

# I. The drivers of total factor productivity in catching-up economies <sup>(1)</sup>

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*The pace of total factor productivity (TFP) convergence in the euro area slowed down in the mid-1990s. This mainly reflects poor TFP growth in the euro area's catching-up economies. Measured in terms of TFP, the technology gap between leaders and laggards in a broad range of industries actually increased between 1994 and 2007. The persistence of the technology gap suggests that the causes are deep-rooted and at least partly structural.*

*Panel regression results based on an endogenous growth model indicate that the TFP divergence between euro area catching-up economies in the decade preceding the global financial and economic crisis can be partly explained by the weakening of the convergence channel, lower spending on innovation activities such as R&D and ICT, deteriorating government effectiveness, and faster population ageing.*

*Throughout the crisis, a broad range of reforms aimed at improving framework conditions have been adopted in catching-up economies and are likely to raise TFP growth rates. However, since convergence is shown to be more difficult for economies getting closer to the technological frontier, the adoption of further structural measures would help ensure a faster TFP convergence process. In particular, policies that foster innovation activities, reduce further the restrictiveness of employment protection legislation, lower corporate tax rates and improve government effectiveness appear to support TFP growth.*

## I.1. Introduction

The pace of euro area income per capita convergence has slowed since the mid-1990s. This mainly reflects poor growth rates in some of the catching-up economies (i.e. Greece, Spain, and Portugal), but also in some Member States with a higher income per capita than the euro area average (e.g. Italy). Their weak performance mirrors an excessive allocation of resources towards less productive sectors, but also reflects low growth in total factor productivity (TFP) in a broad range of industries (see European Commission, 2013). <sup>(2)</sup> TFP measures the efficiency with which inputs are being used in the production process and it can be understood as a rough measure of the rate of technological progress in the economy.

The empirical evidence suggests that the TFP performance of the euro area catching-up economies before the beginning of the global economic and financial crisis in 2008 can be split into three phases: (i) The 1980s and early 1990s were characterised by average TFP growth rates above the euro area's average, supporting a strong convergence towards the rest of the euro area; (ii) around the mid-1990s, TFP performance slowed down significantly, bringing convergence to

a halt; (iii) between the end of 1990s until the crisis, TFP actually declined, resulting in a divergence of catching-up economies from the rest of the euro area Member States. The last period can be illustrated by an atypical positive correlation between the initial level of GDP per capita and average TFP growth rates (see Graph I.1). This evidence on divergence is at odds with the results of seminal papers pointing to a small convergence effect for at least some European regions in previous decades (Barro and Sala-i-Martin, 1991; Sala-i-Martin, 1996). <sup>(3)</sup>

Against this background, the focus section takes a closer look at the key drivers of TFP growth over the period 1994 to 2007 with a special focus on the euro area catching-up economies. The group labelled as 'euro area catching-up economies' hereafter includes Portugal and Spain which were part of the euro since its inception and therefore for most of the sample considered. Due to data constraints at the sectoral level, Greece could not be considered in most of the analysis hereafter. Occasionally, Italy is also discussed as an example. Although not a catching-up country, Italy's TFP performance diverged significantly from the rest of the euro area in the decade preceding the crisis.

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<sup>(1)</sup> The section was prepared by Narcissa Balta and Philipp Mohl.

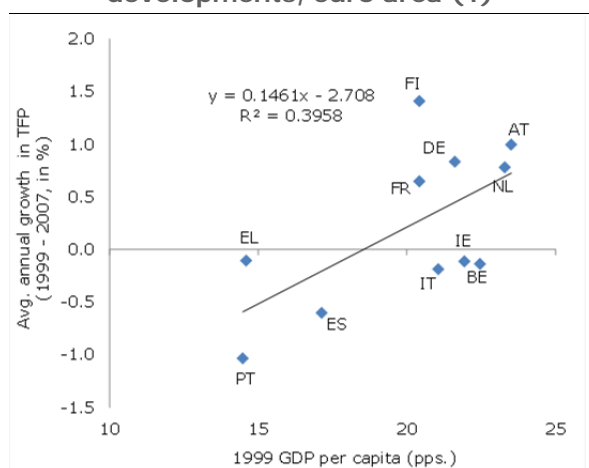
<sup>(2)</sup> European Commission (2013), 'Focus: Catching-up processes in the euro area', *Quarterly Report on the Euro Area*, Vol. 12(1), pp. 7-18.

<sup>(3)</sup> Barro, R. and X. Sala-i-Martin (1991), 'Convergence across states and regions', *Brookings Papers on Economic Activity*, Vol. 1, pp. 107-182; Sala-i-Martin, X. (1996), 'Region cohesion: evidence and theories of regional growth and convergence', *European Economic Review*, Vol. 40, pp. 1325-1352.

The empirical identification of key drivers of TFP is challenging, since TFP cannot be observed directly and it is hard to measure. The TFP data used are taken from the EU KLEMS database, which offers the advantage of sector-level data.

The focus section is structured as follows: Section I.2. provides an overview of TFP performance in the euro area. Section I.3. reviews potential structural drivers of TFP, taking into account the insights of the literature. Section I.4. analyses key drivers of TFP based on a panel econometric approach. Finally, Section I.5. concludes.

Graph I.1: Total factor productivity developments, euro area (1)



(1) The sample consists of the euro area Member States in 2007. Due to data availability, LU is not covered and growth rates for PT and EL refer to the period 1995 to 2006.

Source: DG ECFIN based on EU KLEMS and WIOD.

## I.2. TFP performance in the euro area at sectoral level

*In brief: this section shows that most industries in the euro area catching-up economies exhibited poor TFP performance during the pre-crisis decade, leading to a divergence with the rest of the euro area in several sectors. The persistence of this weakness, as well as its broad sectoral representation, suggests that the weak TFP performance is at least partly structural in nature.*

This section takes a closer look at TFP performance in the euro area at the sectoral level. The data for TFP growth rates are taken from the EU KLEMS database. (4) In the EU KLEMS

(4) EU KLEMS methodology for deriving TFP measures differs from the European Commission TFP trend estimation methodology, which is based on the commonly agreed production

methodology, TFP is corrected for changes in the quality of both labour and capital inputs so as to capture disembodied technological progress. (5) This implies, for instance, that changes in the composition of the labour force or the rapid shifts in investment towards information and communication technologies (ICT) over the recent years are not reflected in the EU KLEMS TFP measure, but in the inputs used in the production function. The TFP level is determined by anchoring the EU KLEMS TFP growth rates to the 1997 PPP-adjusted TFP levels of the Groningen Growth and Development Centre's productivity level database. (6)

Weak productivity growth in the euro area catching-up economies in the decade preceding the financial and economic crisis affected most industries (Graph I.2). On the one hand, a handful of industries have registered significant productivity losses, notably some service sectors and construction. On the other hand, in the manufacturing sector, annual average TFP growth between 1999 and 2007 has been close to zero or even slightly negative (Graph I.2) despite the sector's openness to trade and close integration with the EU market. Only the financial intermediation sector showed significantly positive growth rates.

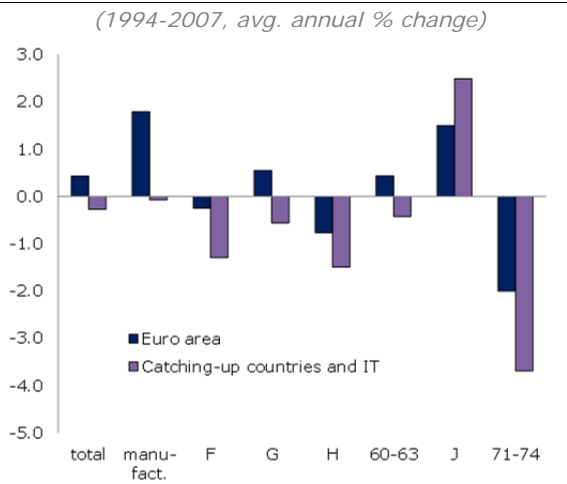
The observed poor performance in productivity led the catching-up economies and Italy to diverge from the rest of the euro area (Graph I.3). The TFP gap between euro area catching-up economies and the technological leaders (i.e. the countries where the TFP level was the highest in the industry considered among a sample of OECD countries) was not concentrated just in a handful of industries. Instead, there was little progress in TFP convergence in most industries.

function methodology for calculating potential output. For details, D'Auria, F., C. Denis, K. Havik, K. Mc Morrow, C. Planas, R. Raciborski, W. Röger and A. Rossi (2010), 'The production function methodology for calculating potential growth rates and output gaps', *ECFIN Economic Papers*, No 420.

(5) For more details on EU KLEMS see: O'Mahony, M. and M.P. Timmer (2009), 'Output, input and productivity measures at the industry level: the EU KLEMS database', *The Economic Journal*, Vol. 119 (June), pp. F374-F403.

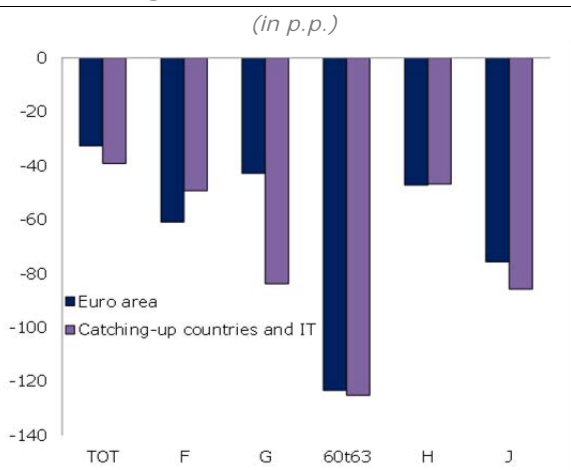
(6) See Inklaar, R. and M.P. Timmer (2009), 'Productivity convergence across industries and countries: the importance of theory-based measurement', *Macroeconomic Dynamics*, Vol. 12 (Sup 2), pp. 218-240.

Graph I.2: TFP performance at sectoral level (1)



(1) The chart shows average annual TFP growth rates over the period 1994 to 2007. Euro area consists of the euro area Member States in 2007 (except EL). Catching-up countries includes PT, ES and IT. The sector classification used for Graphs I.2, I.3 and I.4 includes (sector codes in parenthesis): manufacturing (consisting of food, beverages and tobacco (15-16), pulp, paper, printing and publishing (21-22), machinery (29), electrical and optical equipment (30-33) and other manufacturing (36-37)), construction (F), wholesale and retail trade (G), hotels and restaurants (H), transport and storage (60-63), financial intermediation (J), renting of machinery and equipment and other business activities (71-74), real estate activities (K), public administration, education and health (L-N).  
 Source: EU KLEMS.

Graph I.3: Average technology gap divergence at sectoral level (1)



(1) The graph shows the average technology gap in selected sectors between 1994 and 2007 (see Graph I.2 for a description of sectors and country groups).  
 Source: DG ECFIN based on EU KLEMS.

The persistence of the gap (and in many cases its widening) over the 1994-2007 period, suggests that the weakness of TFP performance is at least partly structural. This implies that some structural

features present in manufacturing and services sectors, and more so in non-tradable services sectors, impeded TFP growth in the catching up economies in the pre-crisis period, even though there was a surge in investment during that time. Without substantial policy action and structural reforms, the catching-up economies could be facing a long period of relatively low TFP growth in the medium-term.

### I.3. Potential TFP drivers

*In brief: the literature has identified a broad set of factors supporting TFP growth. In particular, policy measures which affect the quality of human capital, the capital stock and the structural/institutional framework conditions of the economy seem to be beneficial for TFP growth.*

This section takes a closer look at the key TFP drivers identified in the literature. The review builds upon the insights of endogenous growth models, which put a great emphasis on the role of innovation in promoting productivity. (7) In this framework, TFP is mainly driven by the quality of labour and capital inputs (i.e. the skill structure of the labour force and the quality of the capital stock) as well as the structural and institutional framework conditions, in which the economy operates.

#### Quality of labour inputs

There is plenty of evidence in the literature showing that a higher skilled labour force tends to promote innovation, leading to a rise in productivity. (8)

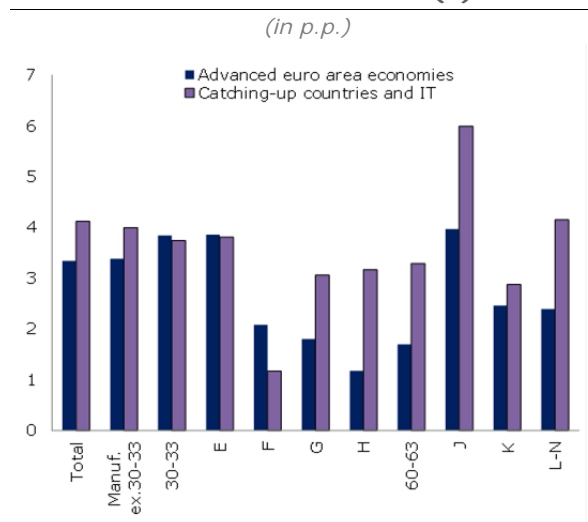
Some euro area catching-up economies (e.g. Portugal), but also some of the more advanced economies (e.g. Italy), started with a very low proportion of high-skilled workers, and despite significant progress, are still struggling with a high share of low-skilled workers in the economy. This driver may still be negatively affecting their TFP performance.

(7) For example, in Aghion, P. and P. Howitt (2006), 'Appropriate growth policies: a unifying framework', *Journal of the European Economic Association*, Vol. 4(2/3), pp. 269-314.

(8) See European Commission (2009), 'Trade costs, openness and productivity: market access at home and abroad', *Industrial Policy and Economic Reform Papers*, No 10, January; Sondermann (2012), 'Productivity in the euro area. Any evidence of convergence?', *ECB Working Paper*, No 1431, April.

However, given the progress observed, the quality of human capital endowments is not likely to have been a potential driver of the divergence in TFP growth rates between the catching-up economies and the rest of the euro area. The evidence suggests that the skill structure improved during the pre-crisis period. The increase in the share of high-skilled hours worked has been broad based in manufacturing, but even more so in services sectors. It has also been more pronounced in the euro area catching-up economies than in those of the core, suggesting that there has been some convergence of skill structures in the euro area (Graph I.4).

**Graph I.4: Change in the share of high-skilled hours worked, between periods 1995-01 and 2001-07 (1)**



(1) Advanced euro area economies: DE, FR, NL, AT, and FI. Catching-up economies (ES and PT) as well as IT. See also Graph I.2 for a description of sectors.

Source: DG ECFIN based on EU KLEMS and WIOD.

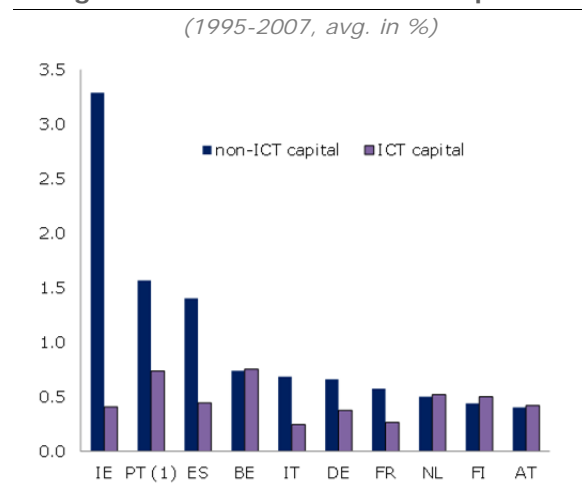
### Quality of capital inputs

In terms of the quality of capital inputs, the literature suggests that investment in ICT plays a prominent role in explaining TFP performance.<sup>(9)</sup> Investment in ICT increases an economy's productive potential by raising its capital stock, but also increases its potential for rapid technical progress with positive effects on TFP growth.

<sup>(9)</sup> Marrocu, E., Paci, R. and S. Usai (2013), 'Productivity growth in the old and new Europe: The role of agglomeration externalities', *Journal of Regional Science*, Vol. 53(3), pp. 418-442; Griffith, R., Redding, S. and J. van Reenen (2004), 'Mapping the two faces of R&D: productivity growth in a panel of OECD industries', *The Review of Economics and Statistics*, Vol. 86(4), pp. 883-895.

In terms of the quality of capital inputs, the relative contribution to the added value of the non-ICT component of capital seems to be much greater in the euro area catching-up economies than in the rest of the euro area (Graph I.5). This pattern is observable across all sectors, with the exception of the ICT-producing industries (i.e. electrical and optical equipment, postal services and communications). Moreover, in most euro area countries, the contribution to growth of the ICT-component of capital, relative to its non-ICT component, further deteriorated in the latter years of the pre-crisis period (2004-2007) especially in the weak TFP performing euro area countries (e.g. Spain, Portugal and Italy). This implies that in terms of the quality of capital inputs, insufficient investment in ICT could be an important explanation for the disappointing TFP performance in the catching-up countries.

**Graph I.5: Contribution to value added growth of non-ICT and ICT capital**



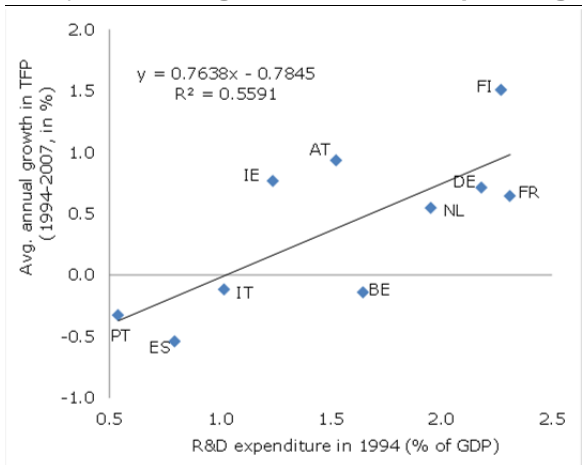
(1) PT: 1995-2005.

Source: DG ECFIN based on EU KLEMS and WIOD.

Finally, the literature provides evidence that countries that spend more on R&D tend to exhibit higher growth rates of TFP.<sup>(10)</sup> This seems to be confirmed over the sample period analysed. Graph I.6 illustrates that countries that spent a smaller share of GDP on R&D (e.g. Spain, Portugal and Italy) also had lower annual average growth rates of TFP during the pre-crisis period.

<sup>(10)</sup> Griffith, R., Redding, S. and J. van Reenen (2004), 'Mapping the two faces of R&D: productivity growth in a panel of OECD

Graph I.6: TFP growth and R&D spending



Source: DG ECFIN based on EU KLEMS and WIOD.

### Structural/institutional drivers related to framework conditions

Apart from the quality of labour and capital inputs, the literature suggests that structural/institutional drivers affecting the framework conditions, in which the economy operates, have a significant impact on TFP.

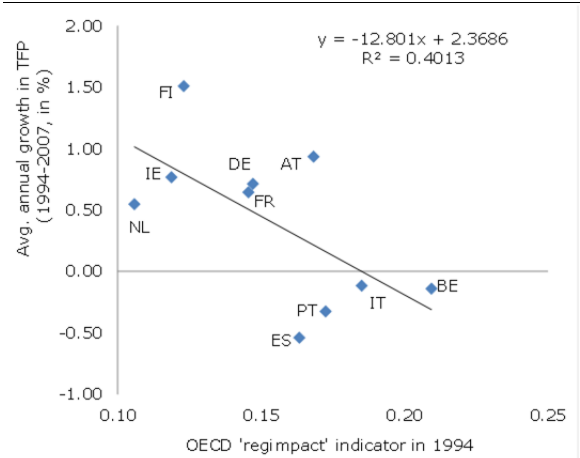
A large body of economic literature suggests that more rigid product and labour markets tend to weaken productivity by slowing down the catching-up process of best-practice technologies, delaying firm-level adjustments and/or reducing direct productivity gains. <sup>(1)</sup>

The OECD product market regulation (PMR) indicators, which measure the degree of anti-competitive regulation in selected sectors of the economy, have improved for most sectors of the euro area countries during the pre-crisis period (1994-2007). At the same time, countries with a higher PMR indicator in 1994, showed lower productivity growth over the period, resulting in a negative correlation between TFP growth and the degree of anti-competitive regulation. All catching-up economies as well as Italy showed stricter product market regulation in 1994 (Graph I.7).

industries', *The Review of Economics and Statistics*, Vol. 86(4), pp. 883-895; Inklaar, R., Timmer, M., and van Ark, B. (2008), 'Market services productivity across Europe and the US', *Economic Policy* 23, pp. 139-194.

<sup>(1)</sup> Nicoletti, G. and S. Scarpetta (2003), 'Regulation, productivity and growth: OECD evidence', *Economic Policy*, April, pp. 9-72; Burda, M. and B. Svergnini (2009), 'TFP growth in old and new Europe', *Comparative Economic Studies*, Vol. 51, pp. 447-466.

Graph I.7: Product market regulation (1)

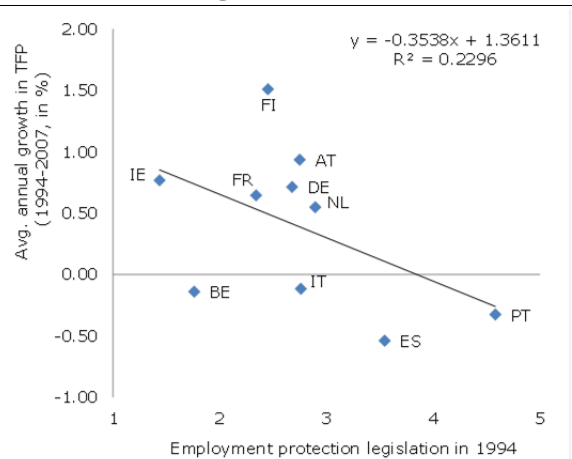


(1) The graph shows the OECD 'regiimpact' indicator, which assigns higher indicators to stricter product market regulation.

Source: DG ECFIN based on OECD.

Looking at labour market rigidities, the OECD employment protection indicators (EPL) show that the catching-up economies started with a relatively high degree of rigidity in their employment protection legislation (Graph I.8). The negative correlation between the average TFP growth over 1994 to 2007 and the score in the EPL indicator in 1994 indicates that the poor TFP performance observed over the pre-crisis period could, to some extent, be negatively related to the initial level of the employment protection legislation. However, the correlation seems to be much weaker than in the case of R&D spending.

Graph I.8: Employment protection legislation (1)

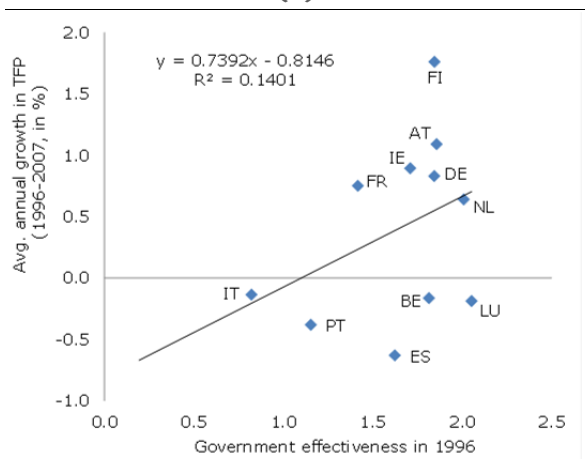


(1) The graph shows the employment protection indicator for regular contracts in terms of individual and collective dismissals. Higher values stand for stricter protection rules.

Source: DG ECFIN based on OECD.

Poor productivity performance has also been linked by several studies to the deteriorating quality of institutions.<sup>(12)</sup> The institutional quality, as measured by the government effectiveness of the World Bank Governance Indicators database, was indeed low in the euro area economies with poor productivity performance (Graph I.9). This seems to be particularly the case of Italy.

Graph I.9: Effectiveness of governments (1)



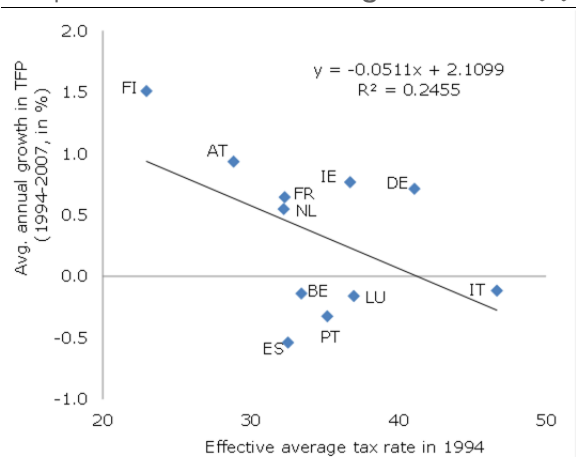
(1) Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Higher values point to higher government effectiveness.  
**Source:** DG ECFIN based on World Bank (2013): Worldwide governance indicators.

Finally, there is also evidence that higher corporate tax rates can distort factor prices and reduce entrepreneurship and R&D activities, resulting in a negative impact on TFP.<sup>(13)</sup> The negative correlation between average TFP growth rates over the period 1994-2007 and the corporate tax rate in 1994 seem to support this hypothesis (Graph I.10).

<sup>(12)</sup> Bertola, G. (2013), 'Policy coordination, convergence and the rise and crisis of EMU imbalances', 'The future of EMU' Fellowship, ECFIN Economic Paper 490; Acemoglu, D., Johnson, S. and J. Robinson (2001), 'The colonial origins of comparative development: an empirical investigation', *American Economic Review*, Vol. 91(1), pp. 1369-1401.

<sup>(13)</sup> Vartia, L. (2008), 'How do taxes affect investment and productivity? An industry-level analysis of OECD countries', *OECD Economics Department Working Papers*, No 656.

Graph I.10: Effective average tax rates (1)



(1) Effective average tax rates are calculated in line with Devereux, M.P. and R. Griffith (2003), 'Evaluating tax policy for location decisions', *International Tax and Public Finance*, Vol. 10, pp. 107-126.

**Source:** DG ECFIN based on Elschner, C. and M. Overesch (2007), 'Trends in corporate tax levels in Europe', *Intereconomics*, Vol. 42(3), pp. 127-132.

#### I.4. Empirical evidence of the drivers of TFP

*In brief: this section presents panel regression results based on an endogenous growth model. The findings show that TFP growth over 1994-2007 was mainly driven by the convergence and spillover channel as well as spending for innovation activities. For euro area catching-up countries, policy measures that reduce employment protection legislation, lower corporate tax rates and improve government effectiveness seem to have the most beneficial impact on TFP growth.*

The aim of this section is to analyse the main drivers of TFP using a panel data approach. The identification of key determinants of TFP is challenging, since TFP is hard to measure and it can be affected by a broad set of factors shaping the institutional and economic features of the economy.

The empirical approach investigates TFP performance in OECD economies, thereby excluding emerging countries. Relying solely on country-specific information may, however, lead to biased results due to the small sample size. Therefore, the analysis benefits from the sector-specific information of the EU KLEMS database. One major drawback of this approach, however, is that EU KLEMS only offers data until 2007. Against this background, the drivers of TFP are analysed using a sample of up to 20 OECD countries and 14 sectors over the time period 1994 to 2007.

The dependent variable is defined as total factor productivity growth in line with the growth accounting methodology of EU KLEMS (see Section I.2.). The selection of potential explanatory factors with a causal impact on TFP was made based on the key explanatory variables presented in Section I.3.

Two independent variables are of particular importance. First, the technology gap, which measures the distance between the TFP level of the country concerned and the country with the highest TFP level. This variable provides an indication of the impact from the convergence channel. It is expected that with a larger technology gap the potential benefit of adopting new technologies increases, resulting in a higher TFP growth rate. Second, the possibility of positive innovation and knowledge spillovers is captured by including the TFP growth rate of the country with the highest TFP level (the technology leader). This variable measures the importance of the spillover channel. Apart from these explanatory variables, the specification includes a large set of control factors in line with Section I.3., such as the impact of ICT compensation, R&D expenditure, the share of high-skilled population, as well as country-, sector- and time-fixed effects (see Box I.1 for more detailed results).

The findings of a first set of (restricted) empirical regressions<sup>(14)</sup> show that convergence and spillover effects are important factors in explaining TFP growth. Both variables appear to be strongly significant. The larger the distance to the frontier, the more sizeable the positive impact from the convergence channel on TFP gets. At the same time, an increase of the spillover effect as realised by the TFP growth of the technology leader, results in a higher TFP growth rate. The empirical findings suggest that the impact from the spillover channel is stronger than the impact from the convergence channel. The results also reveal that the strength of the spillover channel seems to have increased over time, while that of the convergence channel has weakened.

Apart from the convergence and spillover channels, TFP growth appears to be strongly supported by innovation activities as captured by

the share of ICT compensation in total compensation and R&D expenditure. By contrast, labour skills, as measured by the share of population aged 25 and over who have completed tertiary education, turns out not to be significant. This finding indicates that the correction of TFP done in EU KLEMS for changes in the quality of input factors (see Section I.2.) appears to be successful for labour but not completely so for capital input factors.

There is no clear evidence that other structural variables have a direct significant impact on TFP growth. However, it is possible that the impact of other potential factors could depend on the state of the convergence or spillover channel. For instance, certain structural variables may only be significant for more (or less) advanced countries, i.e. those with a small (or high) gap to the technology frontier.

To investigate these conditional effects, another set of regressions was run to estimate a set of interaction models. In these regressions, the technology gap and the spillover term are interacted with the structural drivers related to the framework conditions presented in Section I.3. These indicators capture different policy areas that are proxied by five variables, namely *labour market flexibility* (employment protection legislation), *tax regimes* (effective average tax rates), *institutional quality* (government effectiveness), *population ageing* (old age dependency ratio) and *product market regulations* (OECD regimpact indicator)

The results of these interaction models show that the effect of the structural variables on TFP growth is dependent on the technology gap. More rigid employment protection legislation tends to have a negative impact on TFP growth. The negative impact becomes stronger the less advanced the economy is. The impact on TFP growth is, however, not statistically significant for the least advanced economies, i.e. those which have a very high technology gap. An increase in corporate tax rates and ageing population seem to have a particularly detrimental impact on TFP in less advanced economies. Improving government effectiveness tends to have a positive and significant impact on TFP growth for medium- and more advanced economies. Finally, the results do not suggest a statistically significant impact of product market regulation.

<sup>(14)</sup> As a starting point, TFP growth was regressed on the technology gap and the spillover channel apart from country-, sector- and time-fixed effects, thereby omitting further control variables.

### Box I.1: The drivers of TFP – an empirical assessment

This box provides empirical evidence on the main drivers of total factor productivity (TFP). The empirical identification of the most important explanatory factors of TFP is challenging, since TFP cannot be observed directly and a wide range of indicators influencing the institutional and economic features of the economy can impact TFP.

#### Empirical specification

The drivers of the TFP growth rates ( $\hat{TFP}_{i,j,t}$ ) are analysed with the help of a panel data approach. To mitigate the risk of a small sample bias, the analysis is not limited to euro area Member States, but based on a sample covering up to 20 OECD countries ( $i$ ), 14 sectors ( $j$ ) over the time period ( $t$ ) 1994 to 2007. <sup>(1)</sup> The basic specification follows Mc Morrow et al. (2010) <sup>(2)</sup> and looks as follows:

$$(i) \hat{TFP}_{i,j,t} = \beta_0 + \beta_1 GAP_{i,j,t-1} + \beta_2 \hat{TFP}_{L,j,t} + \beta_4 D_i + \beta_5 D_j + \beta_6 D_t + \varepsilon_{i,j,t}$$

$$(ii) \hat{TFP}_{i,j,t} = \beta_0 + \beta_1 GAP_{i,j,t-1} + \beta_2 \hat{TFP}_{L,j,t} + \beta_3 X_{i,j,t-1} + \beta_4 D_i + \beta_5 D_j + \beta_6 D_t + \varepsilon_{i,j,t}$$

$$(iii) \hat{TFP}_{i,j,t} = \beta_0 + \beta_1 GAP_{i,j,t-1} + \beta_2 \hat{TFP}_{L,j,t} + \beta_3 Z_{i,t-1} + \beta_4 GAP_{i,j,t-1} Z_{i,t-1} + \beta_5 \hat{TFP}_{L,j,t} Z_{i,t-1} + \dots \\ \dots + \beta_6 X_{i,j,t-1} + \beta_7 D_i + \beta_8 D_j + \beta_9 D_t + \varepsilon_{i,j,t}$$

As a starting point the TFP growth rates are regressed on two main independent variables (see equation (i)). The technology gap (GAP) indicates the impact from the catching-up process on TFP growth. GAP measures the log-difference between the TFP level of the country concerned and the country with the highest TFP level in year  $t$  and sector  $j$  ( $\ln(TFP_{i,j,t}) - \ln(TFP_{L,j,t})$ ). The technology gap equals zero for the leading economy and it takes negative values for the economies with a gap. It is expected that a larger technology gap with the leading economy implies a higher potential benefit from adopting advanced technologies, thus increasing TFP growth. In addition, the possibility of positive innovation and knowledge spillovers is captured by including the TFP growth rate of the economy with the highest TFP level ( $\hat{TFP}_{L,j,t}$ ) in the sector and for the year considered. The specification also incorporates country, sector and time-fixed effects ( $D_p, D_j, D_t$ ) apart from an error term ( $\varepsilon_{i,j,t}$ ).

As a second step, further control variables with a potential impact on TFP growth are added to the specification with the matrix  $X$  (see equation (ii)). The selection of these variables was guided by a review of the literature (see section I.3. in the main text). Since the impact of these variables tends to occur only gradually, they are included with a lag of one year.

In the final step, the empirical model is augmented with interaction terms in order to investigate whether the impact of the independent variables occurs conditional on the level of convergence or the growth rate of the frontier economy. For this purpose, the proxies influencing the institutional and economic features of the economy ( $Z_{i,t}$ ) are interacted with the technology gap and the TFP growth rate of the leading economy (see equation (iii)). This approach has the advantage of alleviating potential multicollinearity between the TFP variables and the interaction term.

<sup>(1)</sup> The sample size is clearly constraint by data availability. It consists of the following sectors (*sector codes in parenthesis*): food, beverages and tobacco (15-16), pulp, paper, printing and publishing (21-22), machinery (29), electrical and optical equipment (30-33), manufacturing (36-37), electricity, gas and water supply (E), construction (F), wholesale and retail trade (G), hotels and restaurants (H), transport and storage (60-63), financial intermediation (I), real estate activities (70) and renting of machinery and equipment and other business activities (71-74) and other community, social and personal services (O) for a panel consisting of Australia, Austria, Belgium, Czech Republic, Denmark, Spain, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal, Slovenia, Sweden, the United Kingdom and USA. The period covered reflects the fact that the second stage of EMU integration started on 1 January 1994 with the establishment of the European Monetary Institute (EMI). Note that the panel is unbalanced, since not all variables are available over the entire sample period.

<sup>(2)</sup> For a similar specification see Mc Morrow, K., Röger, W. and A. Turrini (2010), 'Determinants of TFP growth: A close look at industries driving the EU-US TFP gap', *Structural Change and Economic Dynamics*, Vol. 21(3), August, pp. 165-180.

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## Box (continued)

## Data

The main source for the TFP-related indicators is the March 2011 update of the EU KLEMS database, which offers the great benefit of sectoral level data (see section I.2. of the main text for a more detailed description). <sup>(3)</sup> Apart from the technology gap and spillover indicator taken from the EU KLEMS database, the following explanatory variables are analysed in the regression framework: high-skilled as measured by the share of population aged 25 and over with a completed tertiary education (Barro and Lee, 2013), share of labour compensation for ICT-related services as a percentage of total labour compensation (EU KLEMS), corporate income tax rates (Elschner and Overesch, 2007), strictness of employment protection legislation (OECD), strictness of product market regulation (OECD), old age dependency ratio (OECD), R&D expenditure as a percentage of GDP (OECD) and government effectiveness as measured by the World Bank Governance Indicators dataset. <sup>(4)</sup>

The interaction terms are constructed for five different policy areas shaping the institutional and structural framework conditions, in which the economy operates. The following proxies are used: the employment protection indicator (as a measure of *labour market flexibility*), the corporate income tax rate (*tax regime*), the government effectiveness (*institutional quality*), the old age dependency ratio (*ageing societies*) and the regimpact indicator by the OECD (*product market flexibility*). To allow for a better interpretation of the results, all variables are centred around a zero mean.

## Results

## Restricted specification

In the first step, the TFP growth rates are regressed for different sample periods in a restricted specification consisting, apart from the fixed effects, of the technology gap and spillover term (see equation (i) and Table 1). The technology gap turns out to have a negative and significant impact on TFP growth throughout the specifications used. Since the technology gap is defined on a scale from zero for the leading economy to negative values for the catching-up countries, the negative signs of the coefficients imply that a larger technology gap enables higher potential gains for adopting enhanced technologies, thereby increasing TFP growth. The spillover channel as realised by the TFP growth of the leading economy, appears to have a positive and significant influence on TFP growth, irrespective of which sample period is analysed. The country, sector and time-fixed effects seem to be highly significant.

Table 1: Restricted specifications

	1980-07	1985-07	1990-07	1980-93	1985-93	1994-07
	(1)	(2)	(3)	(4)	(5)	(6)
TFP growth ( $L_{j,t}$ )	0.0500*** (4.633)	0.0513*** (4.442)	0.0485*** (4.054)	0.0225** (2.000)	0.0125 (0.976)	0.0605*** (3.505)
GAP ( $i_{j,t-1}$ )	-0.0101*** (-5.434)	-0.00961*** (-4.745)	-0.00908*** (-3.990)	-0.0191*** (-5.975)	-0.0193*** (-4.808)	-0.00690*** (-2.802)
Constant	-0.0125 (-1.271)	0.00175 (0.327)	0.00570 (0.581)	-0.00514 (-0.532)	0.0313* (1.646)	-0.00769 (-1.101)
Observations	6599	5819	4904	2520	1740	4079
R-squared	0.108	0.111	0.107	0.120	0.129	0.118

Notes: The specifications include country, sector and time fixed effects, which are not shown due to space constraints. Wald test provide strong evidence that the fixed effects are statistically significant. t-statistics in parenthesis are derived using the heteroskedasticity robust Huber-White estimator (LSDV). \*\*\*, \*\* and \* denote respectively statistical significance at 1, 5 and 10%.

<sup>(3)</sup> The methodology and construction of the EU KLEMS database is described in: O'Mahony, M. and M.P. Timmer (2009), 'Output, input and productivity measures at the industry level: the EU KLEMS database', *Economic Journal*, Vol. 119(538), pp. F374-F403. For more details on the database see: Timmer, M.P., Inklaar, R., O'Mahony, M. and B. van Ark (2013), 'Economic growth in Europe. A comparative industry perspective', *Cambridge University Press*, January.

<sup>(4)</sup> Barro, R. and J.-W. Lee (2013), 'A new data set of educational attainment in the world, 1950-2010', forthcoming: *Journal of Development Economics*, Devereux, M.P. and R. Griffith (2003), 'Evaluating tax policy for location decisions', *International Tax and Public Finance*, Vol. 10, pp. 107-126; Elschner, C. and M. Overesch (2007), 'Trends in corporate tax levels in Europe', *Intereconomics*, Vol. 42(3), pp. 127-132.

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Box (continued)

A closer look at the size of the coefficients reveals that the size of the spillover channel seems to have increased over time, while that of the convergence channel appears to have weakened significantly and loses significance after the mid/end-1990s. (4) Moreover, the findings suggest that the further the distance to the frontier, the more sizeable the coefficient of a marginal increase of the gap on TFP growth.

#### Benchmark specifications

In a second step, the reduced form specification is augmented by adding further explanatory variables in line with the literature review (see equation (ii) and Table 2). These benchmark specifications broadly confirm the results of the literature. TFP growth seems to be strongly supported by innovation activities in the form of ICT compensation and R&D expenditure, while the proxy for human capital is not statistically significant. This indicates that the EU KLEMS correction of TFP for labour and capital inputs reported above appears to be only successful for changes of labour inputs, while it may not be the case for ICT and R&D expenditure. In addition, the results show that the significance level of the technology gap is reduced compared to the results reported above (see columns (2)-(4)).

Table 2: Benchmark specifications

	(1)	(2)	(3)	(4)
TFP growth ( $L_{j,t}$ )	0.0605*** (3.505)	0.0616*** (3.354)	0.0639*** (3.272)	0.0832*** (3.288)
GAP ( $i,j,t-1$ )	-0.00690*** (-2.802)	-0.00497* (-1.883)	-0.00576** (-2.142)	-0.00432 (-0.885)
ICT compensation ( $i,j,t-1$ )		0.0189** (2.169)		0.0331* (1.829)
High-skilled ( $j,t-1$ )			-0.00104 (-0.698)	
R&D ( $i,j,t-1$ )				0.165*** (2.912)
Constant	-0.00769 (-1.101)	0.0411*** (5.204)	0.000915 (0.0749)	0.0241* (1.847)
Observations	4079	3690	3480	1298
R-squared	0.118	0.117	0.112	0.145

Note: Sample period 1994 to 2007. The specifications include country, sector and time fixed effects, which are not shown due to space constraints. Wald test provide strong evidence that the fixed effects are statistically significant. t-statistics in parenthesis are derived using the heteroskedasticity robust Huber-White estimator (LSDV). \*\*\*, \*\* and \* denote respectively statistical significance at 1, 5 and 10%.

#### Specifications with interactions

In the final step, the regressions are run including interaction terms. The interpretation of the empirical model is then less straightforward. The impact of a change of the structural variable of interest ( $Z$ ) on TFP growth needs to be assessed based on the partial derivative derived from equation (iii), i.e.:

$$(iv) \frac{\partial TFP}{\partial Z} = \beta_3 + \beta_4 GAP_{i,j,t-1} + \beta_5 TFP_{L,j,t}$$

Equation (iv) clarifies that the impact from a marginal increase of the structural variable can only be evaluated conditional on the technology gap and the TFP growth of the leading economy.

For instance, in a specification which incorporates the employment protection indicator interacted with both the technology gap and the spillover variable, the size and significance of an increase of the employment protection indicator on TFP growth needs to be evaluated conditional on the technology gap and the spillover variable. (1) Since the latter are centred around a mean of zero, the coefficient of the employment protection indicator reported in an ordinary regression output table indicates how a marginal change of the EPL would affect TFP growth given the technology gap and the TFP growth of the frontier economy are at its sample mean, i.e. zero.

(1) For the interpretation of interaction models see, among others, Brambor, T., Clark, W.R. and M. Golder (2006), 'Understanding interaction models. Improving empirical analyses', *Political Analysis*, Vol. 14, pp. 63-82 or Braumodler, B.F. (2004), 'Hypothesis testing and multiplicative interaction terms', *International Organization*, Vol. 58(fall), pp. 807-820.

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Box (continued)

However, it may be meaningful to analyse the size and significance of the employment protection legislation for different values of the technology gap, assuming an average growth rate of the leading economy. For this purpose, the marginal effects of the employment protection legislation are plotted for the whole range of observed values of the technology gap. In addition, confidence bands indicate the level of uncertainty regarding the marginal effects by plotting the lower and upper bound of the 95% confidence intervals. The effects are statistically significant whenever the upper and lower bounds of the confidence interval are both above the zero line and when both bounds are below the zero line.

Graph 1 illustrates the effects of an increase of different structural variables on TFP growth conditional on the observed values of the technology gap for an average growth rate of the leading economy. <sup>(5)</sup>

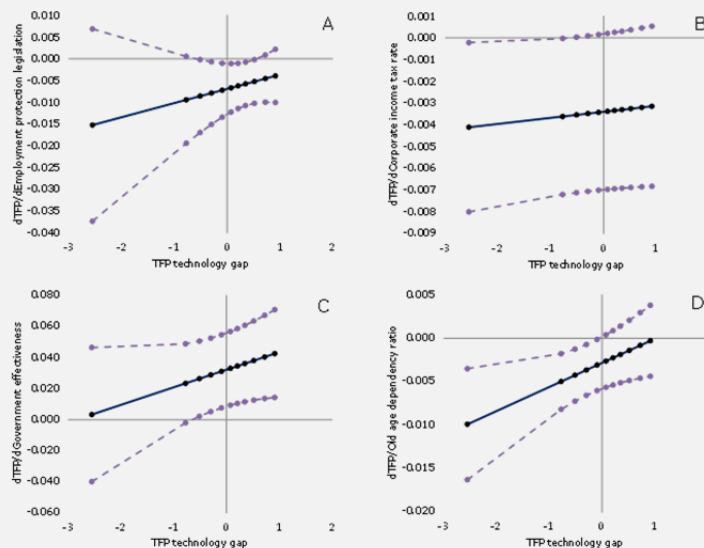
Graph 1A shows that a marginal increase of the employment protection legislation on TFP growth is associated with a negative impact on TFP growth. The positive slope of the regression line can be interpreted to mean that the negative impact from stricter employment protection legislation weakens with smaller values of the technology gap. The confidence bands show that the impact is statistically significant for the overwhelming part of the values for the technology gap.

An increase of the corporate income tax rate appears to have a negative effect on TFP growth (Graph 1B). However, its impact is only statistically significant for economies that are located further away from the economic frontier, i.e. those that are more technologically backwards. As a consequence, the tax regime seems to play an important role in explaining TFP growth for less advanced economies.

The empirical findings provide evidence that the institutional quality seems to matter for TFP growth (Graph 1C). Improving the effectiveness of governments has a positive effect on TFP growth. This effect is significant for a large part of the sample and becomes stronger the closer the economy gets to the frontier as shown by the positive slope of the regression line.

Population ageing also seems to be detrimental to TFP growth. The impact tends to be strongest and statistically significant for less advanced economies (Graph 1D). Finally, the panel results do not provide evidence for a statistically significant causal relationship between product market regulation and TFP growth.

**Graph 1: Marginal effects of structural variables on TFP growth conditional on the technology gap (assuming the TFP growth rate of the frontier is at its mean)**



Graph 2 illustrates the findings of a marginal change of the same structural variables on TFP growth conditional on the observed values of the TFP growth rates of the countries with the highest TFP level, assuming the technology gap to be at its mean. <sup>(6)</sup>

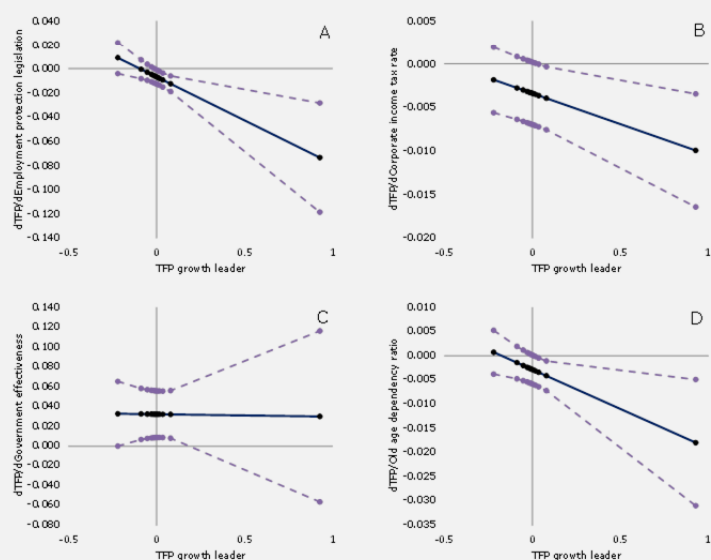
(Continued on the next page)

Box (continued)

The findings suggest that employment protection legislation, corporate income tax and the effect of an ageing society are particularly important for economies at the frontier with high TFP growth rates. Graphs 2A, 2B and 2D show that an increase in these variables has a negative impact on TFP growth rates. This effect is only statistically significant for high TFP growth rates and it becomes stronger the higher the TFP growth rate of the leader. Since sectors closely related to ICT appear to show the highest growth rates over the sample period, the findings implicitly suggest that these sectors tend to react strongest to changes in labour market flexibility, tax regimes and population ageing.

The effect from improving the effectiveness of governments, by contrast, seems to be of particular importance for sectors with a lower TFP growth rate, as illustrated by the slightly negative slope of the regression line (Graph 2C). A more effective government, however, tends to be beneficial and statistically significant for TFP growth for a large part of the sectors examined. Finally, the empirical model indicates that product market regulation does not seem to effect TFP growth no matter the TFP growth rate of the leading economy.

**Graph 2:** Marginal effects of structural variables on TFP growth conditional on the TFP growth of the frontier (assuming the technology gap is at its mean)



The interaction models reveal that the impact of the structural variables also seems to be conditional on the spillover channel, i.e. the growth rates of the economies with the highest TFP level. Stricter employment protection legislation, an increase of the corporate income tax rate, or a higher old age dependency ratio, all have a detrimental impact on TFP growth when the TFP growth rate of the technology leader is high. Since sectors closely related to ICT appear to show the highest growth rates over the sample period, the findings implicitly suggest that these sectors tend to react strongest to changes in labour market flexibility, tax regimes and population ageing. The effect from improving the effectiveness of governments, by contrast, seems to be of great importance for all sectors. Finally, product market regulation does not seem

to matter for TFP growth, irrespective of the growth rate of the leading economy.

Applying the findings of the panel regressions conducted for up to 20 economies to the euro area economies allows for the following tentative conclusions:

- The TFP divergence between euro area catching-up economies relative to the rest of the euro area in the decade preceding the global financial and economic crisis can be partly explained by the following indicators: a weakening of the convergence channel, lower spending on innovation activities such as R&D and ICT, deteriorating government effectiveness and faster population ageing.

- Looking forward, policy measures that foster innovation activities, reduce the restrictiveness of employment protection legislation, lower corporate tax rates and improve government effectiveness could help promote TFP growth in the euro area catching-up economies.
- It is worth stressing that, according to the regression results, employment protection legislation has not contributed to the TFP divergence process, since euro area catching-up economies did not fall behind the rest of the euro area in this respect between 1994 and 2007. Similarly, corporate tax policy does not seem to have been a source of divergence over that period. Nevertheless, the regression results also indicate that policy action in those two areas could improve TFP growth in the catching-up countries as well as in the rest of the euro area.

### I.5. Conclusions

The TFP income convergence process in the euro area weakened in the decade preceding the economic and financial crisis, mainly due to weak TFP growth in catching-up economies. In fact, the gap between euro area catching-up economies and technological leaders actually widened in a broad range of sectors.

The persistence of the technology gap since the mid-1990s suggests that the causes are deep-rooted and at least partly structural. The econometric analysis presented in this focus section shows that the TFP divergence between euro area catching-up economies and the rest of the euro area can be partly explained by the following indicators: a weakening of the convergence channel, lower spending on innovation activities such as R&D and ICT, deteriorating government effectiveness and faster population ageing.

In response to the crisis, catching-up countries have put in place a broad range of reforms aimed at improving framework conditions, labour market flexibility and the efficiency of the business environment. These are likely to raise TFP growth rates in the years to come.

However, since catching-up is shown to be more difficult for economies approaching the technological frontier, the adoption of further structural measures would also help more advanced countries accelerate their TFP convergence. In particular, measures that foster innovation activities, reduce further the restrictiveness of employment protection legislation, lower corporate tax rates and improve government effectiveness appear to be the most effective at promoting TFP growth.