Delta A_{i,GER,t} = \gamma_{i,GER,t} \qquad (3)$$

Subtracting equation (3) from (2) yields the following relationship:

$$\Delta \ln\left(\frac{A_{i,GRC,t}}{A_{i,GER,t}}\right) = (\gamma_{i,GRC,t} - \gamma_{i,GER,t}) + \lambda_{i,GRC} \ln\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right) \qquad (4)$$

Equation (4) represents an equilibrium correction model (ECM) assuming in the long-run that: $\Delta \ln\left(\frac{A_{i,GRC,t}}{A_{i,GER,t}}\right) = 0$. In the steady state the following condition holds:

$$\ln\left(\frac{A^{*}_{i,GER}}{A^{*}_{i,GRC}}\right) = \frac{\gamma_{i,GER} - \gamma_{i,GRC}}{\lambda_{i,GRC}} \qquad (5)$$

Equation (5) describes that in the steady state, relative TFP depends on the rates of innovation in the frontier economy $\gamma_{i,GER}$, the non-frontier economy $\gamma_{i,GRC}$ and on the speed of technology convergence λ between the two economies. From equation (5), we also imply that as long as the German innovation rate is higher than the Greek one (i.e. $\gamma_{i,GER} > \gamma_{i,GRC}$), then Germany will remain the technological frontier country, that is $\ln\left(\frac{A^{*}_{i,GER}}{A^{*}_{i,GRC}}\right) > 0$. Vector $\gamma_{i,GRC}$ includes variables that traditionally are considered as innovation drivers, such as R&D, trade, and conditions in the labour and product market.

The theoretical considerations discussed above underpin that the rate of productivity growth is also dependent on the speed of catch-up process between industries in the two countries. Having in mind that parameter *A* is measured by a TFP index, the econometric specification for the sources of TFP growth in Greek industries takes the following form: [7]

$$\ln \Delta TFP_{i,GRC,t} = \rho_{i,GRC} + \alpha \ln \Delta TFP_{i,GER,t} + \underbrace{\gamma \Gamma_{i,GRC,t-1}}_{\text{Innovation Rate}} + \underbrace{\lambda \ln TFPgap}_{\text{Technology Transfer}}$$
$$+ \underbrace{\mu \Gamma_{i,GRC,t-1} * \ln TFPgap}_{\text{Absorptive Capacity}} + e_{i,GRC,t} \qquad (6)$$

[7] See working paper version for the theoretical set up of the model and about estimation issue of an ADL (1, 1) specification see Pesaran and Smith (1995) and Hendry (1995).

We also augment (6) with $\rho_{i,GRC}$ to control for industry individual heterogeneity, α to capture the direct impact of TFP growth in German industries and a disturbance error term $e_{i,GRC,t}$. Note the term TFP gap is defined as: $\log\left(\frac{TFP_{i,GER,t-1}}{TFP_{i,GRC,t-1}}\right)$.

4. Measurement of TFP, Growth rates and Levels

A discussion about the data sources can be found in the Appendix. We devote this section to the construction of TFP, which is a key variable of the empirical part. TFP is calculated from the Divisia index approach developed by Caves et al. (1982). Maintaining the assumption of constant returns to scale, the TFP growth in industry *i* is defined as:

$$\ln\left(\frac{TFP_{i,c,t}}{TFP_{i,c,t-1}}\right)=\ln\left(\frac{Y_{i,c,t}}{Y_{i,c,t-1}}\right)-a_{L,t}\left[\sum_{j=1}^{3}\bar{\sigma}_{i,c}^{j}\ln\left(\frac{L_{i,c,t}^{j}}{L_{i,c,t-1}^{j}}\right)\right]-(1-a_{L,t})\ln\left(\frac{\tilde{K}_{i,c,t}}{\tilde{K}_{i,c,t-1}}\right) \quad (7)$$

where c refers to Greece (*GRC*) and Germany(*GER*). Output *Y* is measured by value added, labour input is the weighted sum of three different types of workers and $\tilde{K}$ denotes capital stock adjusted for the degree of capacity utilization. The labour share a is initially defined as the ratio of labour compensation to value added entering equation (7) as a weighted measure: $a_{L,t}=\frac{a_{i,c,t}+a_{i,c,t-1}}{2}$. With constant returns to scale, capital share is equal to one minus labour share. The long period under study yields that the composition of labour changes over time resulting in a biased productivity measurement if one treats labour input as homogeneous.[8] Consequently, labour input takes a translog form (Young (1995)) expressed by the sum of three educational groups : (i) high-skilled labour (University graduates), (ii) medium-skilled labour (Intermediary Education graduates) and (iii) low-skilled labour (no formal educational qualifications).[9]

[8] Jorgenson et al. (2005) point out the importance of labour quality differences in growth accounting exercises. Typically, a shift from low to high skilled labour results in an increase in output growth. To the degree that the proportion of high quality workers in Greek manufacturing industries has increased during the sample period, the growth accounting decomposition has to take into account this effect in order to obtain the right TFP measure.

[9] Note the Greek educational system has adopted the German prototype over the last thirty years making the classification of workers consistent. Nonetheless, this does not exclude the possibility that the systems, although identically structured, might have qualitative differences. Certainly, this issue is not easily captured by the existing measure. We refer to the EUKLEMS Growth

The labour input L of each group j is measured by the total hours worked per annum. The share σ in the bracket term denotes the weighted labour compensation share of each group j in total labour compensation and defined as: $\bar{\sigma}_{i,c}^{j} = \frac{\sigma_{i,c,t}^{j} + \sigma_{i,c,t-1}^{j}}{2}$.

The data used throughout the paper are taken from OECD-STAN and Groningen Growth Development Centre (GGDC)-EU KLEMS. These databases are fully compatible with each other as raw data are obtained from Supply and Use tables (SUTs) of the National Accounts system. One characteristic of the EU KLEMS (2007) database is that provides information for the different components of the production inputs allowing for an accurate productivity measure than a crude TFP index.

To make TFP indices comparable across countries, valued added, labour compensation and investment need to be measured in a common currency. O' Mahony (1996) shows that relative TFP levels vary substantially depending on the conversion factor used. The dilemma faced in studies of international productivity comparison is whether to choose an industry or a country specific Purchasing Power Parity (PPP) exchange rate. The main merit of the former conversion factor is that reflects differences in retail prices across industries as well as it accounts for differences in the distribution of output across industries (van Aark and Trimmer, 2001). Nonetheless, apart from the GGDC database (International Comparison of Productivity Program (ICOP)), which reports benchmark data for 1997 industry specific conversion factors are difficult to find. For the purposes of the present analysis, we use an aggregate PPP exchange rate based on prices of final expenditure from the World Bank Development indicators (International Comparison Project (ICP)) to convert data into international USD. After converting data into a common currency, we adjust value added data into 1995 constant prices using industry-specific price deflators.

Capital stock is calculated via the perpetual inventory method as follows:

$$K_{i,j,t} = (1-\delta)K_{i,j,t-1} + I_{i,j,t-1} \tag{8}$$

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and Productivity Accounts manual if the reader needs to know more information about the methodology used for the construction of labour quality indices across countries.

where δ is the physical depreciation rate, defined at the constant rate of 10% for all industries and I denotes investment in fixed capital assets. The type of assets includes compensation only for the services of fixed reproducible assets excluding inventories. We think that any potential problem from this omission is of minor importance as inventories are only short-term cycles without trends over longer periods leaving, thus unaffected the results from growth accounting.[10] The investment flows are converted into constant 1995 prices using gross fixed capital formation deflators taken from OECD-Economic Outlook database.[11] We initialize the series of capital stock from this formula:

$$K_{i,j,1980} = \frac{I_{i,j,1980}}{g_i + \delta} \qquad (9)$$

where g is the average growth rate of industry i's investment over the whole period and the subscript 1980 indicates the first year with available investment data. The measure of capital stock in (8) implicitly assumes that capital stock is always under full utilization. Nonetheless, this assumption is far from being true as the effective use of capital is strongly procyclical depending on the broader economic conditions. Hall's (1990) exogeneity condition about the Solow residual fails if capital stock is under (over)-utilized as it is likely to lead to an over (under)-estimated TFP measure. To express capital stock in effective units, we apply a rate of capacity utilization reported from the Business Tendency Surveys of OECD (Main Economic Indicators database). This rate assesses capacity utilization with reference to the use of physical capital assets such as buildings, plants, machinery, vehicles etc.[12] The effective use of capital stock is obtained by multiplying the actual capital stock with the rate of capacity utilization:[13]

[10] The current capital account does not also include land compensation. To the best of our knowledge, there are not available data concerning the rates of return on land at the industry level implying that this issue cannot be effectively tackled within the existing data resources

[11] The German deflator series has missing values for the period 1980-1991. The missing data are filled in applying an imputation stata technique. Note that the investment deflator is only country specific, a feature that might be a potential problem if one takes into account that the formation of capital assets is not homogeneous across industries. This consideration also implies that price movements of various capital assets might differ substantially over time. Nonetheless, the present aggregate deflator is the best alternative solution, given the shortage of data for different types of assets along with the lack of industry specific investment deflators.

[12] The survey of capacity utilization takes place on a quarterly basis and refers to the aggregate manufacturing sector. The central question posed to the business units is: *What is your current level of capacity utilization*? The respondents take into account the use of capital inputs but it is also likely that some of them to provide answers with reference to financial factors. The reader can find a detailed discussion about the calculation of the rate of capacity utilization in the OECD manual (Business Tendency Surveys Handbook).

[13] The current measure of capacity utilization is time variant but industry invariant. This is not necessarily a reasonable assumption as the level of utilization might depend on the industry capital-labour ratio. Usually, an industry with a high capital-labour ratio is more likely to be subject to a low utilization rate.

$$\tilde{K}_{i,j,t} = u_{j,t} K_{i,j,t} \quad (10)$$

where *u* denotes the percentage rate of capacity utilization.

Finally, we calculate relative TFP in industry *i* between Greece and Germany. The relative TFP index is defined as:

$$\ln\left(\frac{A_{i,GRC,t}}{A_{i,GER,t}}\right) = \ln\left(\frac{Y_{i,GRC,t}}{Y_{i,GER,t}}\right) - \varphi_L \left[\sum_{j=1}^{3} \bar{\psi}^{j}_{i,c} \ln\left(\frac{L^{j}_{i,GRC,t}}{L^{j}_{i,GER,t}}\right)\right] - (1-\varphi_L)\ln\left(\frac{\tilde{K}_{i,GRC,t}}{\tilde{K}_{i,GER,t}}\right) \quad (11)$$

the labour share is now defined as: $\varphi_L = \dfrac{a_{i,GRC,t} + a_{i,GER,t}}{2}$ while the weighted labour compensation share of each group *j* is defined as: $\bar{\psi}^{j}_{i,c} = \dfrac{\sigma^{j}_{i,GRC,t} + \sigma^{j}_{i,GER,t}}{2}$

Table 2 shows average TFP growth rates and relative TFP levels of the aggregate manufacturing sector for Greece and Germany over the period 1980-2003. After dropping from the sample the outlier observations,[14] the results show that the Greek manufacturing sector has grown on average by 7.35% over the sample period while the German counterpart has clearly experienced a lower rate of productivity growth equal to 0.45%. This preliminary evidence reveals that the non-frontier country tends to grow faster lending support to the core proposition of the neoclassical theory of convergence. The last column of Table 2 highlights German's technological leadership compared to Greece. One can interpret the figures in last column as follows: Greece's productivity in 1980 is only 7.8% of the German's, while in 2003 this number has increased to 36%. Another interesting remark from Table 2 is that Greece experiences quite rapid growth rates during 1980s whereas there is a slowdown 1990s, which explains to a large degree why TFP gap between the two countries remains large at the end of the period.

[Insert Table 2 Here]

[14] This test is implemented in STATA 10 with the command `hadimvo`. The total number of observations dropped is twenty-seven.

5. Econometric Estimation and Results

5.1 Specification Tests and Benchmark Estimates

After a careful measurement of TFP growth and relative TFP, we can proceed with the econometric estimation of the econometric model as specified in equation (6). As it stands, equation (6) is a fixed effects specification with $\rho_{i,j}$ denoting time-invariant industry dummies. We prefer the Within-Group Fixed Effects (FE) estimator to least squares dummy variable technique (LSDV) as the bias induced by the former estimator tends to be zero in panels with relatively long time dimensionality.[15]

We perform some standard specification tests concerning the behavior of the error-term $e_{i,GRC,t}$ in columns (1) and (2) of Table 3. First, the modified Wald test refers to whether the error term has a constant variance across industries, $Var(e_{i,t}) = \sigma_i^2$. Second, the Pesaran (2004) statistic tests the cross-sectional dependence of the residuals, $Cor(e_{i,t}e_{k,t}) \neq 0$ for any industry $i \neq k$. These tests indicate that heteroscedasticity and cross-sectional correlation are existent in our sample. Third, the Wooldridge (2002) test examines the hypothesis of serial correlation in the residuals, $Cor(e_{i,t}e_{i,t-1}) \neq 0$. According to this test, we are able to accept the null hypothesis of no first order serial correlation at conventional levels of significance.

Specifications in columns (3)-(6) correct for group wise heteroscedasticity and cross-sectional correlation using the Feasible Generalized Least Squared (FGLS) estimator.[16] The sources of TFP growth included in column (3) are the share of imports and exports with Germany, R&D share, their associated interaction terms and the minimum to median wage.

[15] 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. Evidence from Monte Carlo experiments (Judson and Owen, 1999) shows that if $T>N$, where N is the number of cross-sections then the FE estimator performs better than the instrumental variable (IV)-GMM estimator. The current panel consists of 23 years and 17 industries indicating that the FE estimator outperforms both LSDV and GMM.

[16] The software package used to estimate regressions throughout the paper is STATA 10. 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.

[Insert Table 3 Here]

Focusing our interpretation on the estimates of columns (3)-(6), the positive and statistically significant coefficient of TFP gap confirms the stylized fact that the further an industry lies behind the frontier, the faster is the rate of TFP growth. In the literature, the value of this coefficient varies substantially, the relatively large value of the present coefficient- within the interval 8.9-24%- suggests a substantial technological falling behind of Greece resulting in a large degree of potential for technology transfer. On the contrary, for a similar model of productivity convergence between Japan and USA (Cameron (2005)) the coefficient of autonomous technology transfer lies between 3.6-7.3%, while between France and US (Khan (2006)) is between 6.4-6.7%. The low speed of adjustment in the above studies signifies that laggard countries have almost exhausted technology transfer as a source of productivity growth; hence, other policy instruments should be explored to stimulate growth.

In column (3), the estimates of trade variables initially suggest an ambiguous pattern. The level variables have a negative and statistically significant coefficient, while their associated interaction terms with TFP gap reveal that raising the shares of imports and exports with Germany accelerates the pace of technology transfer. To check whether this negative pattern persists, we allow for time hysteresis in the exploitation of learning effects from imports and exports. Higher order lags of trade variables are considered in columns (4) and (5). The coefficient of the second lag import share now appears positive and statistically significant at the 10% level while the coefficient of the third order lag indicates significance at the 1% level. Nonetheless, the second and the third order lag of exports remains negative suggesting that only import induced benefits are present in the Greek manufacturing sector and their realization is implemented with some time hysteresis. On the contrary, the role of imports and exports is evident on accelerating the speed of technology transfer throughout the whole range of specifications.

The coefficient of R&D share is positive and statistically significant at the 1% percent level in all specifications of Table 3. Nonetheless, the quantitative effect of the R&D estimate- also known as the social return to R&D- is much weaker from the estimates revealed in the literature. Currently our coefficient lies within the interval 4.9-5.5% while in some benchmark studies of the literature, the social return to R&D lies between 21-76% (Griliches and Lichtenberg (1984)) and 29-43% (Scherer (1982, 1984)). As far as the dual role of R&D is concerned, the one-year lag interaction term of R&D with TFP gap has a negative sign but the expected positive effect is uncovered with higher lags of order t-2 and t-3. This finding suggests that domestic R&D activity contributes to a more effective understanding of the frontier technology, hence boosting domestic productivity growth. The positive impact of R&D-based absorptive capacity on TFP growth, even though it is experienced with a quite substantial time lag is in line with the finding of Griffith et al. (2003, 2004) and Kneller (2005).[17] As expected, the coefficient of contemporaneous TFP growth in Germany is always positively associated with productivity growth in Greece. Looking at the estimates of column (5), one can argue that a 1% in the rate of TFP growth in a German industry raises the rate of TFP growth in the Greek counterpart by 4.2%. Intuitively, this coefficients indicates that productivity growth in the frontier country is always beneficial for the laggard country.

Another variable of interest in Table 3 is the minimum to median wage that captures the effect of labour market conditions on productivity growth. As already discussed, labour market regulation through minimum wage is likely to impede efficiency performance increasing labour cost adjustments far above the market-clearing levels hampering the rate of TFP growth. The evidence produced from our analysis confirms the negative impact of minimum wage on TFP growth in almost all specifications of Table 3. The revealing effect stresses the powerful role of trade unions in Greece, which to some degree can cause reverse effects on the manufacturing sector performance.

The results also imply the trade off caused from the implementation of the welfare program in 1980s. To the extent that the current measure of minimum wage is a close proxy for the whole set of underlying labour market rigidities, one can claim that the existence of a welfare state has increased labour cost adjustments driving resources away from productive activities into various employment benefits. The fact that Greece experience one of the highest minimum to median ratios within a group of OECD countries along with the negative impact of this measure on TFP growth (Khan (2006) finds a

[17] In a sample of non-frontier OECD countries, Kneller (2005) obtains an estimated parameter for the interaction term of R&D with TFP gap equal to 8%, while in the present study this estimated parameter is equal to 1% and only after considering the third lag.

similar effect for the French Manufacturing sector) suggest that the negative link between labour protective policies and productivity tends to be systematic.

Column (6) introduces domestic market concentration as a determinant of productivity growth.[18] Note results in column 6 refer to a reduced sample of eleven years, as data for CR are only available from 1993 onwards. The revealed pattern confirms that the greater the concentration ratio in the market the lower the rate of TFP growth. Interestingly, the quantitative effect of this estimate is rather robust suggesting that a 1% increase in the degree of concentration decreases the rate of TFP growth by almost 30%. Regarding the estimates of the remaining variables, the main message is that many estimated parameters are relatively weaker in statistical terms. Estimating a smaller sample, the TFP gap coefficient is now significant only at the 10% level. This result reflects the reduction in the size of the initial sample implying that as the gap between Greece and Germany closes - although quite slowly in some industries - technology transfer becomes a less important source of productivity growth for Greek industries. Interestingly, an estimation on a reduced panel provides a substantially higher value of social return to R&D (i.e. 8.5%) while all the interaction terms are now statistically insignificant at conventional levels. The pattern of the insignificant estimations of the interaction terms suggests that as time progresses, a process of convergence is at work, therefore improvements in absorptive capacity are not as important as when the country falls far behind the frontier. Furthermore, as the country closes the gap that separates it from the frontier further stimulations of TFP growth should be emanated from country's own resources and not from its ability to imitate effectively foreign technology. The latter remark explains why the effect of R&D expenditure becomes substantially larger in the reduced sample.

Results in column (6) provides robust support to the findings of Vickers (1995) and Nickell (1996) who consider concentration as a factor that leads to more slack. On the contrary, Tsekouras and Daskalopoulou (2006) do not reveal a negative impact of the degree of concentration on market efficiency. The reader may treat the consistency of our results with other empirical findings cautiously, as there is no one-to-one correspondence as far as the analytical framework is concerned between our study

[18] The reader can find more details about the construction of this variable in Appendix A.

and the studies mentioned above. For instance, while most of the above papers have a quite similar definition of market concentration to the one used here, productivity is measured in levels and not in growth rates.

5.2 Sensitivity Analysis –Results from an Instrumental Variable (IV) Estimator

Potential endogeneity might exist between TFP growth and some explanatory variables on the right hand side of equation (6). Shocks in relative TFP level in Greece at year *t*-1 affect both TFP growth and the initial distance from the frontier. This realization enhances an endogeneity problem between TFP growth and TFP gap. A similar endogeneity issue might exist between TFP growth and trade. The neoclassical trade theory identifies as a source of comparative advantage the different level of productivity across countries, accordingly productivity is the determinant of trade and not vice versa. To control for endogeneity problems as well as to correct for any potential measurement bias already embodied in the measure of TFP, an IV (instrumental variable) estimator is applied. We choose as instruments higher order lags of the endogenous variables in view of the fact that the residual term is serially uncorrelated based on the reported statistics in Table 3.

The last two rows of Table 4 report some identification tests regarding the validity of instruments. The null hypothesis of the LM test is that the equation is under-identified and the associated statistic follows the Chi-squared distribution with degrees of freedom (L, K+1), where L is the number of instruments and K is the number of endogenous regressors. Alternatively, the null hypothesis of the Sargan test, which follows the Chi-squared distribution with (L-K) degrees of freedom, refers to whether instruments are uncorrelated with the residual term. The reported values of the tests suggest our sets of instruments are valid.

Turning to the IV estimates of Table 4, a general observation is that all estimates are now relatively weaker from a statistical point of view. More importantly, autonomous technology transfer has a coefficient statistically significant only at the 10% level and as we consider higher order lags in some regressors, it becomes insignificant at conventional levels. Innovation rate as reflected through R&D

share is still one of the most important drivers of TFP growth and with a higher social return, 12,7%, compared to the estimates obtained from the FGLS estimation. As before, higher order lags of import share reveal productivity gains, although the estimated coefficient of the third lag is statistically insignificant.

Regarding the interaction terms, the IV estimator confirms the important role of imports and exports on improving absorptive capacity but higher order lags of the interaction R&D term are not appeared statistically significant, without providing any evidence thus about the presence of absorptive capacity gains. Finally, the statistically insignificant coefficient of the minimum to median wage in Table 4 indicates that this type of labour market rigidity has a negative impact on productivity growth but in statistical terms, such an effect is rather weak. The low t-statistics in the IV estimation in comparison with the relatively more robust results in FGLS is an expected cost of controlling for unobserved measurement errors and endogeneity bias. In brief, the most considerable difference between IV and FGLS estimation concerns in the absence of R&D based absorptive capacity even after allowing for time hysteresis.[19]

[Insert Table 4 Here]

[19] For the sake of brevity, we do not report results from further tests of robustness in the specifications presented in Tables 3 and 4. Bournakis (2009) conducts some interesting extensions including a stock measure of R&D as well as controlling for the bounded nature of trade regarding as trade partners the whole group of G-7 countries. The overall pattern of these checks is very similar to the results already shown here.

7. Discussion and Concluding Remarks

This research addresses two main questions. Which are the factors that act as engines of productivity growth and which are the channels that accelerate the pace of technological catch-up? Results from all tables in the paper suggest that autonomous technological transfer is important for the movements of TFP growth. Nonetheless, the speed of autonomous technology transfer is very slow, certainly lower than other findings documented in the literature. The low speed of autonomous technological convergence explains to a large degree why there still exists a high technological gap between Greece and Germany at the end of the period. Excluding column 6 from Table 3, the average value of the coefficients reported is 0.155. From the steady state condition in equation (5), one can derive that a typical Greek manufacturing industry needs about 30 years to close half the gap in technical efficiency that separates it from the German counterpart.[20] This rather discouraging implication[21] suggests that many barriers to technology transfer are still evident in the Greek manufacturing sector preventing from the adoption of productive techniques that are already in use in the frontier country. We believe that the presence of these barriers reflects both industry-specific rigidities and structural problems in the broader business environment. At the industry level, anachronistic organisational schemes decelerate the adoption of foreign technology (Prescott, 1997) while the lack of a central design and implementation of appropriate institutional reforms maintain chronic bureaucratic practices that are serious impediments to a quick adoption of foreign technology.

Apart from the low speed of autonomous technology transfer, the empirical analysis highlights three main findings:

First, the trade impact on productivity growth is robust to alternative trade measures. The critical pattern revealed suggests that the implementation of productivity gains from trade activities occurs with a substantial time lag of three years. The positive estimates of the interaction trade terms states that trade

[20] Appendix B in the working paper shows how it is calculated the time needed to cover half gap of technical efficiency in steady state. In the same appendix there is a formal unit root test for stationarity testing whether the model specified is a good approximation of an equilibrium correction model (ECM).

[21] For comparison purposes, we mention that the time needed to close half gap of technical efficiency between French and US manufacturing is ten years.

must not be ignored in the growth process as it contributes substantially to the faster adoption of the technology of the frontier country.

Second, the effect of R&D on TFP growth is relatively smaller than in other studies but higher rates of innovation are always associated with higher rates of TFP growth.

Third, the variables representing institutional factors, which are minimum to median wage and market concentration, are consistently negative. The empirical findings confirm the existence of a negative impact induced from powerful trade unions. Similarly, the existence of dominant firms in the market causes slack that leads to a slowdown of the aggregate industry's productivity growth.

From a policy-making standpoint, the variable of labour market rigidities can provide interesting insights. Before stating strong conclusions, one might think that the variable currently used describes only some distortions of the labour market. Admittedly, one can find various alternative measures for labour market distortions. Such as the number of missing working hours due to strikes. Note this piece of information is rather difficult to find for a more disaggregate level as well as for a long time series.

The extensive use of a welfare state program in the Greek economy during 1980s has harmed entrepreneurship preventing firms from adjusting their labour inputs effectively and quickly. As a result, firms find it difficult to follow technological opportunities remaining dynamically inefficient for a long period. After all, the crucial question posed is what type of policy reforms within the labour market will have a positive impact on productivity growth? An insightful discussion of this issue is beyond the scope of this paper but less state intervention in labour markets will certainly benefit TFP growth as already suggested by Scarpetta and Tressel (2002). Policy reforms towards a more flexible labour market as well as the adjustment of salary schemes in accordance with the level of labour productivity are highly recommended.

Appendix

Data Sources and Definition of Variables

Total Factor Productivity (TFP)

The source for calculating TFP is Groningen Growth of Development Centre (GGDC) EUKLEMS project.

Output variables:

- Gross value added at current basic prices in millions of Euros (VA), Gross value added price indices Volume, 1995=100 (VA_P),

Input Variables:

- High-skilled labour compensation as a share of total compensation (LABHS),
- Medium-skilled labour compensation as a share of total compensation (LABMS)
- Low-skilled labour compensation as a share of total compensation (LABLS).
- Hours worked by high-skilled persons engaged (H_HS)
- Hours worked by medium-skilled persons engaged (M_HS)
- Hours worked by low-skilled persons engaged (L_MS)
- Capital compensation in millions of Euros (CAP)
- Fixed Capital formation deflators (OECD-Economic Outlook)
- Capacity utilisation(OECD-Main economic Indicators)

Common Currency Conversion:

PPP Exchange rate-National currency per international USD (WBDI- International Comparison Project)

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 and exports over production in nominal values. Trade data are not deflated into real values due to lack of appropriate deflators.

Research and Development

R&D share is defined as the ration of R&D expenditure to value added. Data for R&D expenditure are taken from OECD in current PPP-USD (Main Science and Technology Indicators, releases: 13r2-13r3). This data series starts from 1981 and has many missing values within year intervals. The missing data are filled in with a standard interpolation routine. The nominal R&D values are deflated by an R&D price index, which is defined as: $PR = 0.5(VA\_P + WAI)$, where *VA_P* is a value added industry specific deflator and *WAI* is a nominal manufacturing wage index, taken from the International labour Organization (ILO). The use of this R&D deflator is justified by the notion that half of the R&D expenditures are labour costs (Coe and Helpman (1995)).

Human Capital

Human capital is measured as the share of hours worked by workers with at least a University degree. This information is obtained by GGDC EUKLEMS.

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 disaggregate data set is very difficult to be obtained for Greek manufacturing firms. Following a methodology 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 the total firm population and the group of the 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. The market share of the top five firms in each industry is calculated using information of total assets in nominal values as 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 in the annual financial directory of the Greek manufacturing sector and are only available from 1993 to 2003.

Summary Statistics of Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
imp	384	0.477	0.955	0.030	7.260
exp	384	0.170	0.779	0.020	0.690
HC	384	0.074	0.289	0.042	0.110
$R\&D$	384	0.029	2.059	0.000	5.893
CR	132	0.346	0.251	0.070	0.999

Notes: imp =imports to output ratio, exp = exports to output ratio , $R\&D/VA$ =R&D to Value added

Ratio, *HC*=Share of hours worked with at least of a University degree, and *CR*=Concentration ratio of the top five firms in the industry

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Table 1: Minimum Relative to Median Wages of Full-Time Workers

Country	Mean Values 1980-2003
Belgium	0.527
France	0.598
Greece	0.551
Ireland	0.397
Portugal	0.502
Spain	0.353
United Kingdom	0.429
United States	0.372

Source: OECD-Labour Force Statistics

Table 2: Growth Rates and Relative TFP in Greece and Germany

Year	$TFPG_{GER}$	$TFPG_{GRC}$	RTFP
1980			7.80%
1981	-4.57%	7.72%	7.81%
1982	-2.46%	16.13%	9.42%
1983	-0.20%	14.30%	11.44%
1984	-1.02%	14.98%	13.80%
1985	-0.26%	13.50%	17.66%
1986	-1.17%	1.14%	16.23%
1987	-4.28%	7.46%	22.60%
1988	0.64%	7.60%	20.20%
1989	1.81%	8.20%	21.58%
1990	0.52%	8.05%	23.24%
1991	1.96%	21.92%	29.64%
1992	5.56%	5.31%	23.87%
1993	0.50%	5.87%	26.64%
1994	4.31%	1.71%	23.37%
1995	-1.04%	7.71%	28.41%
1996	1.40%	11.69%	27.63%
1997	2.50%	-1.04%	31.26%
1998	-1.58%	4.67%	29.18%
1999	3.08%	-0.30%	29.78%
2000	1.62%	6.66%	29.52%
2001	0.76%	1.55%	34.02%
2002	0.93%	-0.90%	34.58%
2003	1.81%	4.87%	36.06%
Mean	0.45%	7.35%	22.95%

Notes: TFPG is derived from equation (7) and RTFP from equation (11). The sample includes 17 manufacturing industries. For further information about the construction of these variables see the text

Table 3: Sources of TFP Growth, Estimates from Equation (9)

	(1)FE	(2)FE	(3)FGLS	(4)FGLS	(5)FGLS	(6)FGLS
VARIABLES	TFP growth	TFP growth	TFP growth	TFP growth	TFP growth	TFP growth
TFP gap	0.103***	0.144**	0.111***	0.175***	0.246***	0.089*
	[3.658]	[2.383]	[4.965]	[6.787]	[11.29]	[1.76]
$\log(imp)_{i,t-1}^{GER}$	-0.000	-0.078**	-0.021*			0.01
	[0.031]	[2.185]	[1.686]			[0.321]
$\log(imp)_{i,t-2}^{GER}$				0.014*		
				[1.781]		
$\log(imp)_{i,t-3}^{GER}$					0.034***	
					[7.145]	
$\log(exp)_{i,t-1}^{GER}$	-0.018	-0.005	-0.012**			0.035*
	[1.675]	[0.205]	[1.975]			[1.927]
$\log(exp)_{i,t-2}^{GER}$				-0.019***		
				[3.679]		
$\log(exp)_{i,t-3}^{GER}$					-0.013***	
					[2.854]	
$\log(R\&D)_{i,t-1}$	0.0192**	0.0783***	0.063***	0.018***	0.020***	0.085***
	[2.275]	[3.283]	[12.90]	[5.659]	[7.077]	[4.343]
$\log(Min/Med)_{t-1}$			-0.189*	-0.291***	-0.454***	-0.65
			[1.789]	[2.680]	[4.947]	[1.531]
$\log(\Delta TFP)_{i,GER,t}$			0.025**	0.033	0.042*	0.02
			[1.198]	[1.374]	[1.664]	[0.009]
$CR_{i,t-1}$						-0.308***
						[3.396]
Interaction Terms						
$\log(imp)_{i,t-1}^{GER} \times TFP\ gap$		0.047***	0.02***	0.02	0.03	0.00
		[2.632]	[2.685]	[0.136]	[0.234]	[0.141]
$\log(exp)_{i,t-1}^{GER} \times TFP\ gap$		0.004	0.008**	0.012***	0.019***	-0.01
		[0.315]	[2.421]	[4.036]	[7.349]	[1.242]
$\log(R\&D)_{i,t-1} \times TFP\ gap$		-0.027**	-0.02***			-0.004
		[2.568]	[9.958]			[1.320]
$\log(R\&D)_{i,t-2} \times TFP\ gap$				0.003***		
				[2.723]		
$\log(R\&D)_{i,t-3} \times TFP\ gap$					0.01***	
					[8.809]	
Diagnostic Tests						
Observations	389	389	368	352	336	160
R-squared	0.083	0.118				
Number of sector	17	17	16	16	16	16
Industry Dummies			Yes	Yes	Yes	Yes
Modified Wald Test	12713.75	13190.76				
Chi(17)	(0.000)	(0.000)				
Cross Sectoral	10.173	8.744				
Dependence	(0.000)	(0.000)				
Wooldridge Test	0.179	0.487				
F(1,16)	(0.678)	(0.495)				

Notes: Absolute t-statistics in brackets correspond to *significance at 10%; ** significance at 5%; ***significance at 1%. The null hypothesis of the Modified Wald test is $\mathbf{H}_0 : \sigma_i^2 = \sigma$. The cross-sectional dependence test relies on the Pesaran test under the null $\mathbf{H}_0 : E(e_{i,t}e_{k,t}) = \sigma_{i,k}$, where $i \neq k$ denote industries. The null hypothesis of the Wooldridge test is no serial correlation after allowing for an AR (1) process of the residuals.

Table 4: Sources of TFP Growth- Equation (9), Results from an (IV) Estimator

	(1)IV	(2)IV	(3)IV
VARIABLES	TFP growth	TFP growth	TFP growth
TFP gap	0.107*	0.096	0.025
	[1.763]	[1.156]	[1.172]
$\log(imp)_{i,t-1}^{GER}$	-0.188**		
	[2.015]		
$\log(imp)_{i,t-2}^{GER}$		0.278**	
		[2.210]	
$\log(imp)_{i,t-3}^{GER}$			0.086
			[1.152]
$\log(exp)_{i,t-1}^{GER}$	0.08		
	[1.392]		
$\log(exp)_{i,t-2}^{GER}$		-0.103	
		[1.322]	
$\log(exp)_{i,t-3}^{GER}$			-0.113
			[1.590]
$\log(R\&D)_{i,t-1}$	0.127***	0.036	0.027
	[3.078]	[0.988]	[1.273]
$\log(Min/Med)_{t-1}$	-0.414	-0.225	-0.269
	[0.936]	[0.345]	[0.599]
$\log(\Delta A)_{i,GER,t}$	0.066	0.022	0.058
	[0.625]	[0.158]	[0.657]
Interaction Terms			
$\log(imp)_{i,t-1}^{GER} \times TFP\ gap$	0.095**	-0.236**	0.07
	[1.998]	[-2.284]	[1.059]
$\log(exp)_{i,t-1}^{GER} \times TFP\ gap$	0.032*	0.064	0.005
	[1.68]	[1.634]	[0.185]
$\log(R\&D)_{i,t-1} \times TFP\ gap$	-0.054**		
	[2.074]		
$\log(R\&D)_{i,t-2} \times TFP\ gap$		0.04	
		[1.635]	
$\log(R\&D)_{i,t-3} \times TFP\ gap$			0.001
			[0.0301]
Diagnostic Tests			
Observations	336	320	288
R-squared	0.05	-0.64	0.024
Number of sector	16	16	16
Industry Fixed Effects	Yes	Yes	Yes
Canonical LM Test	23.816	23.816	18.069
	(0.001)	(0.001)	(0.012)
Sargan Test	8.407	13.824	16.329
	(0.209)	(0.131)	(0.126)

Notes: **A**sterisks correspondence is identical to Table 4. The endogenous regressors are TFP gap, $\log(imp)_{i,t-1}^{GER}$, $\log(exp)_{i,t-1}^{GER}$, $\log(imp)_{i,t-1}^{GER} \times TFP\ gap$, $\log(exp)_{i,t-1}^{GER} \times TFP\ gap$ and $\log(R\&D)_{i,t-1} \times TFP\ gap$. The exogenous regressors are $\log(R\&D)_{i,t-1}$ and $\log(Min/Med)_{t-1}$ .The set of instruments in each column are the lagged values of the endogenous variables at years *t*-2, *t*-3. Accordingly, in columns (2) and (3) the instruments are the lagged values at *t*-3, *t*-4 and *t*-4, *t*-5, respectively. The null hypothesis of the canonical LM test is that the equation is under-identified. The null hypothesis of the Sargan test is that the instruments are valid (uncorrelated with the error term). For a further interpretation of these tests, see the text.