Sources of TFP Growth in a Framework of Convergence: Evidence from Greece

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Abstract

The main hypothesis tested in the study is whether technology is a conduit of productivity growth for a country that falls far behind the frontier. The other set of productivity determinants under consideration are derived from the propositions of the endogenous growth theory. Although the current analysis is focused on a country growth narrative, the evidence can be safely generalized since the pattern of the present pair (Greece and Germany) represents quite accurately the structural differences between the periphery and the centre of Europe. From a policy-making point of view, the first lesson taken from the study is quite discouraging suggesting that for more than two decades the speed of productivity adjustment was rather low in Greece underlying the various unobserved rigidities that exist both at an industry-specific level and in the wider institutional frame. Even though the speed of technology transfer is low, adoption of foreign technology remains an important source of productivity growth. Other key findings of the study are that trade- induced productivity gains exist but their realization requires a substantial time lag. Additionally, the degree of trade openness improves absorptive capacity confirming the dual role of trade as recently discussed in the productivity literature. Finally, R&D activity is another key contributor to productivity improvements as most of the cases improve both the rates of innovation and absorptive capacity.

Keywords: Productivity Growth, Productivity Convergence, Trade, R&D, Greece, Germany, Manufacturing

1. Introduction

The two mainstream theories of economic growth, neoclassical and endogenous, emphasise extensively on the importance of technology as a source of economic growth (Sharpe, 2002). In the neoclassical setting, technological progress is exogenous to factors of production and thus technical change is assumed to be disembodied while in the endogenous approach of growth, the factors of production have a more active role as it is considered that technological advancements are embodied in the purchase of production inputs.

In a historical context, the focus on technology as a source of growth has been driven by countries' ability to imitate or transfer technological developments from their counterparts. Abramovitz (1986) notes that the main target of industrialised countries in the so-called Western-world during the second half of the previous century was to bring into their production systems the unexploited technology that is already in use in the US. In conformity with this view, the successful adoption of foreign technology can be one of the most convincing explanations for the productivity catch-up of some countries. Needless to say, the role of technology diffusion becomes even more important for countries that traditionally fall behind technologically. Accordingly, the empirical research 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 decelerate the adoption process causing, thus, substantial productivity disparities around the world (Parente and Prescott (1994)).

The spirit of the present paper is consistent with the above lines offering an analytical country narrative that contributes to the productivity convergence debate. The evidence of the paper focuses on Greece and Germany, and the role assigned for each of them is that Greece is the technological "follower" country and Germany is the technological "frontier". Within this set up, the present study explores the sources of productivity growth of the Greek manufacturing sector paying special attention to the technological catch-up scenario. The main proposition of such a scenario is that the further Greece's productivity falls behind German's the higher the potential for technology transfer and hence the faster the pace of productivity growth. At a later stage, when convergence has been implemented productivity growth of the "follower" country slows down and certainly, the potential of technology transfer is limited.[1]

The selection of countries seeks to stress the technological leadership of Germany and the substantial trade relationships between Greece and Germany. While Germany is the most technologically pioneer country of Europe and within the most technologically advanced globally, it is also the major trading partner of Greece. This offers us a good motivation to investigate whether trade is an important conduit of technology transfer. Additionally, R&D is another key driver of productivity growth according to the priors of the endogenous growth theory. The role of both trade and R&D in a framework of convergence is dual as they can promote productivity growth either via high rates of learning and innovation or via improvements in country's absorptive capacity (Griffith et al. (2003)).

[1] 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.

For technologically “follower” countries like Greece, any investigation about the puzzle of productivity growth without taking into account the influence of international technology transfer is incomplete. The pair of countries selected in the present paper has an interesting implication in the challenging project of European economic integration. The various structural changes that took place in Europe with special emphasis to the removal of trade barriers and similar trade impediments are characteristics that create a new economic environment within which a more rapid implementation of technological transfer is strongly encouraged. With these considerations in mind, the implications of the present study can easily find applications in other peripheral economies of the EU and especially for those countries that share similar structural characteristics with Greece.

Finally, the present study takes into account variables that reflect domestic market conditions and their associated impact on productivity growth. These variables are essential parts of the productivity growth puzzle since in the period under study, many substantial institutional reforms have occurred whose role on productivity shifts is vital. For instance, it would be a crucial omission if one disregards the impact of labour market forces and the degree of domestic competition on driving productivity performance. For these purposes, we also consider as determinants of productivity growth measures of labour market rigidities and product market concentration.

The paper is organized as follows: section 2 overviews the main sources of productivity growth highlighting the important contributions of the lengthy productivity growth literature. In a sub-section, we provide a discussion about some key peculiarities of the Greek economy directly related to productivity performance. This discussion is useful to guide the reader how some business environment in Greece has been influenced by institutional reforms. Sections 3 and 4 present the productivity convergence framework and the issues related to TFP measurement, respectively. Section 5 presents the econometric specification of the analysis and the main results. Section 6 provides a check of robustness of the principal findings and section 7 concludes.

2. Theoretical Considerations

2.1 Sources of TFP Growth: A brief Overview of the Literature

Bernard and Jones (1996a, 1996b) pioneer with a model for the sources of productivity growth as a function of a technological transfer. Cameron et al. (2005) and Cameron (2006) adopt this model to explore the sources of *TFP* growth in the UK manufacturing addressing the role of technological convergence considering the US counterpart as the frontier country. Griffith et al. (2004), Cameron (2005) and Khan (2006) contribute to the empirical validity of the productivity convergence model by applying data for Japan and France, respectively. The existing literature focuses on advanced OECD economies for the role of the technological follower country lacking evidence from less advanced technologically countries, in which the potential of technological transfer is undoubtedly larger. With our paper, we attempt to cover this empirical gap as Greece, although an OECD country still belongs to the peripheral spectrum of the European Union.

The influence of innovation on productivity growth through investment in R&D is well-defined in the literature. Griliches (1980) and Griliches and Lichtenberg (1984) among many others provide evidence for the positive link between these variables. These studies use evidence either from a firm or from a country level data to document that domestic investment is a conduit of productivity improvements and cost reductions.[2] Helpman and Grossman (1991) and Coe and Helpman (1995) provide evidence about the multifaceted role of R&D confirming that a country can gain from its own R&D effort but it can also exploit positive spillovers by imitating R&D outcomes of other countries. A crucial issue of interest is how the gains from R&D initially conducted abroad are distributed across countries. One of the most prominent scenarios is that foreign R&D is diffused to other countries via imports in capital assets and raw intermediate materials. On this line of argument, Keller (1998) provides robust evidence for the hypothesis that imports stimulate productivity growth. Exporting is another channel that can also generate substantial positive spillovers. The static benefit of exporting is the exploitation of economies of scale derived from market expansion. In a more dynamic perspective, exporting brings producers in contact with international best practices (i.e. learning-by-exporting hypothesis); nonetheless, the empirical verification of this scenario is vague. Evidence from Clerides et al. (1998) and Bernard and Jensen (1999a, 1999b) support the self-selection hypothesis, which suggests that good firms (in terms of productivity) are those that become exporters without further benefits from export involvement.[3]

In the discussion so far, the emphasis has been given to the role of trade as a technological transmitter of foreign innovation (i.e. innovation that is initially developed abroad). One should not ignore the role of domestic R&D on productivity growth, which is rather important from two different aspects. There is a standard effect when domestic R&D expenditure leads to successful innovation accelerating the growth of productivity. Nevertheless, even if this effect is weak, domestic R&D is essential since it guarantees that the economy develops the minimum level of technical expertise and technological "know-how" to absorb effectively the technological advancements from abroad. Cohen and Levinthal (1989) point out that R&D activity stimulates the firm's ability to assimilate and exploit the existing information. Additionally, Acemoglu and Zillibotti (2001) stress a similar role of complementarity between technological transfer and human capital. Griffith et al. (2004) address systematically the complementary role of domestic R&D in a panel of OECD countries proving that domestic R&D improves substantially the absorptive capacity of the domestic economy.

2.2 Labour Market Distortions and TFP Growth-The Case of Greece

The institutional environment is a crucial driver of productivity growth. Scarpetta et al. (1999), use specific indices of labour and product markets distortions to evaluate their impact on productivity growth. Nonetheless, these indices can provide informative insights only within a cross-country context as they are invariant within country.[4] In the case of Greece, a plausible way to measure the effect of labour market distortions on productivity

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[2] Note industry level studies for the effect of innovation on productivity need to address the multiply role of R&D. Spence (1984) considers that a firm's R&D investment generates positive spillovers that are exploited by rival firms within the industry leading, hence to an increase in industry's overall productivity. Analogously, R&D spillovers generate free-rider problems affecting negatively a firm's decision to invest in R&D. The presence of diminishing returns in R&D is explored in the sensitivity analysis conducted later in the paper.

[3] See Kraay (1999) and Castellani (2002) for firm level and Anderson (2001) for industry level evidence that confirm a positive causal link from exporting to productivity.

[4] Another feature of these indices is that they also change slowly over time, so their use in a panel data model can be rather problematical.

growth is through the settlement of minimum wage. With this strategy we can effectively capture the phenomenon that during 1980s approximately 15-20 % of the Greek labour force is in receipt of the minimum wage while during the same period the respective share in USA and France is 5% and 12% (Koutsogeorgopoulou (1994)). The national minimum wage in Greece is negotiated annually by representatives of the General Confederation of Greek workers and the main employer organisations. The negotiated level is routinely ratified by the Ministry of Labour and covers the whole range of workers both in the private and the public sector. This legally settled minimum rate of pay is the basis for the contractual wages and salaries set by industry agreements.

During 1980s, the ratio of minimum to average wage in Greece was the highest within a group of OECD countries (Table 1, Neumark and Wascher (2004)). At the end of the period, this ratio has been very close to the OECD average. Two conditions designate the existence of a high minimum to average wage ratio in Greece during 1980s. First, one needs to take into consideration the bargaining power of trade unions. Under the presence of powerful trade unions, the agreed minimum wage was much greater than the perfect competitive wage in many industries. Second, during 1980s there is a program of a welfare state that attempts to narrow the income and wage inequality existed in Greece in the previous decades. An important aspect of this policy is the introduction of a minimum wage indexation, which makes automatic pay adjustments (known as ATA[5]) compensating low income earners for erosion in wages due to inflation. ATA performs in a gradual manner compensating those in the low income scale with a highest payment while workers in the upper income scale receive almost no compensation. The ATA system is abolished in 1991 when a conservative government is elected but trade unions have kept their strong bargaining power in negotiating the determination of minimum wage.

Empirical research tends to support that the negative impact of a minimum wage policy on the outsiders of the labour market (i.e. unemployment) is not serious while it still generates substantial gains towards the elimination of the existing wage differentials. Nonetheless, these empirical considerations disregard the potential effect of minimum wage on productivity (Siebert (1997)).[6] Table 1 shows that within a group of OECD countries France and Greece have the higher minimum to median wage ratio indicating a heavily regulated labour market partly by the existence of powerful trade unions that cause serious rigidities preventing from a rapid and costless allocation of labour inputs. The Greek labour market is a representative case of the above problem; the current paper addresses econometrically this issue in order to test whether increases in unit labour costs due to minimum wage regulation surpass productivity growth.

[5] ATA stands for the Greek acronyms of the Automatic Price Adjustment.

[6] In the likely case, that minimum wage slows down productivity this is reflected into higher levels of unemployment.

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

Country	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

Note: The source of the above table is OECD. Data presented are average values of the period 1980-2003

Another domestic condition with an influence on productivity performance is the degree of competition in the domestic market. According to the traditional Schumpeterian notion, a competitive market is the business environment to ensure the reduction of slack, promotion of innovation and higher levels of efficiency. This scenario gains credibility by Vickers (1995), although some concerns are posed since the competition-productivity link is highly endogenous and thus any empirical confirmation becomes rather ambiguous. Nickell (1996) notes that there are theoretical reasons to believe that competition improves performance but the existing evidence can hardly be viewed as overwhelming. Caves (1987) supports the view that market efficiency is independent from the degree of concentration converging at Jovanovic's (1982) point that competition is not necessarily a vehicle of efficiency instead lets many flowers to bloom and then allows only the best to survive, such a process is infeasible in a monopolistic market.

Turning to the case of Greece, there is a limited number of studies on the competition-productivity relation. The existing findings indicate that the Greek manufacturing sector becomes rather concentrated after the accession to EU (Anagnostaki and Louri (1995)) reflecting the increased level of competition faced in a highly integrated market leading many small and medium sized enterprises to shut down. A similar pattern is also found in Fotopoulos and Spence (1997) highlighting the existence of significant barriers to entry that make some industries blockaded. Nonetheless, Tsekouras and Daskalopoulou (2006) moderate this negative stylized fact proving that a higher degree of market concentration does not necessarily lead to more slack. Although the present analytical framework is rather different from the above approaches, our empirical evidence aims to contribute to the above debate.

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; Cameron et al., 2005). Consider a world with only two countries $c \in \{GRC, GER\}$, 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:

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

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 c will have a higher level of TFP and thus this country is specified as the "technological frontier" economy (Cameron et al., 2005), in the present empirical model this country is Germany and it is indexed by *GER* the follower economy is Greece denoted by *GRC*. In Bernard and Jones (1996a, 1996b), the technological parameter A 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 TFP growth in industry i of country *GRC* is:

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

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. As it stands, the ratio in the right-hand side - $\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right)$ - 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 (2) is zero for the frontier economy

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

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

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

Equation (4) can be viewed as an equilibrium correction model (ECM) with a long-run steady state relative TFP. Assuming that in the long-run, $\Delta \ln\left(\frac{A_{i,GRC,t}}{A_{i,GER,t}}\right) = 0$, the steady state equilibrium is given by:

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

Equation (5) states that in the steady state equilibrium, relative TFP depends on the rates of innovation in the non-frontier economy *GRC*, in the frontier economy *GER* and on the speed of technological convergence λ that occurs between the two economies.

Another inference that can be made from equation (5) is that country *G* remains technologically behind in steady state equilibrium, that is, $\ln\left(\frac{A^{*}_{i,GRC}}{A^{*}_{i,GER}}\right) < 0$ when $\gamma_{i,GRC} < \gamma_{i,GER}$. In other words, these inequalities describe that in the steady state equilibrium technological frontier country *GER* remains as such as long as the rate of innovation in that country is higher than the rate of innovation in country *GRC*. Finally, according to the propositions of the endogenous growth theory, the set of factors included in vector $\gamma_{i,GRC,t}$ in equation (2) and affect the speed of technological transfer $\lambda_{i,GRC,t}$ are R&D, trade, and conditions in the labour and product market of the non-frontier country. Appendix A provides a discussion about the data sources and Appendix B shows the definition of variables and summary statistics. The next section is devoted to define the measure of productivity, which is the key variable of the paper.

4. Data Description and Measurement Issues

4.1 *Main Characteristics of the Manufacturing Sector in Greece and Germany*

The analytical framework presented above requires the calculation of productivity indices in 17 manufacturing industries in Greece and Germany. Before proceeding with the measurement of TFP, it should be useful to display some summary statistics as well as to explain why Germany is an ideal comparator country for Greece's technological catch up. Table 1 shows information about the relative size and labour productivity of the manufacturing sector in a sample of six European countries. One can stress two points from this table: first, the contribution of the Greek manufacturing sector to total output is smaller even if the relative size of the sector is analogous with the other countries, second, Greece's productivity in manufacturing falls behind in comparison to the traditional European economies.

The average size of the manufacturing sector over the period 1980-2003 in the six countries is rather similar ranging from 19% to 28%. The share of value added is a useful indicator for whether manufacturing is a main area of specialisation. Accordingly, in Germany the manufacturing sector contributes almost a quarter of the entire economy's value added for the period 1980-2003.

Table 2 Key Characteristics of the Manufacturing Sector in Six European Countries, 1980-2003

Country	Employment Share	Value Added Share	Value Added Per Employee
Germany	0.271	0.258	40.041
Greece	0.233	0.169	18.546
UK	0.198	0.214	26.088
France	0.195	0.178	39.811
Spain	0.229	0.226	28.198
Italy	0.280	0.232	35.113

Notes: Data are obtained from the EU KLEMS database. Value added per employee is measured in Thousand Euros

Turning to the bilateral comparison between Greece and Germany, a strong remark is that Greece has lower labour productivity than Germany. Interestingly, Germany maintains a productivity leadership in manufacturing among the six countries confirming Germany's role as a technological frontier in our analysis. Additionally, Germany is chosen as a comparator country not only because it is a productivity leader but also due to the strong trade partnership between Greece and Germany. Table 3 displays the disaggregate list of the 17 industries included in the study and the associated share of Greek imports (exports) from (to) Germany. On average, imports from Germany account for the 17 % of total imports while Germany is a major destination of Greek exports (i.e. average exports share 13%). In many industries, the share of Greek imports from Germany accounts for almost a quarter of total imports whereas in almost all industries more than 10% of the whole output is shipped to Germany. To sum, the selection of Germany as a comparator country for investigating the sources of productivity growth in Greece is drawn upon two factors: (i) the productivity leadership of the German manufacturing sector that generates substantial potential of faster technological catch up for the Greek counterpart and (ii) the persistent trade relationships between the two countries.

Table 3 Greece's Bilateral Trade Relationships with Germany, 1980-2003

Manufacturing Industries	Industry Code	Export Share	Import Share
Food , beverages and tobacco	15t16	15.49%	16.02%
Textiles, textile , leather and footwear	17t19	41.24%	19.15%
Wood and products of wood and cork	20	7.43%	6.10%
Pulp, paper, paper , printing and publishing	21t22	5.99%	17.31%
Coke, refined petroleum and nuclear fuel	23	0.25%	3.40%
Chemicals and chemical products	24	8.35%	18.78%
Rubber and plastics	25	11.36%	19.37%
Other non-metallic mineral	26	4.46%	10.79%
Basic metals	27	10.46%	9.09%
Fabricated metal	28	11.06%	20.58%
Machinery	29	11.92%	23.17%
Electrical machinery and apparatus	31	16.46%	24.24%
Radio and television receivers	323	36.42%	23.74%
Medical, precision and optical instruments	33	12.07%	20.77%
Motor vehicles, trailers and semi-trailers	34	5.18%	30.77%
Other transport equipment	35	11.05%	6.01%
Other Manufacturing	36t37	11.99%	13.77%
Average		13.01%	16.65%

Notes: Export share is defined as the ratio of exports shipped to Germany to total output. Similarly, import share is defined as the amount of imports originated from Germany to total output. Figures are based on author's calculations from raw data obtained from OECD-STAN database.

4.2 *Measurement of TFP, Growth rates and Levels*

The first index measures an industry's performance for a specific country over time (i.e. growth index) and the second measures an industry's performance in Greece relative to industry's performance in Germany (i.e. level index).

Total factor productivity (TFP) indices are calculated from the Divisia number approach developed by Caves et al. (1982). The TFP index is derived directly from a flexible translog production function (i.e. a more general case than a standard Cobb-Douglas function) and it is superlative since it is a close approximation of an arbitrary, twice differentiable production function with constant returns to scale. The TFP growth in industry i in any country c is defined as:

$$\ln\left(\frac{A_{i,c,t}}{A_{i,c,t-1}}\right)=\ln\left(\frac{Y_{i,c,t}}{Y_{i,c,t-1}}\right)-a_{L,t}\ln\left(\frac{L_{i,c,t}}{L_{i,c,t-1}}\right)-(1-a_{L,t})\ln\left(\frac{K_{i,c,t}}{K_{i,c,t-1}}\right) \quad (6a)$$

where c= Greece (*GRC*), Germany(*GER*)

Output Y is measured by value added, L is a measure of labour input and K denotes capital stock constructed by the perpetual inventory method that accumulates investment flows in capital assets. The labour share is initially defined as the ratio of labour compensation to value added and enters equation (6a) in a weighted manner as $a_{L,t}=\frac{a_{i,c,t}+a_{i,c,t-1}}{2}$. The assumption of constant returns to scale production function implies that capital share is equal to one minus the labour share.

The data used throughout the paper are obtained from OECD-STAN and Groningen Growth Development Centre (GGDC)-EU KLEMS. Both databases are constructed in a fully compatible manner from Supply and Use tables (SUTs) provided by the National Accounts system. The use of these databases is widely spread in industry level analysis, however in our analysis the information obtained from EU KLEMS (2007) allow for a more consistent and adequate productivity measure than a crude TFP index. Given the long period under study, it is reasonable to assume that the composition of labour does not remain constant across time resulting in a serious bias in productivity measurement if one fails to control for shifts in labour quality.[7] Consequently, we adjust the labour input considering three different groups based on the educational level of workers as reported in the EU KLEMS database. The classification of labour types according to the educational level is sometimes too restrictive as the educational system might vary across countries. In the present case, the Greek and the German system are very alike in the period under study,[8]so the labour classification applied refers to workers with similar qualitative

[7] Jorgenson et al. (2005) point out the importance of the 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 ensure an unbiased TFP measure.

[8] The Greek educational system has adopted the German prototype over the last thirty years so, from this respect, the classification of workers in different levels is consistent. Nonetheless, this does not exclude the possibility that the systems, even if they are identically structured, do not have qualitative differences. Certainly, this issue cannot be captured by the existing data set. We refer to the EUKLEMS Growth and

characteristics. The three groups are: (i) high-skilled labour (University graduates), (ii) medium-skilled labour (Intermediary Education graduates) and (iii) low-skilled labour (no formal educational qualifications).

The decomposed index of labour input has a translog form and has been initially suggested by Young (1995):

$$\ln\left(\frac{L_{i,c,t}}{L_{i,c,t-1}}\right)=\sum^{3}\bar{\sigma}^{j}_{i,c}\ln\left(\frac{L^{j}_{i,c,t}}{L^{j}_{i,c,t-1}}\right) \tag{6b}$$

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

While labour input is measured in physical units, a meaningful TFP comparison requires that valued added, labour compensation and investment are expressed into a common currency. O' Mahoney (1996) shows that relative TFP levels vary substantially according to the conversion factor used. The dilemma faced in international productivity comparison studies is to choose between an industry or country specific Purchasing Power Parity (PPP) exchange rate. The main merit of the former conversion factor is its ability to reflect differences in retail prices across industries as well as to account 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 obtain 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.

As stated in equations (2) and (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:

$$\ln\left(\frac{A_{i,GRC,t-1}}{A_{i,GER,t-1}}\right)=\ln\left(\frac{Y_{i,GRC,t-1}}{Y_{i,GER,t-1}}\right)-a_L\ln\left(\frac{L_{i,GRC,t-1}}{L_{i,GER,t-1}}\right)-(1-a_L)\ln\left(\frac{K_{i,GRC,t-1}}{K_{i,GER,t-1}}\right) \tag{7}$$

the labour share is now defined as: $a_L=\frac{a_{i,GRC,t-1}+a_{i,GER,t-1}}{2}$.

The series of capital stock is 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 is the depreciation rate, defined at the constant rate of 10% for all industries and I denotes investment in fixed capital assets. The latter includes compensation only for the services of fixed reproducible assets. This means that inventories are excluded from the group of fixed capital assets. Although the omission of this component is purely driven by data unavailability, we think that the any potential problem is of minor importance. As it is widely accepted inventories are only short-term cycles without trends over longer periods so growth accounting results

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Productivity Accounts manual if the reader wishes to obtain further insights regarding the methodology used for the construction of labour quality indices across countries.

are not affected.[9] The investment flows are converted into constant 1995 prices using gross fixed capital formation deflators taken from OECD-Economic Outlook database.[10] The series of capital stock is initialised with 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 the subscript 1980 indicates the first year with available investment data.

The above measure of capital stock implicitly assumes that capital stock is always fully utilised. Nonetheless, this assumption is far from being true as the effective use of capital varies over time indicating that one needs to treat more systematically the fluctuations in capital utilisation in order to gather reliable evidence about the true TFP. Hall's (1990) exogeneity condition about the Solow residual fails if capital stock is under (over)-utilised as it is likely to lead to an over (under)-estimated TFP measure. In the present paper, we adjust capital stock for its effective use applying a rate of capacity utilisation taken from the Business Tendency Surveys of OECD-Main Economic Indicators database. Capacity utilisation is assessed with reference to the use of physical capital assets such as buildings, plants, machinery, vehicles etc.[11] The capital input adjusted for cyclical variations is then obtained by multiplying the actual capital stock with the rate of capacity utilisation.[12] After the adjustments discussed above the final TFP growth index is of the form:

$$\ln\left(\frac{A_{i,c,t}}{A_{i,c,t-1}}\right) = \ln\left(\frac{Y_{i,c,t}}{Y_{i,c,t-1}}\right) - a_{L,t}\left(\sum^{3}\bar{\sigma}^{j}_{i,c}\ln\left(\frac{L^{j}_{i,c,t}}{L^{j}_{i,c,t-1}}\right)\right) - (1-a_{L,t})\ln\left(\frac{K_{i,c,t}}{K_{i,c,t-1}}\right) \quad (8)$$

$$\tilde{K}_{i,j,t} = u_{j,t}K_{i,j,t}$$

where u denotes the percentage rate of capacity utilization.

Table 3 shows average TFP growth rates and relative TFP levels of the aggregate manufacturing sector for Greece and Germany over the period 1980-2003. In order to ensure that outliers do not drive the above figures, we perform a standard test to extract

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9 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

10 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.

11 The survey of capacity utilisation 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 utilisation*? 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 utilisation in the OECD manual (Business Tendency Surveys Handbook).

12 The current measure of capacity utilisation is time variant but industry invariant. This is not necessarily a reasonable assumption as the level of utilisation 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 utilisation rate.

extreme values from the sample.[13] After this adjustment, the results show that the Greek manufacturing sector has grown on average by 7.35% over the sample period while the German manufacturing 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 offering support to the core proposition of the neoclassical theory of convergence. The last column of Table 3 highlights German's technological leadership compared to Greece. Figures in the last column are interpreted in the following manner: in 1980, Greek manufacturing is only 7.8% as productive as the German counterpart is, while in the last year of the sample relative TFP level has increased to 36%. Another interesting remark of Table 3 is that Greece experiences quite rapid growth rates during 1980s whereas there is a slow down in the second decade of the sample, which explains to a large degree why the technological gap between the two countries remain large.

Table 3 Growth Rates and Relative Levels of TFP

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 an index of TFP growth from equation (8). RTFP is an index of Relative TFP level between Greece and Germany adjusted for capital capacity utilization and labour quality differences (see equation (7)).

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

Table 4 reports the values of relative TFP at the first and the last year of the sample. Two messages can be obtained from Table 4, first Germany maintains a clear technological leadership in all industries both in the beginning and at the end of the period and second the speed of convergence across industries differs substantially. The Greek industry of pulp and paper shows a notable evidence of convergence as at the end of the period is 70% as productive as the German counterpart. Greece has accelerated the speed of catch- up in the industry of medical, precision and optical equipment as the relative TFP level is something less that 60% at the end of the period. Overall, the figures reported in Table 4 are not encouraging for the Greek manufacturing sector. For instance, the industries of wood, coke and basic metals present a very slow convergence process while in the industry of electrical machinery and apparatus the technological gap that separates Greece and Germany is even larger at the end of the period. The fact that some industries tend to catch-up at a different pace than some others reflects to some degree the existence of different structural patterns within industries. Notably, during the period under study, the major firm in the coke industry is a state-owned one triggering the question whether the monopolistic structure of the industry is a source of slack that affects negatively the rate of productivity growth. The econometric analysis of the next section provides evidence that is more systematic concerning the precise nature of this relationship.

Table 4 Relative TFP between Greece and Germany in 1980 and 2003

Industry	1980	2003
Food products, beverages and tobacco	6.56%	29.38%
Textiles, textile products, leather and footwear	9.11%	43.99%
Wood and products of wood and cork	5.23%	16.12%
Pulp, paper, paper products, printing and publishing	5.44%	72.61%
Coke, refined petroleum products and nuclear fuel	6.57%	14.28%
Chemicals and chemical products	7.46%	28.16%
Rubber and plastics products	5.46%	37.76%
Other nonmetallic mineral products	8.18%	40.36%
Basic metals	6.88%	15.28%
Fabricated metal products, except machinery and equipment	2.06%	42.21%
Machinery and equipment	3.44%	34.82%
Electrical machinery and apparatus	22.20%	15.69%
Radio, television and communication equipment	20.60%	44.32%
Medical, precision and optical instruments, watches and clocks	3.38%	56.90%
Motor Vehicles	9.06%	29.06%
Other transport equipment	5.66%	29.38%
Other Manufacturing	5.29%	43.99%

`5. Econometric Models and Results

5.1 Benchmark Specification from Fixed Effects (FE) and Feasible Generalized Least Square Estimators (FGLS)

The present section shows the econometric specification applied to reveal the sources of productivity growth in Greek manufacturing industries. The current model relies on the theoretical concept discussed earlier, which gives 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,[14] in which the level of productivity in industry *i* is co-integrated with productivity in the frontier country GER as follows:

$$\ln A_{i,GRC,t} = \beta_0 + \beta_1 \ln A_{i,GRC,t-1} + \beta_2 \ln A_{i,GER,t} + \beta_3 \ln A_{i,GER,t-1} + \omega_{i,GRC,t} \tag{9}$$

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

$$\omega_{i,GRC,t} = \sum_k \gamma_k Z_{i,GRC,t-1} + \rho_i + d_t + e_{i,GRC,t} \tag{10}$$

The summation in the right-hand side of (10) includes all the observed factors that have an impact on TFP while ρ and d control for industry and year specific effects, respectively. Assuming that in equation (9) the long-run homogeneity condition (i.e. $1-\beta_1 = \beta_2 + \beta_3$) holds then after transformation:

$$\ln \Delta A_{i,GRC,t} = \beta_0 + \beta_2 \ln \Delta A_{i,GER,t} + (1-\beta_1)(\ln A_{i,GER,t-1} - \ln A_{i,GRC,t-1}) + \omega_{i,GRC,t} \tag{11}$$

The dependent variable in equation (11) is industry *i*'s TFP growth in Greece including in the right hand-side the autonomous rate of industry *i*'s TFP growth in Germany and a term of technological gap in industry *i* between Germany and Greece. The substitution of (10) into (11) yields a specification in which R&D and trade are potential determinants of TFP growth in the non-frontier economy both directly and through the rate of absorptive capacity. These augmentations lead to an estimatable equation of the following form:

$$\ln \Delta A_{i,GRC,t} = \rho_{i,j} + \alpha \ln \Delta A_{i,GER,t} + \gamma Z_{i,GRC,t-1} + \lambda \left(\ln \frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}} \right) + \mu Z_{i,GRC,t-1} \left(\ln \frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}} \right) + e_{i,GRC,t} \tag{12}$$

In (12), $\rho_{i,GRC}$ controls for industry individual heterogeneity, α captures the impact of TFP growth of German industries on the Greek counterparts, λ indicates the speed of technological transfer, Z includes other factors that have a direct effect on TFP growth such

[14] Further details about estimation issues of an ADL (1, 1) model can be found in Pesaran and Smith (1995) and Hendry (1995).

as: R&D, trade, labour market rigidities and market concentration. The estimate of μ measures the responsiveness of TFP growth after changes in the level of absorptive capacity. Intuitively the interaction variable allows for industry heterogeneity in the productivity gap responses, which are mainly affected by the level of trade and R&D conducted in the industry. Note that the term of TFP gap is the inverse of the relative TFP term presented above, $\text{TFP gap} = \log\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right)$.

Equation (12) is a fixed effects specification with the term $\rho_{i,j}$ to denote time-invariant industry dummies. This model can be estimated using a least squares dummy variable technique (LSDV), which is a standard OLS enriched with a set of dummy variables. Potentially, the use of the LSDV estimator can lead to biased results, as the industry fixed effects are likely to be correlated with the other covariates in the right hand-side. A Within-Group Fixed Effects (FE) estimator eliminates $\rho_{i,j}$ by expressing all variables as deviations from their sample 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 a relatively large number of time series the bias tends to zero. 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. In the current sample, after missing one year required for the construction of some variables, the panel consists of 23 years and 17 industries, which is a sufficient indication for the appropriateness of the FE within group estimator over the GMM.[15]

Table 5 examines gradually the sources of productivity growth beginning with a fixed effects estimator (FE) estimator in columns (1) and (2). The first two columns report a set of standard specification tests concerning the behaviour of the error-term $e_{i,GRC,t}$. 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 provides information about 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 present in the current sample. Thirdly, the Wooldridge (2002) test examines the hypothesis of autocorrelation of the residuals, $Cor(e_{i,t}e_{i,t-1}) \neq 0$, the reported values suggest the acceptance of null at all the conventional levels of significance signifying the absence of first order serial correlation.

Specifications in columns (3)-(6) correct for group wise heteroscedasticity and cross-sectional correlation using the Feasible Generalized Least Squared (FGLS) estimator.[16] The

[15] The crucial dilemma faced by the researcher in estimating a dynamic panel data model, as the one specified in (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 $T \approx 30$ a fixed effects estimator is the best alternative producing the smallest root mean square error (RMSE). The GMM estimator can more effectively correct bias in panels with smaller number of years, $T<10$ (i.e. a characteristic more usually to be met in micro data sets), while if $10<T<20$ then an Anderson Hsiao (1981) estimator should be chosen.

[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.

sources of productivity 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. Since our benchmark empirical model in (12) is derived from an equilibrium correction model (ECM), we augment specifications (3)-(6) with a contemporaneous term of TFP growth in Germany to allow for a more flexible relationship between non-frontier and frontier TFP.

Table 5 Sources of TFP Growth, Estimates from Equation 12

	(1)FE	(1)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]
$\log(\Delta A)_{i,GER,t}$			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 $H_0 : \sigma_i^2 = \sigma$. The cross-sectoral dependence test relies on the Pesaran test under the null $H_0 : E(e_{i,t}e_{k,t}) = \sigma_{i,k}$, 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.

Focusing our interpretation on the estimates of columns (3)-(6), the positive and statistically significant coefficient of TFP gap indicates that the further an industry lies behind the frontier, the faster is the rate of TFP growth. This variable captures the effect of autonomous technology transfer and the estimated coefficient is expected to be larger the longer is the distance from the frontier. The literature reveals different values of this coefficient signifying the different technological level of the non-frontier countries and their associated distance form the frontier. From this respect, the relatively large value of the present coefficient, within the interval 8.9-24% suggests a substantial technological fall behind of Greece resulting, thus, a large potential of 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 indicates that the follower 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 provide initially an ambiguous pattern. The level variables hold a negative and statistically significant coefficient, while their associated interaction terms with TFP gap suggest 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 the trade variables are considered in columns 4 and 5. The coefficient of the second lag import share is now appeared positive and statistically significant at 10% level while the coefficient of the third order lag is more robust indicating significance at 1% level. Nonetheless, the second and the third order lag of exports remain negative representing that in the Greek manufacturing sector only import induced benefits are present and their realization is implemented with some time lag, on the contrary the role of imports and exports on accelerating the speed of technology transfer is evident throughout the whole range of specifications.

The coefficient of R&D share is positive and statistically significant at 1% percent level in all specifications of Table 5. Nonetheless, the quantitative effect of the R&D estimate- known also as the social return to R&D- is appeared to be much weaker from what is revealed in the literature. The current estimate is 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)). One would expect that the above estimates only reflect innovation and thus it is likely to underestimate the dual role of R&D, especially in a non-frontier country like Greece. Surprisingly, in column 3, the one-year lag interaction term of R&D with TFP gap provides a negative sign but the expected positive effect is uncovered with higher lags of order t-2 and t-3. This finding signifies 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 the contemporaneous TFP growth, is always positive. For instance in column 5 one can interpret this estimated parameter, a 1% TFP

[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.

growth increase in the German industry raises TFP growth in the Greek counterpart by 4.2%.

Another variable of interest in Table 5 is the minimum to median wage that captures the effect of labour market conditions on productivity growth. As discussed above, labour market rigidities can be serious obstacles for productivity upgrading from various aspects. The variable of minimum to median wage allows us to assess whether a regulated market through minimum wage policy increases labour cost adjustments far above the market-clearing levels hampering the rate of TFP growth. On that basis, the estimates produced have the expected negative sign and their impact become statistically significant in almost all specifications of Table 5. The present effect confirms the notion that trade unions in Greece are rather powerful with a negative impact on performance of the manufacturing sector. In the same line of argument, the present pattern reflects a critical trade off caused by the implementation of welfare state programs, especially during 1980s, which slow down productivity growth. To the extent that the current measure is a close proxy for the other underlying labour market rigidities, one can claim that welfare state policies increase labour cost adjustments as they drive resources away from productive activities into employment benefits. The fact that Greece and France experience the higher minimum to median ratio within a group of OECD countries along with the negative impact of minimum to median wage on TFP growth found in Khan (2006) suggest that the negative link between labour protective policies and productivity tends to be systematic.

Column (6) introduces as a determinant of productivity growth domestic market concentration.[18] While the level of competition in the market is a traditional factor in productivity analysis, studies that use the present conceptual framework do not address the role of market concentration on productivity growth. Note the specification in column 6 refers 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 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 with a quite slow speed for some industries-technology transfer becomes a less important source of productivity growth for Greek industries. Interestingly, an estimation of 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 based on country's own resources and not on its ability to imitate or adopt effectively foreign technology. The latter remark explains why the effect of R&D expenditure becomes substantially larger in the reduced sample.

Turning to the investigation of the productivity-concentration interdependence, the literature is highlighted by many controversies. Certainly, specification in column (6) provides robust support to the findings of Vickers (1995) and Nickell (1996) that consider

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

concentration as a factor that leads to more slack. On the contrary, the revealed negative correlation between concentration and TFP growth is not consistent with the results obtained in Tsekouras and Daskalopoulou (2006). According to the latter study, market efficiency is affected mainly by factors other than the degree of concentration. Nonetheless, the reader should treat the consistency of our results with other empirical findings with caution. We need to make this warning, as there is no one-to-one correspondence as far as the analytical framework is concerned between our study and the studies mentioned above. For instance, while most of the above papers have a quite similar definition of market concentration with the one used here, their focus is on productivity levels rather than on productivity growth rates.

5.2 *Instrumental Variable (IV) Estimation*

An issue that needs special attention in the econometric estimation is the potential endogeneity between TFP growth and some explanatory variables on the right hand side in equation (12). Note TFP growth is measured as $\log\left(\frac{A_{i,GRC,t}}{A_{i,GRC,t-1}}\right)$ whereas on the right hand side TFP gap is defined as $\log\left(\frac{A_{i,GER,t-1}}{A_{i,GRC,t-1}}\right)$, this indicates that shocks in the TFP level of 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.

A vital issue for obtaining meaningful estimates from an IV estimator is the existence of valid instruments for the endogenous variables. The criterion for choosing the correct instruments is to be associated with the endogenous variables and be uncorrelated with the error term of the TFP growth equation (12). With this consideration in mind, potentially suitable instruments can be higher order lags of the endogenous variables in view of the fact that the residual term is serially uncorrelated based on the reported Wooldridge test in Table 5.

The last two rows of Table 6 report some identification tests regarding the validity of instruments. The canonical LM test refers to whether the equation is correctly identified or equivalently that the excluded instruments are relevant. The null hypothesis of this test assumes 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 Sargan test refers to the hypothesis that the instruments are valid or in other words that the instruments are uncorrelated with the residual term. Under the null hypothesis, the Sargan statistic follows the Chi-squared distribution with (L-K) degrees of freedom. According to the reported values in Table 6, the canonical test rejects the null of an under-identified specification while the Sargan test accepts the null of no correlation of instruments with the error term. Overall, the main implication of these statistics is that our set of instruments can be considered as valid.

Turning to the IV estimates of Table 6, 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 6 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 trade-off of controlling for unobserved measurement errors and endogeneity bias. In brief, the most considerable difference between IV and FGLS estimation is that there is no evidence for R&D based absorptive capacity even after allowing for time hysteresis.

Table 6 Results from a Instrumental Variable (IV) Estimator of TFP Growth, Equation (12)

	(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: The correspondence of asterisks at different levels of significance is identical to Table 5. 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.

6. Further Tests of Robustness

This section explores the robustness of findings in Table 5 experimenting with alternative definitions of some key variables of the previous analysis. The two main objectives of this experimental exercise is to investigate the sensitivity of the results using a stock measure of R&D as well as to analyse more systematically some alternative scenarios concerning the impact of trade on TFP growth.

All the specifications of Table 7 consider a stock measure of R&D that is constructed from a standard perpetual inventory method (PIM). The latter method accumulates investment flows of R&D as follows:

$$R\&D_{i,t}^{Stock} = (1-\delta)R\&D_{i,t-1}^{Stock} + R\&D_{i,t-1}^{Investment}$$
$$R\&D_{i,t=1980}^{Stock} = \frac{R\&D_{i,t=1980}^{Investment}}{\frac{1}{n}g_i^{R\&D} + \delta} \qquad (13)$$

The second part of equation (13) describes the formula used to initialize the series of R&D stock. Accordingly, R&D stock in 1980, which is the first year of the sample is calculated as the ratio of R&D investment in 1980 over the sum of the average growth rate of R&D investment in industry *i* plus the standard rate of R&D depreciation currently assumed 15%.

Learning-by-trading shares many similarities with learning-by-doing as rigorously analyzed by Arrow (1962). The analogies of Arrow's analysis in a trade context imply that learning-by-trading might be subject to diminishing returns and thus trade-induced gains are non-infinite but exist only up to a certain threshold beyond which, an increase of trade involvement is not anymore beneficial.[19] Young (1991) and Chaung (1998) formalize this scenario emphasizing a bounded type of trade-induced learning in which the identity of trading patterns is equally important as the types of goods traded. To implement these scenarios for the case of Greece we control for a non-linear relationship between trade and TFP growth and we consider trade with the sum of G7 countries. This broader definition might capture more accurately the opportunity of Greece to absorb knowledge spillovers after developing trade relationships with more technologically advanced countries.

Regarding the estimates of R&D stock, all specification in Table 7 reveal statistically significant coefficients at 1% level but the quantitative effect does not differ much from what is obtained with a flow R&D measure in Table 5. Column 1 replicates specification 3 of Table 5 considering the quadratic terms of trade and the third lag of the interaction term of R&D and TFP gap. While most of the estimates are identical to those obtained in Table 5, the quadratic term of exports is positive and statistically significant confirming the scenario that there are diminishing returns in the learning-by-exporting process. Controlling for trade with G7 countries in column 2 provide positive and statistically significant estimates only after considering the third order lags. This finding does not offer support for the bounded nature of trade-induced gains as the estimates obtained are identical to those shown in Table 5 where Germany is the only trading partner.[20]

Finally, column 3 tests the well–established positive link between human capital and productivity often found in aggregate studies (Black and Lynch (1996, 1997,2000)). In the

[19] This crucial threshold determines only the existence of learning gains that derive from the repetition of the same activity. Exceeding this threshold does not have further implications on the welfare gains of trade that are always present highlighting the static positive effects upon consumer surplus.

[20] We have also used the terms of total trade (results are not reported here) but the effect of the trade variables on TFP growth is qualitatively identical to the one presented in Table 5 and 7.

latter studies, the main hypothesis tested is whether a higher average educational level leads to a higher the productivity. The role of human capital is characterized by the same duality discussed for the other determinants of productivity growth in the paper. Accordingly, education becomes a crucial factor as allows workers to adopt more effectively the technological advancements already developed abroad. In the present study, the measure of human capital reflects the level of education defined as the share of workers with at least a University degree. The estimates shown in column 3 are rather supportive for the positive role of human capital on either stimulating directly productivity growth or improving absorptive capacity.

Table 7 Further Specifications of Equation (12)

VARIABLES	(1)TFP growth	(2)TFP growth	(3)TFP growth
$TFP\ gap$	0.203***	0.221***	0.312***
	[12.86]	[11.39]	[11.45]
$\log(imp \times imp)^{GER}_{i,t-1}$	-0.001		
	[0.688]		
$\log(exp \times exp)^{GER}_{i,t-1}$	0.002***		
	[4.295]		
$\log(imp)^{G7}_{i,t-3}$		0.019**	
		[2.530]	
$\log(exp)^{G7}_{i,t-3}$		-0.002	
		[0.319]	
$\log(imp)^{GER}_{i,t-3}$			0.015**
			[2.151]
$\log(exp)^{GER}_{i,t-3}$			-0.015***
			[2.863]
$\log(R\ \&\ D^{stock}_{i,t-1})$	0.017***	0.018***	0.014***
	[6.407]	[5.235]	[3.535]
$\log(HC_{i,t})$			0.161*
			[1.935]
$\log(Min\ /\ Med)_{t-1}$	-0.033	-0.231**	0.725***
	[0.281]	[1.991]	[2.579]
$\log(\Delta A)_{i,GER,t}$	0.019	0.046*	0.012
	[0.800]	[1.710]	[0.423]
Interaction Terms			
$\log(imp)^{GER}_{i,t-1} \times TFP\ gap$	0.003		0.004
	[0.768]		[1.095]
$\log(exp)^{GER}_{i,t-1} \times TFP\ gap$	0.029***		0.014***
	[8.072]		[5.019]
$\log(imp)^{G7}_{i,t-1} \times TFP\ gap$		0.012***	
		[2.997]	
$\log(exp)^{G7}_{i,t-1} \times TFP\ gap$		0.018***	
		[4.741]	
$\log(R\ \&\ D\ stock)_{i,t-3} \times TFP\ gap$	0.003***	0.002*	0.003**
	[3.835]	[1.925]	[2.277]
$\log(HC)_{i,t-1} \times TFP\ gap$			0.039***
			[4.819]
Observations	336	336	336
Number of sector	16	16	16

7. Discussion and Concluding Remarks

Two main questions addressed in this piece of research, which are the factors that act as engines of productivity growth and which are the channels that accelerate the pace of technology transfer. The role of technology as well as its diffusion across countries gain much of the attention in the present framework since faster adoption of technology, which is already available somewhere else leads to convergence. The convergence debate has been one of the most topical issues in the agenda of European economic integration emphasizing the importance of harmonizing key performance characteristics of the peripheral countries with those of the central EU countries. A principal component of this puzzle is convergence in productivity as improvements in the latter feature have serious implications in both income and welfare of an economy.

The starting point of the analysis is a neoclassical production function, which allows us to use a total factor productivity index as an approximation of technology. Of course, endogenous growth propositions are also considered in understanding which factors boost technology over time. The empirical analysis enriches the research agenda of productivity convergence focusing on a representative pair of peripheral (i.e. Greece) and central (i.e. Germany) countries. Understanding the factors that narrow the productivity gap among EU countries can help policy makers to design devices that are more effective in the promotion of productivity.

Results from all tables appeared in the paper suggest that autonomous technological transfer is rather important on 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 5, 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.[21] This rather discouraging implication[22] suggests that in the Greek manufacturing sector are still present many barriers to technology transfer that do not permit 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 of 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 against a quick adoption of foreign technology.

Apart from the low speed of autonomous technology transfer, the empirical analysis of the paper 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 equal to three years. The identity of trading patterns does not appear to be a crucial factor while the learning-by-exporting gains are bounded, as they exist only up to a certain

[21] Appendix B discusses how it is calculated the time needed to cover half gap of technical efficiency in steady state. The appendix also provides a formal unit root test for stationarity testing whether the model specified in equation 10 is a good approximation of an equilibrium correction model (ECM).

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

threshold. In any case, the positive estimates of the interaction trade terms indicate consistently that trade should 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 from other studies but higher rates of innovation are always associated with higher rates of TFP growth. This result is insensitive to alternative measures of R&D and econometric specifications.

Third, the variables included to reflect institutional factors, minimum to median wage and market concentration are consistently negative. The analysis confirms the existence of a negative effect of powerful trade unions on economic performance while the existence of dominant firms in the market causes slack that leads to a slowdown of the whole 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. From a different point of view, one can find various alternative measures for labour market distortions. For instance, measures that refer to the number of missing working hours due to strikes can also reflect 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 a more disaggregate level as well as for a long time series.

As already discussed, the negative impacts of a distorted labour market on TFP growth are resulted in by the power of trade unions and the extensive use of welfare state policies. With reference to Greece, an extensive use of a welfare state program during 1980s has harmed entrepreneurship preventing firms from adjusting their labour inputs effectively and quickly. As a result, firms find 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.

The current research leaves some issues unexplored that can be paths for further investigation. More analysis is necessary for the direct impact of foreign R&D on domestic TFP (Coe and Helpman (1995) and Kneller (2000)). In addition, the present research is silent about other types of internationalisation that might play a role on TFP growth such as FDI. 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. In the same line of argument, higher levels of exposition to globalization trigger a reallocation mechanism that leads new (old) firms to entry (exit) the market affecting, hence the industry's overall productivity.

Appendix A

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

Appendix B

Relative TFP at Steady State

An empirical counterpart of equation (5) is $\ln\left(\frac{A^*_{i,GRC}}{A^*_{i,GER}}\right) = \frac{\gamma_{i,GRC} - \gamma_{i,GER}}{\bar{\lambda}_{i,GRC}} = \frac{0.0735 - 0.0045}{0.155}$, which can provide us with the value of RTFP (relative TFP) between Greece and Germany in steady state. To calculate the speed of adjustment in autonomous technology transfer, we consider that $\gamma_{i,GRC}$, $\gamma_{i,GER}$ the growth rates of productivity in both countries at steady state equilibrium are approximated by the average TFP growth rate over the whole period under study. The speed of technology transfer is determined by the parameter $\bar{\lambda}_{i,GRC}$, which is the average value of all TFP gap coefficients reported in Table 5 (i.e. estimated coefficient of column 6 is ignored due to the reduced sample). The above calculations indicate that RTFP in steady state is 44%.

A formal Test of Convergence

To obtain a more formal test of convergence for each industry the methodology of Bernard and Durlauf (1995) and Bernard and Jones (1996a) 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. $\text{TFP gap} = \ln(A_{i,GER,t}) - \ln(A_{i,GRC,t})$, 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 shown in both columns of the table below, the null hypothesis of stationarity is accepted in all industries. Equivalently, this suggests that convergence is at work for all industries in the sample. The acceptance of the null hypothesis implies that the model specified in equation 10 is a close approximation of an equilibrium correction model (ECM). The economic intuition of the equilibrium correction model in a framework of productivity convergence is that with not stationary in the *TFP* gap variable, the long-run average productivity growth would be different (Bernard and Jones, 1996a).

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	0.145	0.369
Electrical Machinery and Apparatus	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
Other Manufacturing	0.158	0.396

Notes: The 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 from a rule provided by Schwert (1989). The Schwert criterion for the current test chooses 8 as maximum lags for all industries.

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