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Regulations and productivity: Long run effects and nonlinear influences

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ABSTRACT

This study examines the impact of product market regulations on Total Factor Productivity (TFP) and explores whether regulatory reforms exert a nonlinear influence on TFP growth. It also distinguishes between short run and long run effects of regulation. The obtained empirical evidence reveals that lower regulations in the long run exert a significantly positive effect on TFP of OECD countries. Short run effects of regulation are not always statistically significant. The influence of regulatory changes is higher in countries with high levels of regulation. Also, the damaging effects of regulation are more intense in countries with low technology gaps. These results hold across a wide array of econometric specifications and variables that measure regulation and TFP.

1. Introduction

Recent decades have seen a remarkable increase in the number of product market reforms in the OECD area. Such reforms have been carried out in many countries albeit from a different starting point and to a different degree. The main reason for promoting changes in product markets has been the strengthening of competition and further boost of productivity and competitiveness of countries.

The key question that arises is whether and to what extent have such changes been successful in countries. Although it is a common belief that policies favoring competition raise productivity, the empirical literature has not yet reached to a complete understanding on their economic impact. The influence on lower regulation growth is still an open issue which depends on country specific characteristics and might be subject to nonlinearities.

This paper examines whether the level of regulation affects Total Factor Productivity (TFP) growth of OECD countries. It contributes in two novel directions. First, given that economic growth is a long run phenomenon, it examines whether regulation affects TFP growth in the long run and distinguishes for short term effects. Second, as regulation is likely to affect growth in a nonlinear way, it explores whether its influence depends on country specific factors such as the size of the technology gap and the existing level of regulation.

The results of this study are based on cross country data for 23 OECD countries in 1975–2011. They are clearly in favor of a negative long run influence of regulation on TFP growth. In the short run, the growth impact of regulation is not always statistically significant, implying that its effects on productivity can be realized after an initial adjustment period. Importantly, it is shown that existing regulatory conditions is an important element for assessing the productivity impact of regulatory reforms. Specifically, the influence of regulatory changes is higher in countries with already high levels of regulation. Also, the harmful effects of regulation are more intense in countries with low technology gaps. These results are validated across a wide array of econometric specifications and variables that measure regulation and TFP.

The paper proceeds as follows: In Section 2, the findings of the relevant theoretical and empirical literature are briefly discussed. Section 3 presents the data and provides measures of TFP growth. In Section 4 the econometric results are discussed. Finally, Section 5 concludes.

2. Theory and empirical literature

Economic theory suggests that competition in product markets results to higher productivity through reallocation of markets shares to most efficient businesses. This can be accomplished by forcing exit of less productive firms and by allowing more efficient ones to enter the market. Although early Schumpeterian arguments and endogenous growth models argue that innovation is negatively associated with higher competition (Romer, 1990; Aghion and Howitt, 1992), recent neo-Schumpeterian analyzes question this view by arguing that, as competitive pressures increase the incumbent firms engage in more innovation in order to preserve their market shares. Aghion et al. (2005) show the existence of an inverse U relationship between competition and innovation. At a low level of competition, an increase in competition in the market increases innovation, since the escape competition effect dominates the Schumpeterian effect and pushes

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firms in the 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, as the post innovation rents become very low.

Similarly, competition affects more the growth of countries or industries which are close to the world technology frontier, in which the escape competition effect is more likely to dominate. In contrast, in economies being far away from the productivity frontier, the Schumpeterian effect is likely to prevail and discourage innovation activity. Aghion et al. (2006) notice that the post war catch up of European economies relative to the United States (US) has slowed down as the relative technology gap narrowed. They stress the need for policies in favour of higher competition, which would affect positively innovation and growth. In the same spirit, Acemoglu et al. (2006) assume that innovation becomes important for growth when a country reaches the technology frontier. They argue that in more advanced countries where the possibilities for further growth through factor accumulation have been exhausted, innovation becomes the main vehicle for growth. Therefore, to the extent that a higher innovation rate depends on competition, countries should adopt policies towards higher liberalization. Similar arguments in favor of a positive influence of lower regulations on technology adoption have been offered by Parente and Prescott (1994), Aghion and Schankerman (2004) and Alesina et al. (2005).

Most findings of the relevant empirical literature indicate that lower regulations in markets are positively associated with productivity growth. OECD industry level evidence of Nicoletti and Scarpetta (2003) indicates that entry liberalization involves significant productivity gains in all countries, irrespective of their position vis-a-vis the technology frontier. However, when liberalization is interacted with the technology gap, productivity gains are higher in manufacturing industries of countries which are far from the technology frontier. Similarly, Aghion et al. (2004) show that more liberalized entry conditions have led to faster TFP growth of the UK firms and have improved aggregate productivity performance. Inklaar et al. (2008) find that entry liberalization has been beneficial for productivity growth of telecommunication industries, while Aghion et al. (2009) have established that market rigidities are more harmful for growth of countries close to the technological frontier.

Barone and Cingano (2011) show that lower regulation in the service sector is important for growth of manufacturing industries that use services more intensively. Bartelsman et al. (2013) use firm level data to show that market distortions result in misallocation of resources and account for a large part of cross country productivity differences. Bourles et al. (2013) establish that anticompetitive regulations in upstream industries have curbed productivity growth of OECD industries and show that these effects are stronger in industries which are close to the productivity frontier. Similarly, Buccirossi et al. (2013) establish a positive effect of friendly competition policies on industry level TFP growth of twelve OECD countries. Finally, Dimelis and Papaioannou (2015) clearly indicate that increases in the degree of entry regulation are negatively associated with industry level TFP growth of south European countries.

3. Data and TFP growth estimates

3.1. Market regulation data

The dataset of this paper includes annual data across 23 OECD countries: namely: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxemburg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the USA during 1975–2011. Market regulation is measured by the time varying OECD product market regulation index (see Koske et al. 2014). This index includes a wide array of regulatory provisions in seven network service industries which are: telecommunications, electricity, gas, post, rail, air and road transports. This indicator covers the extent of entry limitations, state control, price control as well as the degree of public ownership in these industries and receives values from 0 to 6, with higher values reflecting a higher degree of regulation.

Table 1
Regulation index in energy transports and communications (1975–2011).
Source: Product Market Regulation Database-OECD.

	1975	1980	1985	1990	1995	2000	2005	2011
United Kingdom	4.86	4.86	4.53	3.50	2.31	1.55	1.12	0.80
Germany	5.38	5.38	5.39	5.00	3.95	2.16	1.43	1.28
Australia	4.10	4.10	4.10	4.10	3.53	2.06	1.86	1.52
Netherlands	5.54	5.54	5.54	5.37	4.16	2.43	1.90	1.58
Denmark	5.49	5.49	5.49	4.85	3.95	2.66	1.95	1.60
Spain	5.38	5.36	5.36	5.14	4.36	3.22	1.97	1.63
Austria	5.50	5.50	5.50	4.57	4.21	3.13	2.04	1.65
Canada	4.53	4.53	4.39	3.21	2.74	1.80	1.78	1.73
United States*	3.40	2.88	2.68	2.52	2.07	1.91	1.85	
Japan	5.25	5.25	4.97	4.06	3.59	2.82	2.00	1.83
Belgium	5.36	5.36	5.32	4.93	4.12	3.06	2.53	1.86
Sweden	4.85	4.85	4.80	4.56	3.44	2.75	2.27	1.93
Italy	5.98	5.98	5.92	5.92	5.15	3.93	2.57	2.01
Iceland	5.33	5.34	5.34	5.34	4.75	3.39	2.07	2.01
Ireland	5.67	5.67	5.67	4.92	4.57	3.83	3.17	2.21
Switzerland	4.55	4.55	4.55	4.55	4.40	3.49	2.66	2.31
Portugal	5.97	5.97	5.97	5.47	5.03	3.94	2.82	2.31
Norway	5.39	5.39	4.96	4.65	3.69	3.24	2.38	2.33
France	5.98	5.98	5.98	5.37	5.08	4.05	3.02	2.52
Finland	5.76	5.72	5.58	5.01	3.65	3.11	2.69	2.53
New Zealand	5.73	5.73	5.00	3.86	3.19	2.51	2.60	2.57
Greece	5.76	5.76	5.76	5.76	5.52	4.81	3.80	2.57
Luxembourg	5.53	5.53	5.53	5.53	4.90	3.52	2.90	2.78

Index values range between 0 and 6, from low to high degree of regulation.
Data for the USA end in 2007.

This index can be used as a measure for the economy wide regulatory environment, since it includes sectors in which much anti-competitive regulation is concentrated (Conway et al., 2006). Services produced in these sectors constitute an essential input for most sectors of the rest part of the economy and therefore regulatory provisions in these industries affect the cost of production and aggregate level productivity performance.

Table 1 shows how this indicator has evolved between 1975 and 2011, across the 23 OECD countries of the sample. It is obvious that in 1975 almost all OECD economies were heavily regulated, with the exception of the USA. However, the degree of regulation started to decrease considerably in all OECD countries during the 1990s with different degrees and to a different extent. The most liberal countries in 2011 were the UK, Germany and Australia. On the other hand, the most regulated economies were Luxemburg, New Zealand and Greece.

3.2. TFP growth measures

In this section we present measures of TFP growth. Intuitively, TFP of an economy increases when more output is produced from a given amount of inputs. This may be the result of technological innovations and improvements as well as of more efficient use of existing inputs. TFP growth estimates are derived directly through growth accounting. A Cobb Douglas production function of the following form is assumed:

$$Y_{i,t} = A_{i,t}(K_{i,t})^{\alpha_{i,t}}(L_{i,t})^{(1-a_{i,t})} \tag{1}$$

where $Y_{i,t}$ represents GDP of each country i in period t, K is the physical capital stock of each country and L is the labor input, measured in total hours worked. A is a labor and capital neutral technology parameter, associated with TFP, t is a time index and a is the income share of capital, which varies across countries and time.

The data for growth accounting were taken from the Penn World Table 8.0 Database (see Feenstra et al., 2013). Values for output and

Table 2
TFP growth rates.

	1976–1990		1990–2000		2000–2011		1976–2011	
	Average TFP growth	Average TFP growth contribution	Average TFP growth	Average TFP growth contribution	Average TFP growth	Average TFP growth contribution	Average TFP growth	Average TFP growth contribution
Canada	−0.12%	−3.58%	0.24%	9.89%	−1.21%	−118.12%	−0.37%	−15.96%
New Zealand	0.94%	43.02%	1.07%	31.77%	−1.00%	−81.89%	0.37%	16.68%
Switzerland	0.31%	14.69%	0.29%	13.37%	1.10%	40.06%	0.49%	21.88%
Australia	0.68%	20.12%	1.34%	40.74%	−0.51%	−27.21%	0.61%	20.28%
Iceland	1.77%	46.74%	0.62%	25.80%	−0.52%	−202.88%	0.71%	31.43%
Sweden	0.44%	20.98%	1.77%	60.24%	0.61%	30.21%	0.80%	36.62%
Portugal	1.40%	40.08%	0.97%	20.73%	−0.47%	−28.76%	0.81%	26.39%
Belgium	1.38%	71.60%	1.68%	57.16%	−0.03%	−1.83%	0.84%	45.98%
United States	0.93%	28.83%	1.37%	41.59%	0.64%	38.35%	0.95%	34.55%
Spain	1.49%	64.04%	1.27%	26.43%	0.24%	7.67%	1.02%	32.85%
Denmark	1.38%	63.61%	1.99%	59.85%	0.16%	16.49%	1.06%	54.03%
Italy	1.87%	49.82%	1.62%	53.98%	−0.10%	−10.08%	1.13%	43.86%
Greece	0.91%	36.97%	2.44%	59.89%	0.54%	29.32%	1.15%	43.72%
Austria	1.03%	42.77%	2.62%	62.45%	0.70%	42.81%	1.26%	50.57%
Luxembourg	2.31%	70.43%	2.69%	38.09%	−1.09%	−54.32%	1.26%	33.58%
France	1.61%	76.98%	1.79%	62.28%	0.68%	40.29%	1.27%	62.55%
Norway	1.95%	53.91%	2.88%	63.26%	−0.29%	−18.72%	1.28%	42.79%
Netherlands	1.13%	57.33%	2.22%	51.02%	1.33%	55.08%	1.30%	52.98%
Finland	1.59%	53.78%	2.25%	86.76%	0.60%	32.94%	1.41%	58.14%
United Kingdom	1.74%	71.03%	2.27%	65.94%	0.39%	31.39%	1.43%	62.65%
Germany	2.00%	75.43%	2.29%	66.57%	1.18%	61.20%	1.67%	66.50%
Japan	2.05%	42.27%	1.94%	64.32%	1.32%	144.61%	1.67%	57.01%
Ireland	2.67%	60.71%	4.04%	54.33%	0.90%	20.40%	2.39%	47.66%

Sorted by average TFP growth over the period 1976–2011.

physical capital are in 2005 chained PPP dollars. The income shares of capital and labor, a_{it} and $1{-}a_{it}$, are measured directly with the use of labor compensation data (Penn World Tables). The variable of total hours worked is measured as the product of average hours per person by the number of persons engaged. After taking logarithms and differentiating both sides of Eq. (1), we obtain

$$\ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) = \ln\left(\frac{A_{i,t}}{A_{i,t-1}}\right) + a_{i,t}\ln\left(\frac{K_{i,t}}{K_{i,t-1}}\right) + (1 - a_{i,t})\ln\left(\frac{L_{i,t}}{L_{i,t-1}}\right) \tag{2}$$

Eq. (2) indicates the main sources of growth of an economy.[1] In particular, the growth rate of output, $ln(Y_{i,t}/Y_{i,t-1})$, comprises of three main components: the growth rate of hours worked, $\ln(L_{i,t}/L_{i,t-1})$, multiplied by its income share $(1{-}a)$, the growth rate of capital, $\ln(K_{i,t}/K_{i,t-1})$, multiplied by its income share (a) and TFP growth, $\ln(A_{i,t}/A_{i,t-1})$. TFP is the part of output growth, not attributable to inputs and includes technological change and the efficiency with which the inputs are used.

Average estimates of TFP growth and TFP growth contribution are reported in Table 2. The highest TFP growth rates over the entire period are reported for Ireland, Germany and Japan. On the contrary, Canada, New Zealand and Switzerland have experienced quite low or even negative TFP growth rates during this period. We also observe that in most countries output growth is mainly driven by the high contribution of TFP growth. This evidence confirms the findings of Jones and Olken (2008) having shown that shifts in the growth process are largely due to changes in productivity growth and do 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 of many developed countries.

Direct measures of TFP levels for each country i at time t are obtained by

$$TFP_{it} = \frac{Y_{it}}{K_{it}^{a_{it}}L_{it}^{(1-a_{it})}} \tag{3}$$

Given that TFP levels are the highest in the US for each year of this period, the technology gap for each country i emerges as its level of TFP relative to the level of TFP in the US economy ($TFP_{US,t}$):

$$\text{Technology gap} = \ln\left(\frac{TFP_{US,t}}{TFP_{i,t}}\right) \tag{4}$$

A high value of the technology gap indicates that a country remains far away from the technology frontier, while a low value shows that this country operates close to the frontier. The frontier technology is defined as that which encompasses the highest level of efficiency in the use of production inputs and includes the highest level of innovation.

4. Econometric estimates

4.1. Time series analysis

As the length of the time span covered by the sample is high, we first assess stationarity in the data and then investigate for the presence of a cointegrating relationship between the variables of regulation and TFP. We use the panel unit root test of Maddala and Wu (1999) which allows for the presence of heterogeneity. We also use the second generation panel unit root test of Pesaran (2007) that accounts for cross sectional dependence in the data. For each variable in its levels (TFP, Index of regulation, technology gap), Table 3 displays the value of the test and the associated p-value under the null hypothesis that the series are I(1). For a wide array of tests regarding the number of chosen lags and the existence or not of a stochastic trend, the majority of the results suggest that the variables are stationary in their first differences.

To investigate the presence of cointegration between the variables of TFP and regulation, we use four panel cointegrating tests proposed by Westerlund (2007).[2] These tests examine for cointegration within a

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

[2] Initially, it was examined whether the variables of technology gap, TFP and

Table 3
Panel unit root tests.

	Total factor productivity[a]		Technology gap		Index of regulation	
	Maddala and Wu test (p-value)	Pesaran test (p-value)	Maddala and Wu test (p-value)	Pesaran test (p-value)	Maddala and Wu test (p-value)	Pesaran test (p-value)
Constant, no lag	13.37 (1.00)	−0.85 (0.19)	42.57 (0.53)	−0.01 (0.49)	1.59 (1.00)	0.19 (0.57)
Constant, 1 lag	17.75 (1.00)	−2.13 (0.01)	47.00 (0.35)	−1.99 (0.02)	2.57 (1.00)	−0.84 (0.20)
Constant, 2 lags	16.22 (1.00)	−1.96 (0.02)	36.05 (0.79)	−1.91 (0.03)	3.35 (1.00)	0.65 (0.74)
Constant, trend, no lag	37.55 (0.74)	2.99 (0.99)	42.13 (0.55)	0.55 (0.71)	19.01 (1.00)	0.13 (0.55)
Constant, trend, 1 lag	60.20 (0.05)	1.31 (0.90)	39.86 (0.64)	−1.70 (0.04)	21.69 (1.00)	−1.09 (0.13)
Constant, trend, 2 lags	53.93 (0.14)	1.76 (0.96)	29.10 (0.95)	−0.65 (0.25)	22.29 (1.00)	0.57 (0.71)

Null hypothesis: Series are I (1).
[a] Variable in logs.

Table 4
Westerlund panel cointegration test.

	G_t (robust p-value)	G_a (robust p-value)	P_t (robust p-value)	P_a (robust p-value)
Constant, 1 lag	−2.02 (0.13)	−9.05 (0.05)	−9.99 (0.06)	−8.64 (0.01)
Constant, 2 lags	−1.99 (0.21)	−8.96 (0.21)	−8.80 (0.20)	−8.51 (0.04)
Constant, trend, 1 lag	−3.05 (0.04)	−18. 23 (0.03)	−14.45 (0.03)	−16.43 (0.02)
Constant, trend, 2 lags	−3.01 (0.08)	−19. 20 (0.09)	−13.15 (0.13)	−15. 26 (0.16)

Null Hypothesis: No Cointegration. Bootstrapped *p*-values computed.

selected group of the panel (G_t and G_a) or for the panel as a whole (P_t and P_a) and control for cross sectional dependence in the data. After performing a variety of tests regarding the number of chosen lags and the existence or not of a trend, we can infer that the variables of TFP and regulation are cointegrated, as the null of no cointegration is rejected in most of the tests presented in Table 4. It should be noticed that bootstrapped critical values have been used and robust *p*-values are reported in Table 4.

4.2. Econometric model

The general empirical model used to study the relation between TFP and regulation follows Nicoletti and Scarpetta (2003) and Aghion and Howitt (2006) and can be expressed in the following way:

$$\Delta lnTFP_{i,t} = \alpha \Delta lnTFP_{USA,t} + \beta TG_{i,t-1} + \gamma \Delta REG_{i,t} + \delta \Delta REG_{i,t} * REG_{i,t} + \theta REG_{i,t} * TG_{i,t-1} + e_{i,t} \quad (5)$$

where indices i and t denote country and year, respectively. For each country i we assume that TFP growth, depends on its ability to keep pace with the technology frontier. Therefore $\Delta lnTFP_{i,t}$ of each country i is modeled as a function of TFP growth of the USA ($\Delta lnTFP_{USA,t}$) which is the economy with the highest level of TFP.

(*footnote continued*)
regulation were cointegrated. The null of no cointegration was not rejected. Results of cointegration tests are available upon request.

$\Delta lnTFP_{i,t}$ also depends on the size of the technology gap between the follower and the leader. The variable of the technology gap ($TG_{i,t-1}$) is derived from Eq. (4) and enters Eq. (5) lagged once so as to reduce the impact of multicollinearity. According to neo-Schumpeterian models of growth, if technology is free to flow across countries, then productivity growth is a positive function of the technology gap between the follower and the leader country, which is often referred as the catch-up phenomenon. Therefore, if coefficient β is positive and statistically significant, this implies the existence of high potential for technological convergence.

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 by including in the regression the terms of $\Delta REG_{i,t} * REG_{i,t}$ and $REG_{i,t} * TG_{i,t-1}$. The first multiplicative term allows the change of regulation variable (ΔREG) to interact with the level of regulation (REG). A negative coefficient on γ and a positive coefficient on δ would be interpreted as a negative effect of regulation of productivity which diminishes at high levels of regulation. The second term allows for the regulation variable (REG) to interact with the level of technology gap (TG). A positive coefficient on θ would imply that the damaging effects of regulation are more intense in countries with low technology gaps.

As evidenced by the results shown in Table 4, there is a long run cointegrating relationship between regulation and TFP. Therefore, Eq. (5) can be re-parameterized to include a long run equilibrium vector between these two variables:

$$\Delta lnTFP_{i,t} = \alpha \Delta lnTFP_{USA,t} + \beta TG_{i,t-1} + \gamma \Delta REG_{i,t} + \delta \Delta REG_{i,t} * REG_{i,t} + \theta REG_{i,t} * TG_{i,t-1} + \varphi\, (lnTFP_{i,t-1} + \beta_1 REG_{i,t-1}) + e_{i,t} \quad (6)$$

TFP growth estimates are derived from Eq. (2). The coefficient β_1 measures the long run effect of regulation on TFP while φ is the error correction speed of adjustment. This parameter is expected to be negative in order for variables to return to their long run equilibrium.

4.3. Main econometric estimates

Turning to the estimation strategy, estimation of Eq. (6) is carried out using the pooled mean group estimator (Pesaran and Smith, 1995; Pesaran et al., 1999) which is suitable when analyzing panel data with a large time series and a 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, whereas long run effects are assumed to be identical across countries. Thereby, this estimator obtains an estimate of the long run impact of regulation on TFP growth, which is common for all countries, without imposing the restrictive assumption of identical short run dynamics. Also, by using this estimator, we account for possible feedback effects.

Although it is possible that regulation adversely affects productivity through channels related to inefficiency and misallocation of resources, it might also be that low productivity growth could lead to policy changes in the direction of lower regulation in the markets. For this purpose Granger causality tests were performed for each country which, in their majority, reassure us that causality does not run from TFP to regulation.[3] It should also be noticed that no serious multi-colinearity problem arises between independent variables of our model, as Table 5 indicates.

Table 6 presents baseline estimates for the whole sample of OECD countries. Each column gives the average long run effect of regulation and the mean coefficient estimate of the error correction term, denoted by φ. The results of the Hausman test show that equality between the mean group and the pooled mean group estimates is not rejected in all

[3] Results of Granger causality tests are available upon request.

Table 5
Correlation matrix of all variables.

	TFP growth	Δ (Regulation)	TFP growth USA	Technology gap (t−1)	Technology gap (t−1)×(Regulation)	Δ (Regulation)×(Regulation)	Regulation
TFP growth	1.00						
Δ (Regulation)	−0.08	1.00					
TFP growth USA	0.25	−0.10	1.00				
Technology gap (t−1)	0.11	−0.10	0.02	1.00			
Technology gap (t−1)×(Regulation)	0.05	−0.10	0.00	0.09	1.00		
Δ (Regulation)×(Regulation)	0.02	−0.27	0.03	−0.01	−0.07	1.00	
Regulation	0.20	0.21	0.10	−0.04	0.02	0.22	1.00

Table 6
Main estimation results.

Dependent variable: TFP growth							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Error Correction Coefficient (φ)	−0.010** (−2.28)	−0.009** (−1.98)	−0.012** (−2.21)	−0.010** (−2.13)	−0.013** (−2.14)	−0.014** (−2.39)	−0.015 (−1.50)
Long run coefficients							
Regulation	−0.306** (−7.36)	−0.304** (−7.02)	−0.248** (−2.50)	−0.311** (−7.67)	−0.217** (−2.12)	−0.392** (−14.47)	−0.511** (−10.70)
Short run coefficients							
Constant term	0.134** (2.29)	0.116** (2.14)	0.116* (1.67)	0.131** (2.11)	0.123* (1.68)	0.193** (2.49)	0.182 (1.20)
Δ (Regulation)	−0.015** (−3.22)	−0.011** (−2.45)	−0.005 (−1.16)	−0.015** (−3.23)	−0.007* (−1.66)	−0.002 (−0.46)	−0.002 (−0.43)
TFP growth USA		0.507** (6.34)	0.437** (5.51)	0.503** (6.45)	0.440** (5.66)	0.436** (4.71)	0.414** (4.36)
Technology gap (t−1)			0.006** (2.81)		0.006** (2.48)		0.0007 (0.24)
Technology gap (t−1)×(Regulation)			0.004** (2.22)		0.003* (1.84)		0.003 (0.89)
Δ (Regulation)×(Regulation)				−0.002** (−3.19)	−0.002** (−1.97)	−0.002** (−2.07)	−0.002** (−2.26)
Manufacturing share×(Regulation)						−0.005** (−2.89)	−0.001 (−0.72)
No. of observations	792	792	792	792	792	697	697
No. of countries	22	22	22	22	22	22	22
Log Likelihood	1907.22	1953.20	1994.46	1959.74	2004.11	1767.42	1812.05
Hausman test (p-value)[a]	1.44 (0.23)	0.54 (0.46)	0.87 (0.34)	0.14 (0.71)	0.15 (0.69)	0.93 (0.33)	0.02 (0.88)

The z-statistics are reported in parentheses.
** Significant at 5%.
* Significant at 10%.
[a] The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elasticity). The null hypothesis accepts homogeneity of long run coefficients.

econometric specifications and suggest that the pooled mean group estimator is the most appropriate choice to estimate Eq. (6).[4]

Column 1 reports the results when the identification strategy involves only regulation variables. The results suggest clearly that product market regulation is negatively associated with TFP. Likewise, the coefficient estimate for the short run effect of regulation is negative and statistically significant. Expectedly, the error correction parameter (φ) is significantly negative suggesting that the variables of TFP growth and regulation return to their long run equilibrium levels. Columns 2–3 of Table 6 present econometric estimates after successively including in the model TFP growth of the leader country (USA) to account for the impact of outward shifts in the technological frontier and the variable of technology gap to allow for convergence effects. Expectedly their impact is positive and statistically significant.

In column 3, we present the effect of the interaction of product market regulation with the technology gap variable. Thus, we introduce a multiplicative term. Given that the correlation between the variables and their interaction term might be high, the variables are mean centered (new variables are generated by subtracting their means). In such a way, we are allowed to interpret the coefficient of product market regulation at the average level of the technology gap rather than at the point where the technology gap is zero. Table 5 confirms that no serious multicolinearity problem arises between the variables of regulation, technology gap and their multiplicative term. The results show that the interaction term enters the estimated equation with a positive and statistically significant coefficient. This implies that in countries where the technology gap vis-a-vis the US is high the damaging effect of regulation on productivity is inferior. Given that the technology gap variable is also present in the estimated equation, we may also argue that catching up is an important factor for growth in highly regulated countries. This is consistent with the arguments offered by Aghion et al. (2006) and Acemoglu et al. (2006) stating that in countries where possibilities for further catch up have been exhausted, liberalization policies are essential elements for higher growth and innovation.

We also check whether the impact of a regulatory reform is affected by the level of regulation. Therefore, we introduce an interaction variable between the level of regulation and its change, measured by the variable *Δ(Regulation)*. Again we mean center the respective variables to reduce the impact of multicollinearity and provide results at the mean of the regulatory variable. The results (column 4) show that the interaction term enters the estimated equation with a negative and statistically significant coefficient reinforcing the conclusion that a high level of regulation increases the impact of a regulatory reform.

[4] 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 the pooled mean group estimator. If homogeneity of long run coefficients holds, then the pooled mean group estimator is consistent and efficient.

Table 7
Robustness estimates: alternative measures of regulation and TFP growth.

Dependent variable: TFP growth	1	2	3	4	5[b]	6[b]
Error Correction Coefficient (φ)	−0.011** (−2.51)	−0.013** (−2.77)	−0.008** (−2.39)	−0.009** (−2.39)	−0.019** (−2.02)	−0.020** (−1.99)
Long run coefficients						
Public ownership	−0.233* (−1.83)	−0.224* (−1.77)				
Entry regulation			0.078 (0.56)	0.022 (0.19)		
Regulation					−0.279** (−3.01)	−0.239** (−2.45)
Short run coefficients						
Constant term	0.104* (1.91)	0.125** (2.22)	0.037 (1.15)	0.051 (1.31)	0.185 (1.52)	0.197 (1.56)
Δ (Public ownership)	−0.002 (−0.40)	−0.017** (−2.80)				
Δ (Entry regulation)			−0.004 (−1.38)	−0.004 (−1.17)		
Δ (Regulation)					−0.009 (−1.18)	−0.013 (−1.61)
TFP growth USA	0.416** (4.90)	0.400** (4.68)	0.429** (5.87)	0.442** (5.93)	0.401** (5.16)	0.404** (5.26)
Technology gap (t−1)	0.007** (2.86)	0.007** (2.49)	0.009** (3.33)	0.009** (3.49)	0.009** (2.58)	0.009** (2.27)
Technology gap (t−1)×(Public ownership)	0.004** (2.31)	0.003** (2.05)				
Δ (Public ownership)×(Public ownership)		−0.004** (−4.41)				
Technology gap (t−1)×(Entry regulation)			0.001 (1.27)	0.001 (1.27)		
Δ (Entry regulation)×(Entry regulation)				−0.001 (−0.77)		
Technology gap (t−1)×(Regulation)					0.005* (1.93)	0.005 (1.61)
Δ (Regulation)×(Regulation)						−0.003* (−1.92)
No. of observations	792	792	792	792	792	792
No. of countries	22	22	22	22	22	22
Log Likelihood	1997.32	2009.36	1993.41	2004.51	1602.30	1612.55
Hausman test (p-value)[a]	1.09 (0.29)	0.03 (0.87)	0.10 (0.74)	2.30 (0.12)	5.25 (0.02)	2.72 (0.01)

The z-statistics are reported in parentheses.
** Significant at 5%.
* Significant at 10%.
[a] The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elasticity). The null hypothesis accepts homogeneity of long run coefficients.
[b] Results of columns 5 and 6 are based on alternative measures of endogenous TFP growth discussed in Section 4.5.

This result is in agreement with neo-Schumpeterian predictions showing that an increase in competition fosters innovation at low levels of competition, as the escape competition effect dominates and pushes firms to innovate in order to avoid losing market shares.

Column 5 presents estimates when both interaction terms enter Eq. (6). The results confirm that product market regulation is negatively associated with TFP. The coefficient estimate for the short run effect of regulation lowers in magnitude but remains statistically significant at the level 10%. The impact of the rest of the control variables practically remains unchanged.

It is likely that manufacturing and service sectors are not affected equally from regulation in energy, transports and communication. To explore this possibility, columns 6 and 7 present econometric estimates which include as an explanatory variable the interaction term between the variable of regulation and that of the manufacturing share of GDP (Manufacturing share×Regulation). Results shown in column 6 indicate that the coefficient estimate of this variable is significantly negative and provide us with evidence that manufacturing industries are more influenced by regulation in network industries. Estimates of column 7 show that the coefficient estimate of this variable is negative but not statistically significant.

The long run coefficient estimates of the variable of regulation are negative and statistically significant across all econometric specifications with its values ranging between −0.21 and −0.51 across specifications. If we consider the estimates shown in column 5, then a reduction of 1% in the degree of regulation would bring about a 0.21% average increase of TFP. The obtained evidence is consistent with the hypothesis that a high level of regulation induces inefficiencies. These in turn lead to increases in the cost of production for sectors that use intensively as intermediate inputs the services provided by the sectors of energy, transports and communications. Most econometric estimates of Table 6 indicate that the short run estimate of the coefficient of regulation is negative and statistically significant.

4.4. Alternative measures of regulation

We now turn to provide some robustness analysis conducted on models of column 3 and 5 of Table 6. First, we validate our estimates by utilizing two different measures for regulation. Specifically, we use the public ownership index, as well as an index showing the extent of entry regulation. Both of these indices have been derived from the Product Market Regulation Database of OECD. The entry regulation index covers the extent of legal limitations on the number of firms in a sector, as well as rules on vertical integration of network industries. When entry is free, this indicator receives the value of 0. On the contrary, this indicator takes the value of 6 in cases where entry is heavily regulated. Similarly, the public ownership indicator takes the value of 0 in cases that there is no public ownership, and 6 in the case of full public ownership.

In brief, the results of Table 7 confirm the existence of a significantly negative long-term relationship between public ownership and TFP growth throughout the whole sample (columns 1-2). The estimates confirm that the influence of changes in public ownership is higher in countries with already high levels of state presence. Also, the damaging effects of public ownership are more intense in countries with low technology gaps. On the contrary, estimates of columns 3 and 4 do not provide us with sufficient evidence in favor of a statistically significant relation between entry regulation and TFP.

4.5. Endogenous TFP growth

We also present results after deriving measures of TFP growth

Table 8
Robustness estimates: TFP growth based on production function estimates.

Dependent variable: TFP growth	(1)	(2)	(3)
Error Correction Coefficient (φ)	−0.025** (−2.31)	−0.027** (−3.29)	−0.013** (−2.50)
Long run coefficients			
Public ownership	−0.051** (−20.27)		
Entry regulation		−0.020** (−7.87)	
Regulation			−0.332** (−8.05)
Short run coefficients			
Constant term	−0.059 (−0.41)	0.045 (0.19)	−0.113 (−1.04)
Δ (Public ownership)	−0.030** (−2.68)		
Δ(Entry regulation)		−0.002 (−0.45)	
Δ(Regulation)			−0.003 (−0.84)
TFP growth Switzerland	0.207** (2.92)	0.264** (3.48)	0.238** (3.27)
Technology gap (t−1)	0.009 (0.45)	−0.005 (−0.17)	0.010 (0.50)
Technology gap (t−1)×(Public ownership)	0.001 (0.91)		
Δ (Public ownership)×(Public ownership)	−0.004** (−3.29)		
Technology gap (t−1)×(Entry regulation)		0.004** (2.09)	
Δ (Entry regulation)×(Entry regulation)		0.001 (0.73)	
Technology gap (t−1)×(Regulation)			0.005** (2.48)
Δ (Regulation)×(Regulation)			0.001 (1.06)
No. of observations	788	788	788
No. of countries	22	22	22
Log Likelihood	2120.96	2100.84	2109.64
Hausman test (p-value)[a]	0.92 (0.33)	0.10 (0.74)	0.54 (0.46)

The z-statistics are reported in parentheses.
** Significant at 5%.
[a] The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elasticity). The null hypothesis accepts homogeneity of long run coefficients.

which control for TFP induced capital deepening.[5] We follow Madsen (2010b) and Madsen et al. (2010) to model the production function in per worker terms in the following way:

$$\frac{Y_{i,t}}{L_{i,t}} = A_{i,t}^{1/(1-a_{i,t})}\left(\frac{K_{i,t}}{Y_{i,t}}\right)^{a_{i,t}/(1-a_{i,t})} \tag{7}$$

Taking logs and differentiating the above equation yields the following output per worker growth equation:

$$g_{Y/L_{i,t}} = \frac{1}{1-a_{i,t}} g_{A_{i,t}} + \frac{a_{i,t}}{1-a_{i,t}} g_{K/Y_{i,t}} \tag{8}$$

where $g_{Y/L}$ is labor productivity growth. The term g_A is the growth rate of TFP and its contribution is magnified by the factor $1/(1-a_{i,t})$ accounting for TFP induced capital deepening. That is, by adopting the above specification, we allow for TFP to contribute to growth directly through technological progress and higher efficiency, as well as indirectly through the channel of capital deepening. The results are presented in columns 5–6 of Table 7 and reassure us that lower regulations exert a significantly positive effect on TFP in the long run. We also confirm that the influence of regulatory changes is higher in countries with high levels of regulation and that the harmful effects of regulation are more intense in countries which are close to the productivity frontier.

4.6. TFP growth based on production function

We also derive measures of TFP growth based on the econometric estimation of a production function (see Cowing and Stevenson, 1981). Standard growth accounting estimates may be subject to estimation bias as inputs might not be paid their marginal products. In such a case it would be desirable to estimate a production function and then use the obtained production function parameters to derive measures of TFP growth. This measure of TFP can then be used as dependent variable in Eq. (6) to evaluate the impact of regulation on TFP growth.

As the production function is unlikely to share the same coefficient across all countries, we control for heterogeneity in technology by estimating for each country i a logarithmic production function of the following form:

$$\ln Y_t = c + a \ln K_{t-1} + \beta \ln L_{t-1} + e_t \tag{9}$$

Y represents GDP of each country i in period t, K is the physical capital stock of each country in period t−1 and L is the labor input, measured in total hours worked. Given that labor and capital might be endogenously determined, K and L enter Eq. (9) with one period lag to reduce the possibility of estimation bias. Also c is a constant parameter and e is the disturbance error term. The data for GDP, capital and hours worked were derived from the Penn World Table 8.0 Database.

We estimate Eq. (9) by OLS to obtain production function parameters for each country.[6] These production function estimates are used to derive TFP growth estimates which are used as dependent variables in Eq. (6).[7] Based on Eqs. (3) and (4) we also derive TFP levels and technology gaps vis-à-vis Switzerland, which is the country with the highest estimated level of TFP across the entire period 1975-2011.

The econometric results are presented in columns 1–3 of Table 8 and reassure us that lower regulations exert a significantly positive effect on TFP in the long run. When using entry regulation or public ownership as regulation variables, we obtain a negative estimate as regards their long run influence on TFP. We also confirm that the influence of changes in the degree of public ownership is most negative in countries with high degree of public ownership (column 1) and that the harmful effects of regulation are more intense in countries which are close to the productivity frontier (column 3).

4.7. Sub-sample analysis

Having found evidence that lower regulations exert a positive long run influence on TFP growth, we proceed to analyze whether this relationship holds in different samples. First, we divide countries into two subgroups to study whether the regulation productivity nexus matters different in low regulated and high regulated countries. The least regulated countries in our sample are the USA, the UK, Canada, Australia, Sweden, Japan, Germany, New Zealand, Denmark,

[5] It has been argued that relying on a standard growth accounting framework would neglect endogenous formation of capital deepening and attribute TFP only to its direct effect on growth (Klenow and Rodriguez-Clare, 1997; Prescott, 1998; Barro, 1999). Madsen (2010a) showed that standard growth accounting exercises attribute too much growth to capital deepening.

[6] Before estimating Eq. (9), we first assess the stationarity of the variables of GDP, capital and labor by performing the Augmented Dickey Fuller test. We also check for the presence of a cointegrating relationship between these variables with the use of the Johansen trace test. The majority of these tests for each country show that the variables are stationary in their first differences and indicate the presence of a cointegrating relationship between GDP, capital and labor. Results of unit root and cointegration tests are available upon request.

[7] Production function estimates and measures of TFP are not reported here but are available upon request.

Table 9
Sub sample analysis.

Dependent variable: TFP growth	(1) Low regulated countries	(2) High regulated countries	(3) Low TFP countries	(4) High TFP countries
Error Correction Coefficient (φ)	−0.017**	−0.003**	−0.012*	−0.011*
	(−2.26)	(−2.97)	(−1.77)	(−1.77)
Long run coefficients				
Regulation	−0.314**	0.645	0.083	−0.604**
	(−3.69)	(0.49)	(0.32)	(−12.91)
Short run coefficients				
Constant term	0.189	−0.012	0.035	0.185
	(1.06)	(−0.70)	(0.50)	(1.30)
Δ (Regulation)	−0.007	−0.009	0.0006	−0.015**
	(−1.14)	(−1.23)	(0.11)	(−2.89)
TFP growth USA	0.621**	0.250**	0.426**	0.449**
	(6.75)	(2.07)	(3.07)	(4.87)
Technology gap (t−1)	0.004	0.007**	0.015**	−0.004
	(1.21)	(2.53)	(2.71)	(−1.17)
Technology gap (t−1)×(Regulation)	0.003	0.002	0.002	0.003
	(1.07)	(1.09)	(0.98)	(0.80)
Δ (Regulation)×(Regulation)	−0.003**	−0.0008	−0.0007	−0.004**
	(−2.15)	(−0.74)	(−0.43)	(−2.89)
No. of observations	396	396	396	396
No. of countries	11	11	11	11
Log Likelihood	1055.82	948.83	933.78	1077.28
Hausman test (p-value)[a]	1.23 (0.26)	1.19 (0.27)	1.16 (0.28)	0.00 (0.94)

The z-statistics are reported in parentheses.
** Significant at 5%.
* Significant at 10%.
[a] The Hausman test is a test of poolability of the long run coefficients (all countries share the same long run elasticity). The null hypothesis accepts homogeneity of long run coefficients.

Switzerland, Norway and Netherlands while the most regulated countries are Austria, Spain, Belgium, Finland, Iceland, Ireland, Luxemburg, Portugal, Italy, France and Greece. The main results (columns 1–2 of Table 9) can be summarized as follows: the long run impact of regulation remains negative and statistically significant only in low regulated countries. The coefficient of the technology the gap is positive and statistically significant in the group of high regulated economies. TFP growth of the leader country exerts a measurable and statistically significant effect in both groups of countries.

We also check the stability of the obtained results by considering two sub-samples of countries, divided on the basis of whether they are close or far from the technology frontier. Based on the estimates of TFP levels, two groups of countries arise: the first one consists of more productive ones which are the USA, the UK, Canada, Australia, Japan, Germany, New Zealand, Switzerland, Finland, Italy, France and Spain. The second group includes Austria, Belgium, Iceland, Ireland, Luxemburg, Portugal, Greece, Netherlands, Denmark, Norway and Sweden. The results of columns 3 and 4 clearly indicate the existence of a positive and significant long run effect of lower regulations on TFP in the sample of more productive countries. Similarly the coefficient of the technology gap is positive and statistically significant only in less productive countries. It is interesting to notice that the short run effects of regulation are negative and statistically significant in the group of more productive economies. Likewise the coefficient estimates of the interaction terms imply that in more productive economies a high level of regulation strengthens the negative impact of a regulatory change.[8]

[8] We observe that the error correction and long run coefficients vary significantly between sub groups of Table 9. This is likely due to the fact that the cross section dimension becomes lower relative to the time dimension.

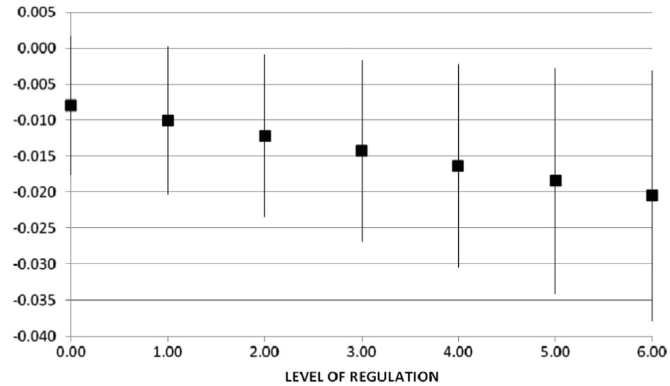

Fig. 1. TFP growth impact of regulatory changes. *Note*: The average impact of regulatory change is given by the black squares. Bounds of confidence intervals are given by the upper and lower ends of the associated straight lines.

4.8. Graphical illustrations

The interpretation of the main coefficient of ΔREG (γ) is its effect on TFP growth when the level of regulation REG is zero. This becomes evident when taking the partial derivative of Eq. (6) with respect to ΔREG:

$$\frac{\partial(\Delta \ln TFP)}{\partial(\Delta REG)} = \gamma + \delta * REG \tag{10}$$

Similarly, when estimating a model with interaction terms, the resulting output of standard errors is misleading. Standard errors of ΔREG conditional on various levels of regulation ($REG=x_j$) are re-calculated with the following formula:

$$s_{\gamma+\delta REG|REG=x_j} = (\mathrm{var}[\gamma] + x_j^2\mathrm{var}[\delta] + 2x_j\mathrm{cov}[\gamma, \delta])^{\frac{1}{2}} \tag{11}$$

The variances and co-variance in (11) are directly obtained from the variance-covariance matrix in the original output. In a similar fashion, it is shown that the growth effect of regulation depends at various levels of the technology gap TG, assuming that ΔREG is held constant:

$$\frac{\partial(\Delta \ln TFP)}{\partial(REG_{it})} = \beta_1 + \theta * TG \tag{12}$$

Standard errors are given by

$$s_{\beta_1+\theta TG|TG=x_j} = (\mathrm{var}[\beta_1] + x_j^2\mathrm{var}[\theta] + 2x_j\mathrm{cov}[\beta_1, \theta])^{\frac{1}{2}} \tag{13}$$

We get an insight into the influence of regulatory changes (ΔREG) at various levels of regulation by using Eqs. (10) and (11) and baseline regression results reported in column 5 of Table 6. Fig. 1 provides us with estimates of the TFP growth contribution of ΔREG (vertical axis) at various levels of regulation (horizontal axis) along with its two standard error confidence intervals. We observe that the influence of regulatory changes on productivity remains negative with the damaging effects being higher as the index of regulation increases. However, this finding should be treated with some caution as the point estimates are accompanied with relatively high standard errors.

Similarly, we use Eqs. (12) and (13) and baseline regression results of Table 6 (column 5) to evaluate the impact of regulation across various levels of the technology gap. Fig. 2 reveals that the impact of regulation on productivity is negative across the range of values of the technology gap. The damaging effects are slightly higher in countries with lower technology gaps.

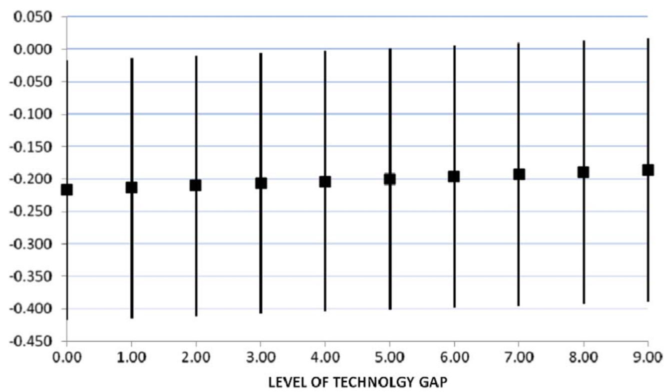

Fig. 2. TFP growth impact of regulation at various levels of the technology gap. *Note*: The average impact of regulatory change is given by the black squares. Bounds of confidence intervals are given by the upper and lower ends of the associated straight lines.

5. Concluding remarks

The main purpose of this paper was to assess the impact of regulation on TFP. The econometric results were based on a sample of 23 OECD countries for the period 1975–2007. A unique feature of this study was the distinction between short run and long run effects as well as the assessment of nonlinear influences of regulation. The empirical findings clearly suggest that lower product market regulation is important for long run increase of TFP. Importantly the influence of regulatory changes is reinforced in countries with already high levels of regulation. Also, the damaging effects of regulation are more intense in countries with low technology gaps.

On the contrary, short run effects of regulation on productivity are not always statistically significant. This evidence is consistent with the view that the effects of lower regulation are expected with a time lag as in the period shortly after deregulation its impact might be negligible due to adjustment costs. These findings are robust across different specifications.

The findings of this study clearly indicate that institutions that promote lower regulation are important for higher productivity. A key mechanism through which lower regulation increases productivity is the reallocation of resources and output towards most efficient production units. Therefore, any improvement in the conditions of conduct of competition should be considered as a policy aimed at increasing long term productivity and economic growth. The impact of regulation on productivity is an issue which remains open for further research, as regards its influence in countries with different institutional characteristics, such as bureaucracy and corruption.

References

Acemoglu, D., Aghion, P., Zillibotti, F., 2006. Distance to frontier, selection and economic growth. J. Eur. Econ. Assoc. 4, 37–74.
Aghion, P., Howitt, P., 1992. A model of growth through creative destruction. Econometrica 60, 323–351.
Aghion, P., Schankerman, M., 2004. On the welfare effects and political economy of competition enhancing policies. Econ. J. 114, 804–824.
Aghion, P., Howitt, P., 2006. Joseph Schumpeter lecture appropriate growth policy: a unifying framework. J. Eur. Econ. Assoc. 4, 269–314.
Aghion, P., Comin, D., Howitt, P., 2006. When does domestic saving matter for economic growth? NBER Working Paper No. 12275.
Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and innovation: an inverted U relationship. Q. J. Econ. 120, 701–728.
Aghion, P., Askenazy, P., Bourles, R., Cette, G., Dromel, N., 2009. Education, market rigidities and growth. Econ. Lett. 102, 62–65.
Aghion, P., Blundell, R., Griffith, R., Howitt, P., Prantl, S., 2004. Entry and productivity growth: evidence from micro level panel data. J. Eur. Econ. Assoc. Pap. Proc. 2, 265–276.
Alesina, A., Ardagna, S., Nicoletti, G., Schiatarelli, F., 2005. Regulation and investment. J. Eur. Econ. Assoc. 3, 791–825.
Barone, G., Cingano, F., 2011. Service regulation and growth: evidence from OECD countries. Econ. J. 121, 931–957.
Barro, R., 1999. Notes on growth accounting. J. Econ. Growth 4, 119–137.
Bartelsman, E., Haltiwanger, J., Scarpetta, S., 2013. Cross country differences in productivity: the role of allocation and selection. Am. Econ. Rev. 103, 305–334.
Bourles, R., Cette, G., Lopez, J., Mairesse, J., Nicoletti, G., 2013. Do product market regulations in upstream sectors curb productivity growth? Panel data evidence for OECD countries. Rev. Econ. Stat. 95, 1750–1768.
Buccirossi, P., Ciari, L., Duso, T., Spagnolo, G., Vitale, C., 2013. Competition policy and productivity growth: an empirical assessment. Rev. Econ. Stat. 95, 1324–1336.
Conway, P., De Rosa, D., Nicoletti, G., Steiner, F., 2006. Product market regulation and productivity convergence. OECD Economic Study No. 43.
Cowing, T., Stevenson, R., 1981. Productivity Measurement in Regulated Industries. Academic Press.
Dimelis, S., Papaioannou, S., 2015. Public ownership, entry regulation and TFP growth within a productivity convergence model: industry level evidence from south European countries. Manch. Sch.. http://dx.doi.org/10.1111/manc.12131.
Feenstra, R., Inklaar, R., Timmer, M., 2013. The next generation of the Penn World Table. Penn World Table Version 8.0. Available at: ⟨www.ggdc.net/pwt⟩.
Inklaar, R., Timmer, M., Van Ark, B., 2008. Market services productivity across Europe and the US. Econ. Policy 23, 140–194.
Jones, B., Olken, B., 2008. The anatomy of one stop growth. Rev. Econ. Stat. 90, 582–587.
Kehoe, T., Prescott, E., 2002. Great depressions of the twentieth century. Rev. Econ. Dyn. 5, 1–18.
Klenow, P., Rodriguez-Clare, A., 1997. The Neoclassical revival in growth economics: has it gone too far? NBER Macroecon. Ann. 12, 73–103.
Koske, I., Wanner, I., Bitetti, R., Barbiero, O., 2014. The 2013 update of the OECD's database on product market regulation: policy insights for OECD and non-OECD countries. OECD Economics Department Working Paper No. 1200.
Maddala, G.S., Wu, S., 1999. A comparative study of unit root tests and a new simple test. Oxf. Bus. Econ. Stat. 61, 631–652.
Madsen, J., 2010a. Growth and capital deepening since 1870: is it all technological progress? J. Macroecon. 32, 641–656.
Madsen, J., 2010b. The anatomy of growth in the OECD since 1870. J. Monet. Econ. 57, 753–767.
Madsen, J., Ang, J., Banerjee, R., 2010. Four centuries of British economic growth: the roles of technology and population. J. Econ. Growth 15, 263–290.
Nicoletti, G., Scarpetta, S., 2003. Regulation, productivity and growth: OECD evidence. Econ. Policy 18, 11–72.
Parente, S., Prescott, E., 1994. Barriers to technology adoption and development. J. Polit. Econ. 102, 298–321.
Pesaran, H., 2007. A simple panel unit root test in the presence of cross section dependence. J. Appl. Econom. 22, 265–312.
Pesaran, H., Smith, R., 1995. Estimating long run relationships from dynamic heterogeneous panels. J. Economet. 68, 79–113.
Pesaran, H., Shin, Y., Smith, R., 1999. Pooled mean group estimation of dynamic heterogeneous panels. J. Am. Stat. Assoc. 94, 621–634.
Prescott, E., 1998. Needed: a theory of total factor productivity. Int. Econ. Rev. 39, 525–551.
Romer, P., 1990. Endogenous technological change. J. Polit. Econ. 98, S71–S102.
Westerlund, J., 2007. Testing for error correction in panel data. Oxf. Bus. Econ. Stat. 69, 709–748.