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Long run effects of regulation across OECD countries: Panel data evidence within a productivity convergence model

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Abstract

The purpose of this paper is to econometrically quantify the long run impact of market regulation on TFP (Total Factor Productivity) in OECD economies. To this end, recently developed panel data econometric techniques are used to distinct between short run and long run effects, to account for country heterogeneity and to control for the presence of common factors across countries. The results of this study indicate the presence of a long run equilibrium relationship between regulation and TFP. The empirical evidence of the estimated dynamic error correction model reveals that, in the long run, lower regulation exerts a significantly positive effect on TFP in OECD countries. This impact is robust only in the group of more productive countries. Short run effects of regulation on TFP are not statistically significant.

JEL classification: L51, O47, O50

ΠΕΡΙΛΗΨΗ

Ο σκοπός της παρούσας εργασίας είναι να προσδιοριστεί ποσοτικά η μακροπρόθεσμη επίδραση στη συνολική παραγωγικότητα των συντελεστών (ΣΠΣ) των ρυθμίσεων σε επιμέρους χώρες του ΟΟΣΑ. Για το σκοπό αυτό, χρησιμοποιούνται πρόσφατες οικονομετρικές τεχνικές προκειμένου να διαχωριστούν οι μακροχρόνιες από τις βραχυχρόνιες επιδράσεις, να ληφθούν υπόψη τυχόν διαφοροποιήσεις μεταξύ επιμέρους χωρών και να ελεγχθεί τυχόν παρουσία κοινών παραγόντων σε όλες τις χώρες. Τα αποτελέσματα αυτής της εργασίας αναδεικνύουν την ύπαρξη μιας μακροχρόνιας σχέσης ισορροπίας μεταξύ του δείκτη ρυθμίσεων στις χώρες του ΟΟΣΑ και της ΣΠΣ. Τα εμπειρικά αποτελέσματα του δυναμικού υποδείγματος διόρθωσης λαθών (error correction model) δείχνουν ότι, μακροπρόθεσμα, η μείωση στο βαθμό ρύθμισης των οικονομιών του ΟΟΣΑ ασκεί μια σημαντικά θετική επίδραση στη ΣΠΣ. Αυτή η επίδραση, ωστόσο, παραμένει ισχυρή μόνο στην υποομάδα των πιο παραγωγικών χωρών. Τέλος, οι βραχυχρόνιες επιπτώσεις των ρυθμίσεων στην παραγωγικότητα δεν είναι στατιστικά σημαντικές.

1. Introduction

During the last twenty years significant changes have been observed in the regulatory environment of most OECD countries, towards the direction of higher liberalization in product markets. Although, in general, product market regulation has become less restrictive, this has occurred at different starting points, to a different extent and probably with varying economic impact across the economies.

Aghion and Griffith (2005) argue that economics still does not have a complete understanding on the effects of competition on economic growth. Early theoretical views provided negative predictions on the impact of competition on innovation and growth, while most recent neo-Schumpeterian arguments (Aghion et *al.*, 2005) and most of the recent empirical studies support that competition is positively associated with innovation and higher economic growth. However, a major shortcoming of the existing literature is that it has not distinguished so far between long run and short run influences of regulation on productivity.

Compared with the existing literature, this paper contributes in the relevant field in two aspects. First, a dynamic error correction model is used to distinguish between short run and long run effects of market regulation on Total Factor Productivity (TFP) of OECD countries, for the period 1975-2007. Second, this paper improves on the econometric methodology of previous studies by using recently developed panel data econometric techniques, which allow for the existence of heterogeneity across countries and control for the presence of common factors across panel members. This is a particularly useful approach when studying the effects of regulation across a panel of interconnected OECD countries, which are subject to common shocks.

Given the large time span covered by this study, the scope of productivity improvement after initial regulatory efforts remains largely unknown. Large

heterogeneity among OECD countries in terms of productivity performance and degree of market regulation renders the investigation of the productivity effects of regulation an issue of high empirical importance with OECD constituting a particularly interesting case to measure the effects of liberalization, since large policy changes have taken place in this area during the last twenty years. Given that productivity convergence remains a priority issue for economic policy, the findings of this study may prove useful to understand how competition can affect growth in the long run.

This study is based on a model of TFP convergence. The results indicate the presence of a long run equilibrium relationship between regulation and TFP. The empirical evidence of the estimated dynamic error correction model reveals that in the long run lower regulation exerts a significantly positive impact on TFP of OECD countries. However, these effects seem to depend on the proximity of countries to the productivity frontier, with a significant influence observed only for relatively more productive economies. In the short run, the growth impact of regulation is not statistically significant, implying that the effects of regulation on productivity can be realized after an initial adjustment period. The results are robust to various specifications and econometric estimators which take account for the presence of common factors in structure of the data.

The paper proceeds as follows: In sections 2 and 3, the findings of the relevant theoretical and literature are presented, while in section 4, measures of TFP growth across countries are derived. Section 5 introduces the econometric framework and presents the data. Section 6 discusses the regression results. Finally, section 7 concludes.

2. Theoretical framework

Aghion and Griffith (2005) argue that economics still has a limited and contradictory understanding on the effects of competition on economic growth. On the one hand, economic theory suggests that competition in product markets results in higher efficiency and productivity by reallocating markets shares to most productive businesses, by forcing exit of less efficient ones and by allowing more efficient firms to enter the market (Melitz, 2003). It also ensures that managers and workers do not slack and spend their time on leisure. However, to the extent that monetary incentives have an effect on managerial performance, managerial incentives may worsen due to lower profitability caused by higher competition (Vickers, 1995).

The Schumpeterian view stresses that competition discourages innovation, since it reduces post entry rents. Similarly, in endogenous models of economic growth (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992) a higher rate of innovation is the result of property right protection of patents. Therefore, an increase in market competition has a negative effect on productivity growth, because it discourages innovation.

Recent theoretical models of growth argue that competition affects the growth of countries which are close to the world technology frontier. Acemoglu et *al.* (2006) constructed a simple endogenous growth model to investigate how certain policies that affect growth at early stages of development, then become harmful for growth. The main assumption in their analysis is that innovation becomes highly important when a country reaches the technology frontier. They argue that it is optimal for countries which are away from the productivity frontier to invest in factor accumulation and technology adoption which can both prosper under conditions of limited competition. In more advanced countries where the possibilities for further

growth through factor accumulation and imitation have been exhausted, innovation becomes the main vehicle for higher growth. To the extent that a higher innovation rate depends on competition, countries should adopt policies towards higher liberalization.

In this context, Aghion et *al.* (2006) note that the post war catching-up of the European economies to the US slowed down as the relative technology gap narrowed. They argue that policies and institutions which were designed towards technology adoption are not now appropriate for most European economies which are now closer to the technology frontier and stress the need for policies in favour of higher competition in the markets, which in turn will affect positively innovation and growth. However, Parente and Prescott (1994) have assumed a model of technology adoption where the decision of a firm to invest in technology depends on the degree of legal and regulatory barriers, the existence of which increase the cost of technology adoption. In the same spirit, Alesina et *al.* (2005) argue that fewer regulations lower the cost of expanding capital stocks of firms and argue that the cost of reorganizing the production process after adoption of a new technology is lower in regulatory friendly environments.

The early Schumpeterian arguments stress that innovation and growth are negatively correlated with competition, since the monopoly rents decrease with higher competition. However, recent neo-Schumpeterian analyzes have questioned this view by arguing that, as competitive pressures increase then incumbent firms will engage in competition in order to preserve their market shares. Aghion et *al.* (2005) have attempted to reconcile theory with the existing empirical evidence and showed the existence of an inverted-U relationship between competition and innovation.

Particularly, in their model, both leaders and followers in an industry can innovate, with the incentives to innovate depending upon the difference between post-innovation and pre-innovation rents of incumbent firms. Essentially, at low stages of competition, an increase in competition in the market will increase innovation, since the escape competition effect dominates the Schumpeterian effect and pushes firms in an industry to innovate in order to avoid losing market shares. At higher levels of competition, the Schumpeterian effect is more powerful than the escape competition effect, because the post innovation rents will become very low. According to this view, there exists an inverted-U relationship with too little or too much competition being harmful for innovation.[1]

Therefore, an increase of competition would have a positive impact on innovation, and thereby growth, at low levels of competition. At higher levels of competition, a further increase of competition would probably damage growth, as incentives to innovate are discouraged. Askenazy *et al.* (2013) supplement this evidence by showing that competition does not impact on R&D behavior when firms are small or when the cost of innovation is relatively large. In such cases the inverted U shape of the curve becomes flatter.

3. Empirical literature

Most findings of the recent empirical literature indicate that higher competition in the markets or lower regulations in the economies are positively associated with productivity growth. Nickell (1996), based on UK firm level data, considered the impact of market structure on productivity and established a negative effect of higher

[1] Another prediction is that increased competition tends to foster innovation only in technologically advanced sectors. In this way, the technology gap between leaders and followers increases, since competition fosters innovation in the former and discourages innovation in the later.

concentration rates on TFP growth. Blundell et *al.* (1999) also used UK firm level data and analyzed the relationship between innovation output and degree of competition, as measured by market concentration, market shares and import penetration. The results indicated that sectors characterized by less competition had also lower innovation output.

Nicoletti and Scarpetta (2003) looked at the effects of regulation on productivity of manufacturing and services across 18 OECD countries for the period 1984-98. Their results showed that product market regulation on its own had no impact on productivity. However, when interacted with the technology gap, the estimates indicated that that lower regulation helps industries catch up with the technology frontier. Aghion et *al.* (2003) looked at the effect of entry liberalization on productivity of UK firms. They showed that liberalizing and reducing barriers to entry has a positive effect on economic performance of firms and industries which are initially closer to the technology frontier and can survive competition by innovating. On the other hand, it has a negligible or even negative effect on firms and industries which are far from the frontier and may be damaged by liberalization, since they are in a relatively weaker position to fight entry.

The empirical results of Conway et al. (2006) indicate that strict product market regulations have hindered technology adoption and diffusion of technology in several EU countries, resulting in widening productivity gaps between the US and the EU, as well as between southern and northern European countries. Arnold et *al.* (2008) provided industry level evidence that tight product market regulations in service sectors of continental EU countries have affected productivity growth by hindering the allocation of resources towards most efficient firms.

Inklaar et *al.* (2008) looked at the effects of entry liberalization on productivity of market services, however their results showed that liberalization has been beneficial for productivity growth only in the telecommunications' industry. Barone and Cingano (2011) showed that lower regulation in services has resulted in higher growth rates of value added, productivity and exports in manufacturing industries that use services more intensively. Importantly, they show that higher regulation in professional services and energy has particularly strong negative effects on the outcomes of the above variables.

Bena et *al.* (2011) investigated whether liberalization in the industries of utilities, transport and telecommunications has affected productivity of European network firms. After having taken account of country, industry and year effects, they showed that liberalization had a positive impact on TFP growth during 1998-2007. Finally, Bartelsman et *al.* (2013) used firm level data to investigate the effect of policy distortions on aggregate productivity. They showed that market distortions result in misallocation of resources and account for a large part of cross country productivity differences.

4. TFP growth estimates

4.1 Growth accounting framework

In order to compute TFP growth series for each OECD country, we start with growth accounting. We assume the following neoclassical, constant returns to scale Cobb Douglas production function:

$$Y_{it} = A_{it}(K_{it})^{\alpha}(L_{it})^{(1-a)} \quad (1)$$

where Y_{it} represents total gross value added of each country *i*, *K* is the physical capital stock of each country and *L* is the labor input, measured in total hours worked. Furthermore, *A* is a labor and capital neutral technology parameter, associated with

TFP growth, *t* is a time index and *a* is the elasticity of capital with respect to output, which varies across countries and time. After taking logarithms, differentiating both sides of Equation (1) and accepting the hypothesis of constant returns to scale,[2] we obtain:

$$\ln(\frac{Y_{it}}{Y_{it-1}}) = \ln(\frac{A_{it}}{A_{it-1}}) + a\ln(\frac{K_{it}}{K_{it-1}}) + (1-a)\ln(\frac{L_{it}}{L_{it-1}}) \quad (2)$$

Equation (2) indicates the main sources of growth of an economy. In particular, the growth rate of output, $\ln(\frac{Y_{it}}{Y_{it-1}})$, is comprised of three main components: the growth rate of labor, $\ln(\frac{L_{it}}{L_{it-1}})$, multiplied by its income share *(1-a)*, the growth rate of capital, $\ln(\frac{K_{it}}{K_{it-1}})$, multiplied by its income share *(a)* and TFP growth, $\ln(\frac{A_{it}}{A_{it-1}})$.

With this framework, changes in output growth can be decomposed into the contributions of physical capital, labor and measured TFP growth. Each input's contribution is measured by its growth rate weighted by its income share, which, in turn reflects its output elasticity. The part of output growth not attributable to inputs is the TFP residual and includes technological change, the efficiency with which the inputs are used, deviation from competitive equilibrium, as well as measurement errors and unmeasured inputs:

$$\ln(\frac{A_{it}}{A_{it-1}}) = \ln(\frac{Y_{it}}{Y_{it-1}}) - a\ln(\frac{K_{it}}{K_{it-1}}) - (1-a)\ln(\frac{L_{it}}{L_{it-1}}) \quad (3)$$

By using growth accounting, technology gaps are also estimated for each OECD country. USA is considered as the frontier country with the remaining

[2]It is assumed that inputs are paid according to their marginal products and therefore the income shares of labor and capital income sum up to 1.

countries considered as the follower ones. Therefore, the technology gap for each follower country i is expressed as the level of TFP of the US economy relative to the level of TFP in country i:

$$\text{technology gap} = \ln\left(\frac{A_{USAt}}{A_{it}}\right) = \ln\left(\frac{Y_{USAt}}{Y_{it}}\right) - a_K \ln\left(\frac{K_{USAt}}{K_{it}}\right) - (1 - a_K)\ln\left(\frac{L_{USAt}}{L_{it}}\right) \quad (4)$$

A low value of technology gap indicates that a country operates close to the frontier, while a high value indicates that this country is far away from the frontier.

4.2 Data, real capital stocks and income shares

The data used for this empirical study cover 21 OECD countries for the period 1975-2007 and are expressed on an annual basis. The data for total gross value added in each OECD country (expressed in 1995 prices) as well as for hours worked were taken from the EU KLEMS Database (2013). Data for physical capital stocks in each country and up to 2001 were also taken from the OECD database, with their construction analytically described in Kamps (2005). For the years 2002-2007, the construction of physical capital stock series for each country is based on the perpetual inventory method:

$$K_{t+1} = I_{t+1} + (1-\delta)\, K_t \quad (5)$$

The data for real gross fixed capital formation have been provided by the OECD STAN Industrial Database (2013). The value for the depreciation rate of capital, δ, was chosen to be consistent with the observed data on the consumption of fixed capital, provided by the OECD STAN Industrial Database (2013), for each country and year.

The income shares of capital and labor, *a* and *1-a*, were measured directly with the use of labor and capital compensation data, provided by the EU KLEMS

database.[3] These income shares, combined with the available data on the growth rates of capital, labor and output, allow us to estimate the relative growth contribution of each factor of production, as well as TFP growth.

4.3 Growth accounting results

The growth accounting estimates for TFP growth and technology gaps for each country are shown in Table 1. The highest TFP growth rates are observed in Finland, Ireland and Portugal with average rates exceeding 2%. On the contrary, Switzerland, Greece, Canada and Spain have experienced quite low TFP growth rates during this period, which were below 1% which are below those of the US economy (1.03%).

In most countries, technology gaps have narrowed with the most striking case that of Finland, with its technology gap falling from 43.1% in 1975 to 1.7% in 2007. In eight out of the 21 countries technology gaps had become negative in 2007, indicating non existence of a technology gap vis-a-vis the US. On the other hand in few countries (Canada, Greece, Switzerland and Spain), technology gaps have widened. The highest technology gaps in 2007 were observed in south European countries (Portugal, Spain, Greece and Italy) as well as in New Zealand and Japan.

In the same Table, we observe that in most countries output growth was mainly driven by the high contribution of TFP growth. Particularly, in thirteen OECD countries more than half of total value added growth was contributed by TFP growth during 1975-2007, while in nineteen countries of the sample more than 30% of total value added growth was fuelled by TFP growth.

This analysis confirms the findings of Jones and Olken (2008) showing that shifts in the growth process are largely due to changes in productivity growth and do

[3] For further details see Timmer et *al.* (2007).

not rely on changes in the factors of production. Prescott (1998) has, also, argued that TFP is the basic determinant of income differences across the world economy. Comparable evidence has been offered by Kehoe and Prescott (2002), indicating that the rate of TFP can adequately explain long economic periods across many developed countries (e.g. USA, UK, Germany).

5. Econometric framework and data

5.1 Econometric framework

The model of this study is based on Aghion and Howitt (2006) where productivity growth of a country depends on its ability to keep pace with the technology frontier. It also depends on the size of the technology gap between the follower and the leader country. Therefore, for each country *i* we assume a model of TFP growth in the following form:

$$TFP_{it} = \alpha TFP_{USAt} + \beta TG_{it} + \gamma REG_{it} + \delta REG_{it} * TG_{it} + \mu_i + d_t + e_{i,t} \quad (6)$$

where indices *i* and *t* denote country and year, respectively. TFP_{it} is total factor productivity growth of the follower country *i* (and TFP_{USAt} is TFP growth of the leader country (USA). Therefore, productivity growth of the leader economy may influence productivity growth of the follower country.

The term of technology gap (TG_{it}) is calculated by Equation (4) as the ratio of the level of TFP of the leader country, relative to the level of TFP of the follower country *i*. Recent neo-Schumpeterian models of growth argue that if technology is free to flow across countries and industries, then productivity growth is a positive function of the technology gap between the follower and the leader country, often referred to as the catch-up phenomenon. Therefore, if coefficient β is positive and

statistically significant, this implies the existence of high potential for technological catching-up with the leader country.

By considering the REG indicator, we wish to search for the existence of any effects of regulation on TFP growth. The impact of regulations can be measured, also, indirectly be including in the regression the term REG * TG, allowing for the regulation variable to interact with the level of technology gap. A negative coefficient on δ implies the existence of indirect negative effects by slowing down the catching-up process of laggard countries.

Country effects (μ_i) and year effects (d_t) are also considered in this model to account for unobserved country specific effects and common productivity shocks, respectively.

5.2. Market regulation data

To analyze the impact of regulation on TFP growth, the time varying indicator of regulation in energy, transport and communications is used, which summarizes regulatory provisions in seven network services: telecommunications, electricity, gas, post, rail, air and road passenger transport. This indicator covers the extent of entry limitations, state control, price control as well as the degree of public ownership in these sectors and receives values ranging from 0 to 6, with higher values reflecting a higher degree of regulation. This indicator is analytically described in Conway and Nicoletti (2006) and is available in the OECD product market regulation database.

The advantage of using this regulation index is its time dimension, covering a long period of time for each OECD country, and, therefore, allowing for time series and panel data analysis. Although it covers certain industries, it can be used as a proxy for the economy wide regulatory environment, since it includes sectors in which much anti-competitive regulation is concentrated (Scarpetta and Tressel, 2002; Conway et

al., 2006). In addition, this index is highly correlated with the cross section economy wide product market regulation in the years in which they overlap (Conway et *al.*, 2006). A further advantage of this index of regulation is that it can be treated as an exogenous measure of regulation, which is not affected by productivity outcomes.[4]

Figure 1 shows how this indicator has evolved between 1975 and 2007, across 21 OECD countries of the sample. It is readily evident that in 1975 almost all OECD economies were heavily regulated, with the exception of the USA. However, the degree of regulation has been significantly reduced in all OECD countries, at different degrees and to different extent however, with the most liberal countries in 2007 being UK, Germany and Denmark. On the other hand, the most regulated economies were Greece, Ireland and Portugal.

6. Econometric estimates

6.1 Introduction

The panel data set used by this study consists of 21 OECD countries for the period 1975-2007. When the time dimension of the panel is large, traditional panel data estimators lead to biased coefficient estimates, unless the slope coefficients are identical across cross sections (Pesaran and Smith, 1995; Pesaran et *al.*, 1999). The use of an error correction model in the form of a pooled mean panel data estimator is particularly recommended in cases that both the cross section and the time dimension are large (Pesaran and Smith, 1995). This estimator is useful as it allows us to distinguish long run from short run effects, while at the same time it takes account for cross country heterogeneity. Going one step further, cross country heterogeneity in the

[4] A large amount of microeconomic literature uses traditional indicators of mark-ups or industry concentration rates to analyze the impact of competition on productivity. However, such indicators cannot be treated as exogenous, since higher productivity of firms in an industry could lead to higher concentration in the market.

presence of unobserved common factors is addressed by using Pesaran's (2006) common correlated effects estimator.

In summary, the empirical strategy of this study consists of (i) assessing cross sectional dependence and stationarity of the time series, (ii) investigating the presence of a cointegrating relationship between regulation and TFP, based on unit root and cross sectional dependence tests and (iii) in case cointegration is accepted, estimating an error correction model.

6.2 Cross sectional dependence, stationarity, cointegration

Panel unit root and panel cointegration tests are distinguished between first and second generation ones, on the basis of whether they take into account the presence of cross sectional dependence in the data. Therefore, before assessing the order of integration as well as the presence of cointegration in the series, we first test for the presence of cross sectional dependence in the data.

Cross sectional dependence has been in the focus of recent literature due to high degree of economic and financial integration observed in the economies (Eberhardt and Teal, 2011). Such effects arise from the presence of global or local common shocks with heterogeneous effects across countries, like for example the recent global financial crisis. The presence of common factors in the data is tested here by employing the Pesaran (2004) test for cross section dependence. The tests are based on pair wise correlation coefficients and are presented in Table 2. The results of the test strongly suggest rejection of the null hypothesis of no cross sectional dependence in the data.

In the panel data literature several unit root tests have been proposed, starting from those of Levin et *al.* (2002) and Breitung (2000) which are based on the

existence of a common autoregressive parameter across individual units. The Im et *al.* (2003), as well as the Fisher type test of Maddala and Wu (1999) allow for heterogeneity in the value of the autoregressive parameter, however they ignore cross section dependence in the data. The second generation panel unit root test of Pesaran (2007) allows for the presence of unobserved common factors with heterogeneous factor loadings in the data, while at the same time allows for heterogeneity in the autoregressive coefficient.

We can see the results of all these tests in Tables 3 and 4. For each variable in its levels {Total Factor Productivity (TFP), Regulation (REG), Technology Gap (TG)}, Table 3 displays the value of the test and the associated p-value. The majority of the tests suggest that all three variables are non stationary in their levels, while the Pesaran (2007) second generation test does not reject the hypothesis that all variables are I(1). Table 4 reports panel unit root tests for the first differences of variables, where the null of no stationarity is rejected for all variables, suggesting that these become stationary after having taken their first differences. The number of chosen lags is based on the optimization of the Schwartz information criterion.[5]

Table 5 presents the results of seven panel cointegration tests proposed by Pedroni (1999, 2004). Among those, four of them accept the hypothesis of a common autoregressive coefficient, while the rest of them relax this assumption. Using a variety of assumptions on the existence of intercept and trend in the cointegrating regression, the majority of the tests do not reject the null hypothesis of no cointegrating relationship among the variables.

Based on tests of Table 2, we have been informed that the data exhibits cross sectional dependence. Westerlund (2007) proposes four tests (G_t and G_a, P_t and P_a)

[5] Several versions of these tests have been employed, with respect to the existence or not of country specific trends, all of which indicate that the series are integrated of order one.

which test for panel cointegration and, at the same time, control for the existence of common factor effects in the data. The idea is to test for the presence of cointegration within a selected group of the panel (G_t and G_a) or for the panel as a whole (P_t and P_a). Since we suspect the presence of common factors in the data, bootstrapped critical values of the test have been obtained, while robust p-values of these tests have also been reported (Table 6). The majority of the tests strongly reject the null hypothesis for the absence of a cointegrating relationship between REG and TFP. Several versions of the Westerlund test are employed which control for the existence of trend and include a number of leads and lags in the cointegrating regression. Most of these suggest that the series are cointegrated.

On the basis of validity of the assumption for the presence of common factors in the variables, as suggested by the results of the cross section dependence test of Pesaran and based on the results of the Westerlund cointegration test, we can accept the hypothesis of a long run cointegrating relationship between TFP and regulation, which can be econometrically quantified.

6.3 Econometric estimates

The panel cointegration test of Westerlund (2007) indicates the presence of a long run equilibrium relationship between regulation and TFP. However, it does not provide parameter estimates for long run and short run effects of regulation on TFP. Having established that all series are I(1) and a long run cointegarting relationship exists between TFP and regulation, we are now able to proceed with the estimation of a panel error correction model, which will allow us to assess the long run impact of regulation on TFP.

The model of Equation (6) can be re-parameterized into an error correction equation as follows:

$$\Delta lnTFP_{it} = \varphi\{lnTFP_{it-1} + \beta_1 ln(REG_{it-1})\} + \delta_1 \Delta ln(TFP_{it-1}) + \delta_2 \Delta ln(REG_{it-1}) +$$

$$\delta_3 \Delta lnTFP_{USAt-1} + \delta_4 \Delta(TG_{it-1}) + \delta_5 \Delta(REG_{it-1} * TG_{it-1}) + \mu_i + e_{it} \qquad (7)$$

where φ is the error correction speed of adjustment. If φ<0, there is a long run relationship between TFP and REG. If φ = 0, then there is no evidence in favor of a long run relationship. Therefore, this parameter is expected to be significantly negative in order for the variables to return to long run equilibrium. Furthermore, β_1 is the coefficient which represents the long run relationship impact of regulation on TFP, μ_i are country specific effects and δ_i are the short run coefficients of variables.

Equation (7) represents a typical pooled mean group estimator in which short run coefficient estimates are allowed to differ across countries (Pesaran and Smith, 1995). This estimator is useful in analyzing panel data with large time series and large cross section dimension. In contrast to traditional panel data estimators, where homogeneity of coefficients is assumed, the pooled mean group estimator allows the short run coefficients to differ across countries, while long run effects are assumed to be identical across countries. In summary, this estimator obtains an estimate on the long run impact of REG on TFP, common across all countries, without imposing the restrictive assumption of identical short run dynamics.

Table 7 presents estimates across OECD countries for the period 1975-2007. Based on the estimates of the Hausman test (1978), equality between the mean group and pooled mean group estimates is not rejected, showing that a common long run elasticity is accepted by the data.[6] Coefficient estimates are estimated by maximum

[6] The choice between the mean group and pooled mean group implies a consistency-efficiency tradeoff. The mean group estimator provides consistent estimates of the mean of long run coefficients, however it is less efficient as compared to pooled mean group estimator. If homogeneity of long run coefficients holds, then the pooled mean group estimator is consistent and efficient. Following the results of the

likelihood, with the appropriate lag length chosen by the minimization of the Schwartz Bayesian Criterion. Apart from long run effects of deregulation (REG), short run effects are also allowed (ΔREG), while controlling for the influence of technology gap (TG*)* as well as for TFP growth of the leader country (TFP GROWTH USA).

The results presented in the first column of Table 7 show that the coefficient estimate associated with the long run impact of regulation is negative and statistically significant. It shows that in the long run the impact of lower regulation is beneficial for the increase of cross country productivity. More specifically, the magnitude of the estimated coefficient implies that a 1% decrease in the degree of regulation results in a 0.15% average increase of TFP. With respect to short run effects of regulation, the estimate of the associated coefficient is negative but statistically insignificant, indicating that short run gains from lower regulation cannot be realized due to market imperfections.

The magnitude of the error correction parameter (φ) represents the speed of adjustment with which the values of TFP and REG return to their long run equilibrium levels. The larger the absolute value of φ, the higher is the speed towards convergence, after a deviation from long run equilibrium. The estimated coefficient of the error correction parameter is negative and statistically significant. This is in line with theoretical predictions for convergence towards long run equilibrium and implies that a change in one variable results in a feedback effect to the other variable.

In column 2 of Table 7, we control for the effects of technology transfer captured by the variable of technology gap (TG). In contrast to neo-Schumpeterian predictions, the estimate of the associated coefficient is negative and statistically

Hausman test, the estimates of Table 7 are based on the pooled mean group estimator, which allows for country specific short run coefficients but imposes common long run effects.

significant, suggesting that countries lagging behind the productivity frontier do not experience higher TFP growth rates.

In column 3, we test whether the degree of regulation has an indirect impact on TFP growth, through its influence on technological catch-up, by including as a regressor the interaction term TG*REG. Neo-Schumpeterian models of growth argue that if technology is free to flow across countries, in the form of lower regulation, then productivity growth is a positive function of the technology gap (Aghion et al., 2005). Therefore, a higher degree of regulation should have an indirect negative impact, by slowing down the catch-up process. The results, with respect to this variable, although negative, are not statistically significant and do not provide us with clear evidence on the validity of this theoretical prediction.

Regression results in columns 4 and 5 control for the effects of outward shifts in the technological frontier, as captured by the variable of TFP growth of the leader country (TFP GROWTH USA). However, it seems that TFP growth of the leader country does not significantly affect productivity growth of the follower economies. It is noteworthy that the estimates of the coefficient of regulation remain negative and statistically significant, irrespective of econometric specification, providing us with more confidence to argue that lower regulations exert a positive influence on TFP in the long run.

6.4 Robustness check

Having established that lower regulations exert a significantly positive long run effect on TFP of OECD countries, we go one step further to test whether this relationship holds across two separate samples covering the sub periods of 1975-90 and 1990-2007. The division of the sample in these two sub-periods can be justified on the basis

that the first one can be characterized as a period with higher regulation and small changes over time, while the second one is a period with significant structural changes and lower degree of regulation. The time dimension remains sufficiently large in the two sub-periods to justify the use of a pooled mean group estimator.

Column 1 of Table 8 presents the regression results for the period 1975-90. The main results can be summarized as follows: the long run impact of lower regulation remains negative and statistically significant, while the short run effects are statistically insignificant. The coefficient of TG is negative, but statistically significant, unlike estimates of Table 7, where the effect of TG was significantly negative across all specifications. We are also obtained with some evidence that TFP growth of the leader country exerts a significantly positive (at 10% level of significance) effect on productivity growth of the follower economies.

Column 2 of Table 8 covers the estimates for the later period 1990-2007. It is interesting to notice that long run effect of lower regulation is much higher, compared to the estimated impact for the entire period 1975-2007. To get more intuition, the estimate of the long run effect of regulation indicates that, on average, a 1% reduction in the index of regulation has to an increase of TFP by 0.2%. We are also obtained with a positive and statistically significant short run effect of regulation on TFP, which can be explained as the result of negative transitional effects of deregulation, in the form of adjustment costs of firms and industries. Balsvik and Haller (2011) have shown that competition from new entrants is likely to have a detrimental effect on productivity, if firms are not able to adjust their input usage. The rest estimates of Table 8 show a significantly negative effect of technology gap on TFP growth, as well as a significantly positive effect of TFP growth of the leader country on productivity growth of the follower economies.

Robustness of the obtained results is also checked by considering two distinct samples of countries which are either close or far from the technology frontier. Based on the estimates for average technology gaps, two groups of countries arise: the first one consists of more productive ones which are the UK, Sweden, Canada, Denmark, Switzerland, France, Ireland, Netherlands, Norway and Belgium. The second one consists of countries which have average technology gaps higher than 10% and includes those of Portugal, Greece, New Zealand, Finland, Spain, Australia, Japan, Austria, Italy and Germany. The results demonstrate the existence of a positive and significant long run effect of lower regulation on TFP of more productive countries (column 3). Short run effects of regulation are also negative and statistically significant (at 10% level of significance). On the contrary, in less productive countries, the long run coefficient of regulation, although negative is not statistically significant, implying non existence of any serious effect of lower regulation on average productivity.

In the case that the explanatory variables of Equation (6) are correlated with global or local unobserved shocks we may have been obtained with biased estimates. The common correlated effects estimator of Pesaran (2006) allows for the presence of unobserved common factors in the variables, with heterogeneous impacts across countries. This estimator has a particular appeal for this kind of study which examines the productivity effects of regulation across a number of interconnected economies. The error correction equation (7) is augmented with cross sectional year averages of the dependent variable $\Delta \ln TFP_{it}$, which can blend out the biasing impact of the unobserved common factor:

$$\Delta lnTFP_{it} = \varphi \{lnTFP_{it-1} + \beta_1 ln(REG_{it-1})\} + \delta_1 \Delta ln(TFP_{it-1}) + \delta_2 \Delta ln(REG_{it-1}) + \delta_3 \Delta lnTFP_{USAt} + \delta_4 \Delta(TG_{it-1}) + \delta_5 \Delta(REG_{it-1} * TG_{it-1}) + \delta_6 Avg\Delta ln(TFP_{it-1}) + e_{it} \quad (8)$$

As shown by the regression results of Table 9, the negative impact of regulation on TFP is verified in all regression estimates, confirming that policies towards lower regulation result in higher average TFP growth.

6.5. Discussion

The results of this study are in favor of a long run equilibrium relationship between regulation and TFP. The empirical evidence of the dynamic error correction estimated model reveals that in the long run lower regulation has a positive effect on productivity. On the contrary, short run effects of regulation on productivity are statistically insignificant in most of the cases. This evidence is consistent with the view that in the period after deregulation, the impact of liberalization might be insignificant or even negative in the form of adjustment costs and, therefore, the effects of lower regulation are expected with a time lag. In contrast to recent neo-Schumpeterian models which argue that productivity growth is a positive function of the technology gap, the estimates of this term are in most cases negative and statistically significant, suggesting that countries with high technology gaps do not experience higher TFP growth rates.

These results have been checked for their robustness across time and suggest that the productivity impact of regulation remains negative and statistically significant across both periods of 1975-90 and 1990-2007. However when dividing the entire sample into two different groups based on the distance of countries from the technology frontier, we are obtained with evidence that the effects of lower regulation on productivity are positive and statistically significant only in the group of more productive economies. Such asymmetric effects of deregulation may be caused by different productivities as well as different stages of competition across countries. In

particular, countries that are close to the technology frontier can survive higher competition by innovating. In contrast, countries which are away from the frontier are in a relatively weaker position to fight increased competition. This view has been supported by Aghion et *al.* (2003), showing that liberalizing and reducing barriers to entry has a positive effect on economic performance of firms and industries which are initially close to the technology frontier. On the other hand, it has a negligible or even negative effect in firms and industries which are far from the frontier and may be damaged by liberalization. In the same spirit, Van Ark et *al.* (2008) have argued that although there is a direction towards higher flexibility and liberalization in Europe, the extent and the impact of regulatory reforms varies across EU countries, while Acemoglu et *al.* (2006) highlighted that we should not expect an immediate impact of lower regulation on productivity of laggard industries, since the effect of tough competition is stronger for industries operating close to the frontier.[7]

This paper also controls for the presence of cross sectional dependence in the data, by using the common correlated effects estimator of Pesaran. The negative impact of regulation on TFP is verified in regression estimates. In summary, the findings of this study indicate that institutions that promote higher competition in product markets through lower regulation are important for higher productivity. However, these effects seem to depend on the proximity of countries to the productivity frontier, with significant impacts observed only for relatively more productive economies.

[7] Convergence between Europe and the US, after the Second World War, has been mostly linked to the existence of institutions that favored imitation of foreign technology. In this context, Aghion et *al.* (2006) suggested that policies and institutions that facilitated imitation of technology are not suitable any more for further convergence and growth, since Europe now operates close to the productivity frontier. Therefore, they proposed that Europe should further promote liberalization in the markets, which will in turn positively affect innovation and growth in the long run.

7. Conclusions

The main purpose of this study was to assess the long run impact of regulation on TFP of OECD countries. The study was based on an econometric model of TFP convergence, in which TFP growth of the follower was modeled as a function of the degree of regulation, TFP growth of the leader, as well as of technological catch-up. The impact of regulation on TFP growth was estimated for the period 1975-2007, by using recently developed panel data econometric methodologies which distinct between short run and long run effects, allow for the presence of heterogeneous coefficients across countries and take account for the presence of common factors across panel members.

We have been obtained with sufficient evidence in favor of a long run negative relationship between regulation and TFP. The results remain robust across estimators and econometric specifications. Short run effects of regulation on TFP are not statistically significant implying than any benefits of lower regulation in the markets can be realized only in the long run. Also, the impact of regulation seems to depend on the proximity of countries to the productivity frontier, with a significant influence observed only for more productive economies. It seems therefore that the association between regulation and productivity is an issue which remains open for further research as to the impact of liberalization in countries and sectors with different initial levels of competition and diverging productivity performance.

With respect to policy making, our results are in agreement with those of Acemoglu et al. (2006) and Aghion et al. (2006). Backward economies should choose institutions and policies that initially encourage technology adoption by imitation. In this way, countries that are away from the productivity frontier may prosper under conditions of limited competition. However, for countries that are close to the

technology frontier, innovation becomes more important for higher growth. To the extent that a higher innovation rate depends on competition, leading economies should adopt policies towards higher liberalization.

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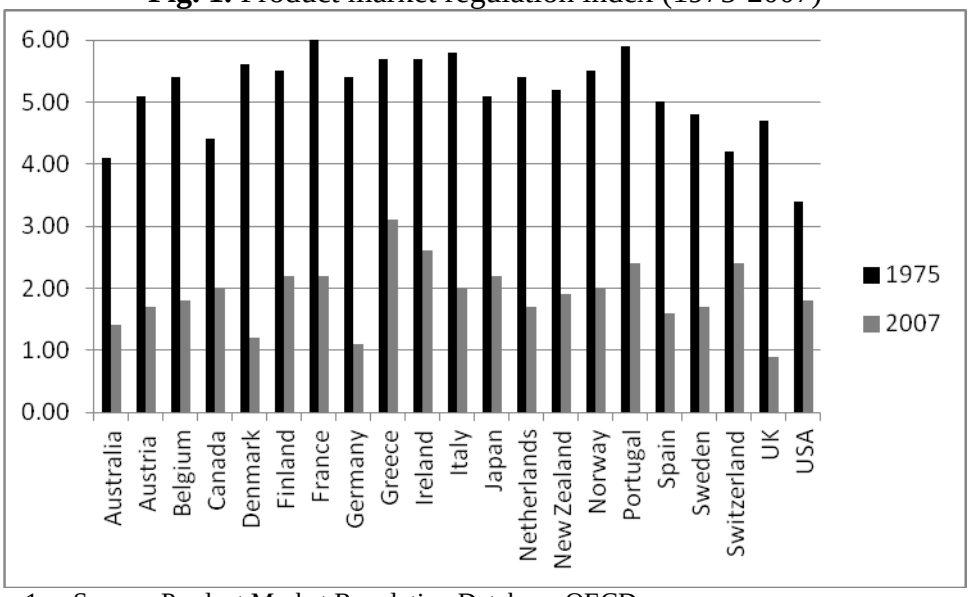
Tables & Figures

Table 1. TFP growth rates and technology gaps

	TFP GROWTH	TECHNOLOGY GAP		VALUE ADDED GROWTH
	AVERAGE (1975-2007)	1975	2007	AVERAGE
Australia	1.13%	23.53%	19.08%	3.29%
Austria	1.51%	26.14%	11.17%	2.42%
Belgium	1.33%	-3.41%	-13.48%	2.08%
Canada	0.49%	-3.26%	10.38%	2.93%
Denmark	1.28%	10.89%	-1.36%	1.89%
Finland	2.30%	43.15%	1.69%	2.66%
France	1.54%	10.11%	-3.30%	2.11%
Germany	1.61%	24.79%	7.22%	2.07%
Greece	0.96%	40.04%	44.99%	2.61%
Ireland	2.07%	18.19%	-18.67%	4.97%
Italy	1.09%	23.57%	20.57%	2.06%
Japan	1.61%	30.05%	21.10%	3.04%
Netherlands	1.48%	-2.33%	-2.98%	2.55%
New Zealand	1.10%	26.88%	22.69%	2.50%
Norway	1.84%	1.30%	-17.39%	3.18%
Portugal	2.03%	97.83%	61.20%	2.74%
Spain	0.80%	23.37%	26.73%	2.74%
Sweden	1.36%	3.67%	-5.25%	2.19%
Switzerland	0.14%	-15.84%	9.80%	1.39%
UK	1.47%	19.74%	-0.48%	2.14%
USA	1.03%			3.08%

Fig. 1. Product market regulation index (1975-2007)



1. Source: Product Market Regulation Database-OECD.

Table 2. Cross sectional dependence test

	CSD-test	p-value	Corr. (abs)
TFP	61.97	0.00	0.81
REG	71.05	0.00	0.93
TG	11.74	0.00	0.58

1. Null hypothesis: cross sectional independence.
2. TFP: Total Factor Productivity, REG: Index of Regulation, TG: Technology gap.

Table 3. Panel unit root tests (levels of variables)

Cross sectional independence			
Homogeneity of the AR coefficient			
	TFP*	REG*	TG
Levin et al. (2002)	-1.65	0.30	-2.10
	(0.04)	(0.62)	(0.01)
Breitung (2000)	2.00	8.33	1.63
	(0.97)	(1.00)	(0.94)
Heterogeneity of the AR coefficient			
	TFP	REG	TG
Maddala and Wu	34.41	31.31	16.66
(1999)**	(0.79)	(0.88)	(1.00)
Im et al. (2003)	-0.85	6.72	0.58
	(0.19)	(1.00)	(0.72)
Cross sectional dependence			
	TFP	REG	TG
Pesaran (2007)**	5.19	0.63	1.09
	(1.00)	(0.73)	(0.86)

1. Length selection based on Schwartz information criterion. Intercept and trend included.
2. Null hypothesis: Series are not stationary.
3. p-values are reported in parentheses.
4. Variables are defined in Table 2.
* variables in logs. ** Null hypothesis: the series are I(1).

Table 4. Panel unit root tests
(first differences of variables)

Cross sectional independence			
Homogeneity of the AR coefficient			
	TFP	REG	TG
Levin et al. (2002)	-16.35	-11.92	-16.02
	(0.00)	(0.00)	(0.00)
Breitung (2000)	-8.54	-11.29	-10.73
	(0.00)	(0.00)	(0.00)
Heterogeneity of the AR coefficient			
	TFP	REG	TG
Im et al. (2003)	-13.59	-11.24	-13.84
	(0.00)	(0.00)	(0.00)

1. Length selection based on Schwartz information criterion. Intercept and trend included.
2. Null hypothesis: Series are not stationary.
3. p-values are reported in parentheses.
4. Variables are defined in Table 2.

Table 5. Pedroni cointegration tests

Common AR coefficients (Panel tests)			
	No intercept, no trend	Intercept, no trend	Intercept and trend
v test*	-3.46	-0.46	8.53
	(0.99)	(0.68)	(0.00)
rho test	4.06	-0.25	-0.24
	(1.00)	(0.40)	(0.40)
PP test	8.49	-1.74	-1.06
	(1.00)	(0.04)	(0.14)
ADF test	5.49	-1.81	-2.40
	(1.00)	(0.03)	(0.00)
Individual AR coefficients (Group tests)			
rho test	7.18	2.03	1.31
	(1.00)	(0.97)	(0.90)
PP test	13.40	-0.67	-0.62
	(1.00)	(0.24)	(0.26)
ADF test	6.28	-1.43	-3.51
	(1.00)	(0.07)	(0.00)

1. Null Hypothesis: No Cointegration.
2. Number of lags are chosen automatically so that the Schwartz information criterion is optimized.
3. p-values are reported in parentheses.

Table 6. Westerlund panel cointegration tests

1 lag, constant and trend				
	value	z-value	p-value	robust p-value
G_t	-3.26	-5.19	0.00	0.02
G_a	-33.99	-15.22	0.00	0.00
P_t	-14.22	-5.29	0.00	0.26
P_a	-25.96	-13.05	0.00	0.08
2 lags, constant and trend				
	value	z-value	p-value	robust p-value
G_t	-3.85	-8.53	0.00	0.00
G_a	-32.89	-14.46	0.00	0.00
P_t	-81.19	-83.29	0.00	0.00
P_a	-94.09	-65.31	0.00	0.00
1 lag, 1 lead constant and trend				
	value	z-value	p-value	robust p-value
G_t	-3.38	-5.85	0.00	0.00
G_a	-30.04	-12.49	0.00	0.00
P_t	-14.12	-5.17	0.00	0.33
P_a	-23.19	-10.92	0.00	0.16
2 lags, 2 leads constant and trend				
	value	z-value	p-value	robust p-value
G_t	-4.19	-10.46	0.00	0.00
G_a	-27.40	-10.68	0.00	0.00
P_t	-90.58	-94.22	0.00	0.00
P_a	-80.18	-54.64	0.00	0.01

1. Null Hypothesis: No Cointegration.
2. Bootstrapped p-values computed.

Table 7. Error correction estimates

Dependent variable: log(TFP)					
	(1)	(2)	(3)	(4)	(5)
Error Correction Coefficient (φ)	-0.074* (-4.14)	-0.292* (-6.77)	-0.309* (-6.61)	-0.067* (-3.51)	-0.320* (-7.08)
Long run coefficients					
log (REG)	-0.155* (-6.67)	-0.208* (-5.19)	-0.118* (-10.64)	-0.106* (-3.18)	-0.124* (-12.40)
Short run coefficients					
Δ REG	-0.070 (-1.28)	0.029 (0.71)	0.034 (0.89)	-0.090 (-1.38)	0.025 (0.81)
TG		-0.588* (-2.81)	-0.503* (-2.18)		-0.546* (-2.38)
TG*REG			-0.027 (-1.47)		-0.026 (-1.45)
TFP GROWTH USA				- 0.020 (-0.09)	0.085 (0.34)
C	0.353* (4.39)	1.558* (5.69)	1.608* (5.66)	0.314* (3.69)	1.662* (5.94)
Obs.	649	617	617	617	617
COUNTRIES	21	20	20	20	20
Log Likelihood	1733.33	1730.05	1765.72	1657.86	1802.97
Hausman test	0.00 (0.99)	3.77 (0.05)	0.91 (0.33)	1.11 (0.29)	0.87 (0.35)

1. The z-statistics are reported in parentheses.
2. * Significant at 5%, ** Significant at 10%.
3. The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elesticities). The null hypothesis accepts homogeneity of long run coefficients.
4. Variables are defined in Table 2.

Table 8. Error correction estimates (robustness checks)

Dependent variable: log(TFP)				
	Period 1975-90	Period 1990-2007	High productivity countries	Low productivity countries
Error Correction Coefficient (φ)	-0.466* (-5.44)	-0.545* (-7.39)	-0.060* (-2.00)	-0.038* (-2.46)
Long run coefficients				
log (REG)	-0.742* (-8.29)	-0.204* (-32.27)	-0.078* (-2.92)	-0.331 (-0.21)
Short run coefficients				
Δ REG	-2.846 (-1.42)	0.036* (2.46)	-0.024** (-1.67)	0.362 (0.88)
TG	-3.617 (-1.17)	-0.682* (-5.09)	-1.091* (-9.51)	-0.748** (-1.83)
TG*REG	0.407 (0.98)	-0.027 (-0.77)	0.105* (4.13)	-0.145 (-0.73)
TFP GROWTH USA	0.630** (1.63)	0.616* (5.63)		
C	3.202* (3.66)	2.740* (7.40)	0.299** (1.74)	0.221* (2.09)
Obs.	266	351	317	300
COUNTRIES	19	20	11	11
Log Likelihood	834.12	1230.32	1058.67	889.474
Hausman test	0.00 (0.98)	0.33 (0.56)	1.74* (0.18)	

1. The z-statistics are reported in parentheses.
2. * Significant at 5%, ** Significant at 10%.
3. The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elesticities). The null hypothesis accepts homogeneity of long run coefficients.
4. Variables are defined in Table 2.

Table 9. Common correlated effects

Dependent variable TFP growth			
	(1)	(2)	(3)
REG	-0.005* (-2.01)	-0.009** (-1.89)	-0.011** (-1.86)
TG		-0.117* (-2.66)	-0.007 (-0.07)
TG*REG			-0.015 (-0.54)
C	-0.002 (-0.77)	-0.004 (-0.41)	0.017 (0.56)
Obs.	669	636	636
COUNTRIES	21	20	20

1. The z-statistics are reported in parentheses.
2. * Significant at 5%, ** Significant at 10%.
3. Robust coefficient estimates are reported.
4. Variables are defined in Table 2.

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