III. Determinants of trend TFP growth and key policies that influence it

The decline in productivity growth in the euro area, as well as in the EU overall, and the slow-down in catching-up with US productivity levels in the last decade has been spurring policy debates on how to re-launch total factor productivity (TFP) growth. The efficiency in the use of inputs in production and technological progress — as captured by TFP — is seen ultimately as the only source of long-term growth. To better understand the underlying causes of these dynamics, we empirically test for catching-up and spill-overs with the US and explore potential determinants of trend TFP growth using an error-correction model. While we do not find evidence for catching-up (or convergence in TFP levels) of euro area countries with the US, we find evidence for (upward or downward) convergence in TFP growth rates (a result that holds for other groupings of EU Member States too). Convergence in growth rates can be explained by spill-overs stemming, for instance, from technological adoption or imitation and also by the global impact of the economic crisis. Spill-over effects with the US are found to be strong. The quality of education, business investment in intangible capital, public R&D expenditure, trade openness and policies fostering job transitions and self-employment are found to be positively associated with trend TFP growth. On the contrary, an ageing workforce is found to be negatively associated with it. While this analysis does not provide the answer to the widely discussed 'productivity puzzle', it sheds some light on factors that could play a role in determining the long-run dynamics of TFP growth in the euro area and beyond (69).

III.1. Introduction

Alongside capital and labour components, total factor productivity (TFP) is a driver of potential growth. The efficiency in the use of inputs in production and technological progress, as captured by TFP, is seen as ultimately the only source of long-term growth, especially in the context of an ageing population as is the case in European societies.

The decline in productivity growth in the euro area, as well as the EU, and the slow-down in catching-up with the US in the last decade have been spurring policy debates on how to re-launch TFP growth. According to the ECB (70), the contribution of TFP to potential growth has halved in the euro area in the period before the financial crisis, from around 1 % in 2000 to ½% in 2007.

In this section the focus will be specifically on structural determinants of TFP growth, i.e. on trend TFP growth (obtained by cleaning TFP growth of its cyclical component using a time series filter) (71). The work presented here builds on previous work done by the European Commission, Directorate General for Economic and Financial Affairs and the Output Gap Working Group, tackling some of the issues raised in that context:

Firstly, a model is investigated in which convergence in the long run to US TFP growth, rather than to the level, is tested.

Secondly, updated education indicators are used, including the PISA score (72), which it could be argued is a more accurate measure of skills than the number of years spent at school -that can vary largely in quality.

Finally, the issue of non-homogeneity of the convergence terms is addressed by using a Pooled Mean Group (PMG) estimator, which allows for heterogeneity in the speed of convergence. Results do not point to convergence in TFP levels in the euro area, but provide some evidence of convergence in TFP growth rates. The same is true for other groupings of EU Member States and convergence seems to be strongest in the EU's new Member States (NMS).

(69) This section was prepared by Anna Thum-Thysen and Rafal Raciborski. The authors wish to thank Werner Roeger, Eric Ruscher, Emmanuelle Maincent, Josefina Monteagudo, Phillip Mohl, Erik Canton, Gaetano d'Adamo and Karel Havik for their very useful comments.

(70) ECB (2011), 'Trends in potential output', ECB Monthly Bulletin January 2011.

(71) A multivariate Kalman filter is used to obtain parameter estimates of an unobserved components model. Capacity utilisation is used to model the cyclical component of TFP.

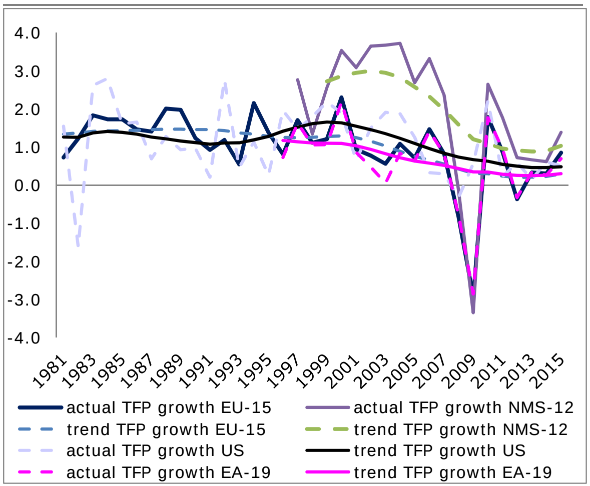
(72) PISA refers to the OECD's Programme for International Student Assessment (http://www.orec.org/pisa/).

The remainder of this section is structured as follows. Sub-section IV.2 discusses developments in trend TFP in the EU and across euro area countries. Sub-section IV.3 provides an overview of the literature on structural determinants of TFP. Sub-section IV.4 presents the empirical analysis and sub-section IV.5 concludes.

III.2. Trend TFP in the EU and across euro area countries

The differences between actual and trend TFP growth in the euro area, the EU-15, the EU's new Member States (NMS-12) and the US respectively are shown in Graph IV.1. While actual TFP growth declined dramatically with the economic and financial crisis, trend TFP growth, by construction, declines smoothly with a tendency to start picking up again around the most recent years, as cyclical spikes are smoothed out.

Graph III.1: **TFP growth and trend TFP growth [EA-19, EU-15, NMS-12 and US]**



Source: Commission services

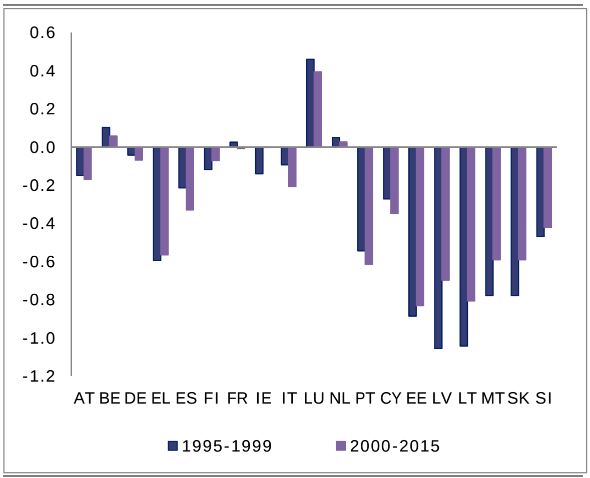
In the 1980s trend TFP growth rates for the EU-15 had stabilised around 1.5 % (after a period of high TFP growth in the 1960s and 1970s related to catching-up with the US). While a growth rate of 1.5 % would be considered healthy in the current environment, it implied that the catching-up process with the US had stalled. In the 1990s the US TFP trend growth rate temporarily rebounded, following the IT revolution, while in the EU-15 it continued to decline, falling for the first time to a level below US productivity growth.

In the 2000s trend TFP growth rates in the euro area, the EU-15 and the US kept falling dramatically, while the gap relative to the US persisted. In the NMS we observed high growth rates of around 3 % up to 2003 when trend TFP growth also started declining dramatically. Recently, however, we have been observing a recovery in terms of trend TFP growth in the euro area and the EU, as well as in the US.

Looking more closely at developments in euro area countries vis-à-vis the US, Graphs IV.2 and IV.3 depict the gaps in terms of trend TFP levels and growth rates for the period 1995-2015 (73). The time interval is split around 2000 as the approximate starting point for the dramatic decline in trend TFP growth rates.

In terms of trend TFP levels (74) (see Graph IV.2), most euro area countries lie below the US with the exception of Belgium, Luxembourg and the Netherlands, but the gap has shrunk for all these countries since 2000. In terms of growth rates (see Graph IV.3), most euro area countries (among those not belonging to the NMS) display trend TFP growth rates that are lower than the US rate (except for Ireland and also before 2000 Greece and Finland). On the other hand most NMS among the euro area countries display a positive gap in trend TFP growth compared to the US (with the exception of Cyprus).

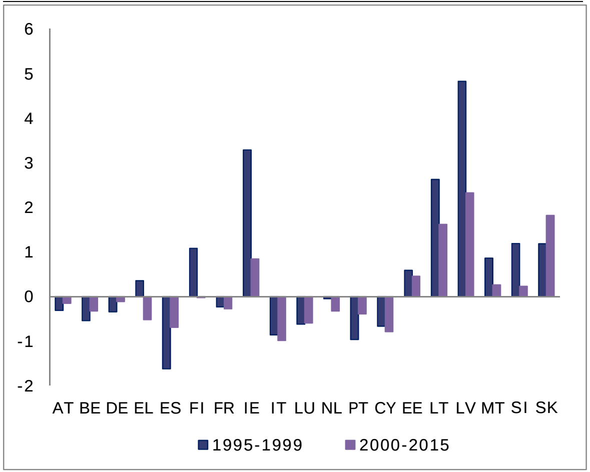
Graph III.2: **Gap in trend TFP levels vis-à-vis the US[EA-19]; log differences**



Source: Commission services

(73) For the NMS data is only available since 1995.
(74) The TFP trend is computed on the basis of data in national currencies. To be able to compare the data in levels in Graphs 2 and 3 we computed actual TFP in euros and corrected for the TFP gap (which is equal in euros and national currencies).

Graph III.3: **Gap in trend TFP growth vis-à-vis the US [EA-19]; percentage points**



Source: Commission services

III.3. Review of the determinants of TFP

The reasons for the disappointing performance in (trend) TFP growth are unclear. Various possible explanations have been proposed in the literature. They include:

- a reduced ability of some advanced economies to benefit from technological advances, i.e. problems in technological diffusion (75);
- the fact that technological innovation may have become marginally less important because innovation (in particular ICT-related) is characterised by diminishing returns (76);
- a declining efficiency in combining factors of production (77);
- the misallocation of resources (especially capital) which are somehow not being allocated to the most productive sectors, thus impeding productivity growth;
- the fact that developed economies are returning back to 'normal' and that the recent subdued pace of productivity growth might be merely the return to more normal rates of growth, following extraordinary gains from the information technology revolution (78);
- measurement errors or data problems and conceptual issues, e.g. with regard to capturing intangible assets (especially in light of the emerging knowledge-economy).

This contribution concentrates on the *structural* developments in TFP growth and explores its potential long-run determinants with a view to understanding which key policies may influence it. As summarised by the EIB (79), there appears to be an extensive list of potential structural determinants, which include: (i) educational attainments (quality and quantity); (ii) lifelong learning and ICT skills; (iii) ageing; (iv) product market reforms (particularly in the services sector) and reforms of employment protection legislation; (v) public and private R&D (coupled with liberalising elements of the patent system); (vi) ICT and broadband investment; and (vii) competitiveness and trade openness.

Many papers test the macro-empirical link between TFP (growth) and these determinants using panel data on a range of OECD or EU countries (80). In the remainder of this section we discuss studies looking at a range of different factors, then focus on findings related to the key areas and briefly discuss some additional potential factors of interest.

(75) OECD (2016), 'Technological slowdown, technological divergence and public policy: A firm level perspective', ECO/CPE/WP1(2016)26.
(76) Gordon, R. J. (2015), 'Secular Stagnation on the Supply Side: US Producivity Growth in the Long Run', *Communications & Strategies*, 1(100), 19-45.
(77) Cardarelli, M. R., and L. Lusinyan (2015), 'US Total Factor Productivity Slowdown: Evidence from the US States', International Monetary Fund Working Paper No 15-116.
(78) Fernald, J. G. (2015), 'Productivity and Potential Output before, during, and after the Great Recession', *NBER Macroeconomics Annual*, 29(1), 1-51.
(79) European Investment Bank (2011), 'Productivity and growth in Europe: Long-term trends, current challenges and the role of economic dynamism', *EIB Papers* 16(1).
(80) There is also a number of studies focusing: (1) on particular countries (Calligaris, S., Del Gatto, M., Hassan, F., Ottaviano, G., and F. Schivardi (2016), 'Italy's productivity conundrum', *European Economy Economic Discussion Paper* No. 030.; Hsieh, C., and P. Klenow (2009), 'Misallocation and manufacturing TFP in China and India', *Quarterly Journal of Economics*, No. 124 (4), 1403-1448) or (2) firm data (Hall, B. (2011), 'Innovation and productivity', *Nordic Economic Policy Review* No. 2, p. 168-195; Mohnen, P., and B. Hall (2013), 'Innovation and productivity: an update', *European Business Review* No. 3(1), p. 47-65; Bartelsman, E., and Z. Wolf (2014),'Forecasting aggregate productivity using information from firm-level data', *The Review of Economics and Statistics* No. 96(4), 745-755).

III.3.1. Studies examining a range of different factors simultaneously

Systematic attempts to find the main determinants of TFP growth are rare ([81]). Some studies however test a range of different factors simultaneously.

McMorrow et al. ([82]) estimate a simple error-correction model with EUKLEMS sectoral panel data over 1980-2004 and find that ICT-intensive industries are more likely to catch-up. On the other hand human capital seems to be important for explaining differences across countries, and regulations seem to matter most for network sectors. Balta and Mohl ([83]) extend and update the analysis by McMorrow et al. using new EUKLEMS data up to 2007 and confirm that fostering R&D activities can promote TFP growth. Furthermore, they show that reforms to restrictive employment protection legislation, lowering corporate taxes as well as improving government effectiveness can foster productivity growth.

A very recent paper by Gehringer et al. ([84]) looks at a panel of 17 EU countries and 13 industries over the period 1995-2007 and confirms the key role of ICT and human capital. Dabla-Norris et al. ([85]) also confirm, based on a sectoral analysis, the important role of knowledge capital and innovation, a favourable business environment and the right policy mix.

III.3.2. Innovation and human capital

Schreyer ([86]) argues that ICT allows network externalities to come into play by offering a platform and thereby fostering productivity. Meanwhile O'Mahony and Van Ark and Van Ark et al. ([87]) show empirically that ICT has a positive and significant effect on productivity and argue that the US versus EU productivity gap is mainly due to differences in ICT performance. Uppenberg and Strauss ([88]) discuss the link between innovation and productivity growth in the EU services sectors and identify three main determinants: (i) tangible fixed investment, (ii) intangible investment and (iii) exchange of technological know-how.

The role of R&D is not clear-cut and transmission channels are complex ([89]). R&D can, for instance, lead to improved production processes, new goods or higher quality of output, with possibly little or no impact on traditional measures of productivity. Nevertheless, many empirical studies show that business R&D has a positive effect on TFP, with coefficients ranging from 10-30 per cent ([90]). Meanwhile Adams ([91]) finds that public R&D has a positive effect on productivity. Intangible capital (as a broader measure of innovative assets, going beyond R&D and software products) is also found to have a positive link with multi-factor productivity growth ([92]).

In line with theoretical considerations stemming from endogenous growth models ([93]), human capital has been found to have a positive effect on TFP. ([94]) For instance, Prichett ([95]) finds a negative

([81]) Danquah, M., Moral-Benito, E., and B. Ouattara (2014), 'TFP growth and its determinants: a model averaging approach', *Empirical Economics* No. 47, 227-251.

([82]) McMorrow, K., Roeger, 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, 165-180.

([83]) Balta, N., and P. Mohl (2015), 'The drivers of total factor productivity in catching-up economies', *Quarterly Report on the Euro Area*, Vol. 13, No 1, 7-19.

([84]) Gehringer, A., Martinez-Zarzoso, I., and F. Nowak-Lehmann Danziger (2016), 'What are the drivers of total factor productivity in the European Union', *Economics of Innovation and New Technology* Vol. 25, No. 4, 406-434.

([85]) Dabla-Norris, E., Guo, S., Haksar, V., Kim, M., Kochhar, K., Wiseman, K., and A. Zdzienicka (2015), 'The New Normal: A Sector-Level Perspective on Productivity Trends in Advanced Economies', *IMF Staff Discussion Note* 15/03.

([86]) Schreyer, P. (2000), 'The contribution of information and communication technology to output growth', OECD Publishing.

([87]) O'Mahony, M., and B. Van Ark (2003), 'EU Productivity and Competitiveness: An Industry Perspective. Can Europe Resume the Catching Up Process?', Luxembourg: European Commission/Enterprise Publication; Van Ark, B., O'Mahony, M., and M. P. Timmer (2008), 'The Productivity Gap between Europe and the United States: Trends and Causes', *Journal of Economic Perspectives* 22 (1), 25-44.

([88]) Uppenberg, K., and H. Strauss (2010), 'Innovation and productivity growth in the EU services sector' Luxembourg: European Investment Bank.

([89]) Gehringer et al. (2016); Guellec, D., and B. van Pottelsberghe de la Potterie (2001), 'R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries', *OECD Economic Studies* No. 33.

([90]) Guellec et al. (2001).

([91]) Adams, J. (1990), 'Fundamental stocks of knowledge and productivity growth', *Journal of Political Economy* No. 98(4), p. 673-702.

([92]) Corrado, C., Haskel, J., and C. Iona-Lasinio (2013), 'Knowledge spillovers, ICT and productivity growth', available from www.intan-invest.net; Van Ark, B., Hao, J.X., Corrado, C., and C. Hulten (2009), 'Measuring Intangible Capital and Its Contribution to Economic Growth in Europe', *EIB Papers* No. 14 (1), 63-93.

([93]) Romer, P. (1990), 'Endogenous technological change', *Journal of Political Economy* Vol. 98, No5, S71-S102; Jones C. (2005), 'Growth and Ideas', in P. Aghion and S. Durlauf (eds.) Handbook of Economic Growth (Elsevier, 2005) Volume 1B, 1063-1111; Jones, C., and P. Romer (2010), 'The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital', *American Economic Journal: Macroeconomics*. Vol. 2, No. 1.

([94]) Barro, R., and J. Lee. (2001), 'International Data on Educational Attainment: Updates and Implications', *Oxford Economic Papers* 53, 541-563; Sianesi, B., and J. van Reenen. (2003), 'The Returns to effect, which he explains by highlighting a possible decrease in returns to education unfavourable governance structures and decreasing quality in education.

The link between economic performance and human capital measures (going beyond years of schooling or educational attainments and taking into account the quality of education) has attracted a lot of attention. Earlier research, for instance, looked at the effect of test scores, which would reflect the quality of entrants into the work force, on productivity ([96]). This research found that US workers would have been 2.9 per cent more productive if test scores had not declined after 1967. Hanushek and Kimko and Hanushek and Woessmann ([97]) confirm the importance of the quality of education for economic outcomes, implying also a considerable role for TFP. Balart, Oosterveen and Webbink ([98]) go a step further and argue that both cognitive and non-cognitive skills matter for economic growth.

McGowan and Andrews ([99]) examine the role of yet another measure of education, namely that of skill mismatch based on the OECD's adult cognitive skills database ([100]), and examine the role on firm-level labour productivity. They find that skill mismatch is likely to affect productivity through resources being allocated less efficiently. The authors indicate that managerial quality, reforms to restrictive product and labour market regulations and improving bankruptcy legislation can affect this link. Research is nonetheless still scarce on the effect of skill mismatch on productivity in developed countries ([101]).

III.3.3. Regulatory framework conditions and institutional quality

Theoretical work on the regulatory framework's role in driving productivity suggests an inverted U-shaped relationship, implying there is an intermediate optimum in the level of regulation ([102]). One way in which regulation can impact productivity is through its effect on resource re-allocation. For example, as some authors argue ([103]), the abundant credit in some euro area countries in the first 10 years of EMU, together with restrictive product and labour market regulations, might have fostered unfavourable resource allocation that may have reduced TFP levels.

Nicoletti and Scarpetta ([104]) examine this relationship empirically and indicate that competition-enhancing reforms, in particular privatisation and entry liberalisation, are likely to foster productivity. Based on sectoral OECD data, the authors estimate growth regressions to test the relationship between regulation and productivity, controlling for human capital. Indeed, entry liberalisation may have a big impact on productivity through increasing competition. Canton ([105]) empirically confirms this theoretical link, already established in Schumpeterian growth models. Based on macro data for 2002-12, the author shows that firm birth rates are positively and significantly linked with TFP growth. Extending his analysis to firm exit rates, he finds that

Education: Macroeconomics', *Journal of Economic Surveys* 17, 157-200; Benhabib J, and M Spiegel (1994), 'The role of human capital in economic development: evidence from aggregate cross-country data', *Journal of Monetary Economics* No. 34, 143-174; Vandenbussche J., Aghion P., and C. Meghir (2006), 'Growth, distance to frontier and composition of human capital', *Journal of Economic Growth* No. 11, 97-127.

([95]) Prichett, L. (2001), 'Where Has All the Education Gone?', *World Bank Economic Review* 15, 367-391.

([96]) Bishop, J. (1989), 'Is the test score decline responsible for the productivity growth decline?', *American Economic Review* 79 No. (1), 178-197.

([97]) Hanushek, E. A., and D. D. Kimko (2000), 'Schooling, labor-force quality, and the growth of nations', *American Economic Review* 90(5), 1184-1208; Hanushek, E. A., and L.Woessmann (2008), 'The role of cognitive skills in economic development', *Journal of Economic Literature*, 607-668; Hanushek, E., Link S., and L. Woessmann (2012), 'Does school autonomy make sense everywhere? Panel estimates from PISA', *Journal of Development Economics* No. 104, 212-232.

([98]) Balart, P., Oosterveen, M., and H. Webbink (2015), 'Test Scores, Noncognitive Skills and Economic Growth', *IZA Discussion Paper* No. 9559.

([99]) McGowan, M., and D. Andrews (2015), 'Labour Market Mismatch and Labour Productivity', *OECD Economics Department Working Paper* 1209.

([100]) Programme for the International Assessment of Adult Competencies (PIAAC) (http://www.oecd.org/skills/piaac).

([101]) Mahy, B., Rycx, F., and G. Vermeylen (2013), 'Educational Mismatch and Firm Productivity: Do Skills, Technology and Uncertainty Matter?', *IZA Discussion Paper* No. 8885; Kampelmann, S. and F. Rycx (2012), 'The impact of educational mismatch on firm productivity: Evidence from linked panel data', *Economics of Education Review* No. 31, 918– 931.

([102]) Aghion, P., and P. Howitt (2009), 'The Economics of Growth'. MIT Press.

([103]) Cette, G., Fernald, J., and B. Mojon (2016), 'The pre-Great Recession slowdown in productivity', *European Economic Review* 88, 3-20; Díaz, A., and L. Franjo (2016), 'Capital goods, measured TFP and growth: The case of Spain', *European Economic Review* 83, 19-39; Reis, R. (2013), 'The Portuguese slump and crash and the Euro crisis', *Brookings Papers on Economic Activity*,46, 143-193.

([104]) Nicoletti, G., and S. Scarpetta (2003), 'Regulation, productivity and growth: OECD evidence', *OECD Economics Department Working Paper* No. 347.

([105]) Canton, E. (2016), 'Drivers of TFP growth in the EU: The role of firm entry and exit', *Quarterly Report on the Euro Area* Vol. 14 (3).

facilitating firms' exit from the market can be of importance in high-productivity countries.

Bouis and Duval ([106]) confirm the key role of the regulatory framework based on pooled mean group estimates of growth regressions. The authors find that regulatory barriers to entrepreneurship, barriers to trade as well as patent rights protection are robust determinants of the productivity level. After noting that there is a large range of estimated parameters concerning the effect regulations have on productivity, Egert and Gal ([107]) also examine the role of regulations for boosting productivity based on dynamic ordinary least squares estimation. They find there are positive effects from product markets deregulation. Bourles et al. ([108]) disaggregate the effect of regulations on productivity and find that strict regulations in upstream sectors have hampered TFP growth over the last 15 years.

Regulations are often linked to the degree of competition. Based on firm-level data for Belgium and the Netherlands, Dobbelaere and Vercauteren ([109]) find that different competition regimes on the product and labour markets (perfect or imperfect competition on the product market and different bargaining schemes on the labour market) affect TFP. The authors find that labour market regimes seem to be more decisive in shaping TFP distributions than product market regimes. They also find that TFP distributions vary with the type and level of product and labour market regulations. Literature ([110]) on the impact of employment protection legislation confirms that overly strict regulations can affect productivity for instance by reducing job flows, employment of outsiders and by encouraging labour market duality.

Fiscal policies also seem to play an important role for productivity, as shown by Everaert et al. ([111]). Budget deficits are found to be detrimental to TFP, whereas productive expenditures and corporate tax reduction have a positive effect on productivity. Finally, in terms of government effectiveness, Challe et al. ([112]) argue that cheap external capital undermines incentives to maintain good institutions. This in turn results in a high share of inefficient projects and therefore lowers average productivity.

III.3.4. Trade and globalisation

As underlined also by the OECD, ([113]) openness appears to be favourable to the adoption of new technologies, thereby fostering productivity growth ([114]). Gerlinger et al. ([115]) summarise the potential transmission channels of trade openness and foreign direct investment (FDI) noted by Griffith et al. ([116]) Firm entry can increase the pressure to innovate and, on the other hand, FDI can go hand-in-hand with a technology transfer. The authors also add a novel dimension, which they term 'rationalisation'. This refers to pressures arising from globalisation and European integration to reduce factor costs. They measure this concept by factoring cost savings over time and find a significant relationship with TFP, based on dynamic OLS estimation on EUKLEMS data. Anyway this method does not allow the explicit measuring of catching-up and spill-overs.

III.3.5. Ageing and other factors

There has been an increasing interest in the relationship between ageing and TFP, in particular

([106]) Bouis, R., Duval, R., and F. Murtin (2011), 'The Policy and Institutional Drivers of Economic Growth Across OECD and Non-OECD Economies: New Evidence from Growth Regressions', *OECD Economics Department Working Paper* No. 843.

([107]) Egert, B., and P. Gal (2017): The Quantification of Structural Reforms in OECD Countries: A New Framework. *CESifo Working Paper No. 6420*, March 2017.

([108]) Bourlès, R., Cette, G., Lopez, J., Mairesse J., and G. Nicoletti (2013), 'Do Product Market Regulations in Upstream Sectors Curb Productivity Growth? Panel Data Evidence for OECD Countries', *The Review of Economics and Statistics* 95(5), 1750-1768.

([109]) Dobbelaere, S., and M. Vandercauteren (2014), 'Market imperfections, skills and total factor productivity: firm-level evidence on Belgium and the Netherlands', *National Bank of Belgium Working Paper* No. 267.

([110]) Martin, J.P., and S. Scarpetta (2012), 'Setting it right: employment protection, labour reallocation and productivity', De Economist, Vol. 160, 89-116.

([111]) Everaert, G., Heylen, F., and R. Schoonackers (2015), 'Fiscal policy and TFP in the OECD: measuring direct and indirect effects', *Empirical Economics*, No. 49(2), 605-640.

([112]) Challe, E., Lopez, J., and E. Mengus (2015), 'Southern Europe's institutional decline' *HEC Paris Research Paper* ECO/SCD-2016-1148.

([113]) OECD (2012), 'Long-term growth scenarios', Working Party No. 1 on Macroeconomic and Structural Policy Analysis, ECO/CPE/WP1(2012)5.

([114]) See also Coe, D. T., and E. Helpman (1995), 'International R&D Spillovers', *European Economic Review* 39, 859-887; Coe, D.,. Helpman, E., and A.Hoffmaister (1997), 'North-South spillovers', *Economic Journal* No. 107, 134-149; Alcalá, F., and A. Ciccone (2004), 'Trade and Productivity', *Quarterly Journal of Economics* No. 119, 613-646; Buera, F., and E. Oberfeld (2016), 'The global diffusion of ideas and its impact on productivity and growth', VOX, CEPRs Policy Portal, 12 June.

([115]) Gehringer et al. (2016).

([116]) Griffith, R., Redding, S., and H. Simpson (2003), 'Productivity Convergence and Foreign Ownership at the Establishment Level', *Discussion Paper* No. 57, London: Centre for Economic Performance.

as TFP is seen as the main source of growth in times of a decreasing working age population across Europe. This relationship can be affected by differences in health status and adaptability to new technologies across age-groups. Based on demographic projections, Aiyar et al. (117), for instance, find that TFP growth in the euro area would decrease by 0.2 percentage points per year over the next 20 years. Policies found to mitigate this effect include (i) training through active labour market programs, (ii) increased access to health services, (iii) fiscal reforms to lower tax wedges and (iv) public R&D spending to foster innovation, which in turn can help the adaptation to change in the global environment.

Based on a panel VAR model for 21 OECD countries and a theoretical model, Aksoy et al. confirm that a decrease in the share of young workers leads to lower innovation and productivity in the long-run. For instance middle-aged workers between the ages of 40-49 appear to have the most positive affect on patent applications. Ariu and Vandenberghe (118) confirm these findings in the case of Belgium. They find that ageing may account for a loss of 4.5 percentage points in TFP growth from 1991-2013. They also predict this number to increase to 7 percentage points for the period up to 2020. These more recent findings confirm earlier findings by Feyrer (119), who detected a robust relationship between demographics and productivity. Creativity (which is linked to innovation) can also be affected by age (see for instance Acemoglu, Akcigit, and Celik (120) who in particular studied the case of CEO's).

Other factors of potential interest to explain TFP developments include: (i) managerial practices (Bloom et al. (121) find that managerial practices account for half of the TFP gap between the US and other countries); (ii) trust (122); (iii) investment (123); (iv) entrepreneurship (124); and (v) state aid (125).

III.4. Empirical analysis

In this section we empirically analyse a set of potential determinants of trend TFP growth. We first assess a restricted specification consisting of fixed effects, a spill-over term and a variable measuring the TFP gap vis-à-vis the US. We then proceed to analysing the model including also a set of potential determinants (Box V.1 describes the methodology used in more detail).

III.4.1. Baseline model

In Table IV.1 we show results for the baseline specification described by equation (1) in Box IV.1 including only catching-up and spill-over effects concerning the US. Results show that TFP levels do not seem to converge in the euro area. The comparison with other groups of EU Member States shows that there is no evidence for convergence in TFP levels in the EU-28, nor in the EU-15. There is some evidence of convergence in TFP levels for the NMS-13 though. However, given the stark differences in trend TFP levels vis-à-vis the US across NMS-13 countries, we believe it is premature to draw strong conclusions on convergence for these countries. All groupings of EU countries, on the other hand, seem to be well placed to capture spill-over effects from the US.

(117) Aiyar, S., Ebeke, C., and X. Shiao (forthcoming), 'The impact of workforce ageing on Euro area productivity', Euro Area Policies, International Monetary Fund.

(118) Ariu, A., and V. Vandenberghe (2014), 'Assessing the role of ageing, feminising and better-educated workforces on TFP growth' *National Bank of Belgium Working Paper* No. 265.

(119) Feyrer, J. (2007), 'Demographics and Productivity', *The Review of Economics and Statistics* No. 89(1), 100-109; Feyrer, J. (2008), 'Aggregate Evidence on the Link between Age Structure and Productivity', *Population and Development Review* No. 34, 78-99.

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Box III.1: Empirical assessment of TFP drivers

The empirical model and its estimation

TFP growth and its evolution are modelled by an Error-Correction-Model (ECM). The ECM captures a set of assumptions about the dynamics of TFP growth. In the long-run we expect convergence in productivity across countries to what can be described as the technological frontier, typically represented by a country considered as a forerunner in terms of technological progress. Taking into account contributions from, for instance, Nicoletti and Scarpetta ([1]) and Domenech and de la Fuente ([2]) we consider this benchmark country to be the USA. Convergence can occur through different channels such as imitation (Aghion and Howitt([3])) or innovation. This long-run convergence in TFP is typically expected to be conditional in the sense that differences in structural factors with the frontier country can still persist. In the short-run TFP is driven by a catching-up process (making it converge faster if it is relatively far from the frontier (or best-performimg) country) and potentially some additional short-term dynamics (for example due to direct spill-over effects from the frontier country).

The standard ECM typically takes the following form:

$$\Delta(TFP^{TR})_{it} = c + \alpha_i + \beta_0[TFP^{TR}_{it-1} - TFP^{TR}_{Lt-1} - \alpha_i] + \beta_1\Delta(TFP^{TR})_{Lt} + \varepsilon_{it} \quad (1)$$

where

- $\Delta(TFP^{TR})_{it}$ denotes trend TFP growth in country i in time t;
- $\Delta(TFP^{TR})_{Lt}$ denotes trend TFP growth in the leader country L in time t;
- TFP^{TR}_{it-1} denotes the logarithm of TFP levels in country i;
- TFP^{TR}_{Lt-1} denotes the logarithm of TFP levels in the leader country L;
- c and α_i denote respectively a constant term and a country fixed effect which captures time-invariant differences across countries;
- $\beta_0, \beta_1, \beta_2, \beta_3$ denote coefficents on the respective explanatory variables;
- the crucial term, $[TFP^{TR}_{it-1} - TFP^{TR}_{Lt-1} - \alpha_i]$, ([4]) indicates the difference between productivity in country i and at the frontier, conditional on the fixed effect α_i;
- $\Delta(TFP^{TR})_{Lt}$ indicates the impact of spill-overs from the leading economy.

For convergence and catching-up to be confirmed by the data (and for the crucial co-integration assumption to hold) β_0 must be negative, indicating that if national TFP is below the US level, TFP must grow faster.

However, the data seems to suggest that the standard catching-up model in TFP levels may not hold and that instead there is some evidence of co-integration in terms of growth rates. Stationarity and co-integration pre-tests for the ECM model as well as visual inspection of the data strengthen this conclusion. An alternative to the model described by equation (1) is a model expressed in differences (see equation (2)), which would capture the assumption that TFP growth rates, not levels, are converging in the long-run. As we are interested in the relationship between structural indicators and TFP growth we add the former to the model denoted by SI_{it-1}. For the estimation of the model we choose the Pooled Mean Group estimator (PMG; see Pesaran, Shin, and Smith (1999) ([5])), which — under the condition of co-integration — addresses

([1]) Nicoletti, G. and S. Scarpetta (2003), 'Regulation, productivity and growth: OECD evidence', OECD Economics Department Working Papers, No. 347, OECD Publishing.
([2]) Domenech, R. and A. De la Fuente, (2006), 'Human capital in growth regressions: how much difference does data quality make?', Journal of the European Economic Association, No. 4(1).
([3]) Aghion, P. and P. Howitt (2009), The Economics of Growth, MIT Press.
([4]) Note that this term denotes a lagged dependent variable (as the dependent variable can be written as a function of levels) and may entail the well-known econometric problem of endogeneity in form of the lagged dependent variable bias. It is challenging to find an econometric method that addresses both non-stationarity and endogeneity. However, in the presence of co-integration (for which some evidence is given if β_0 is significantly negative), error terms are stationary and parameter estimates are super-consistent, which means that the parameter estimate converges to its theoretical value and even faster than if the series were stationary (see Sims 2013 'Graduate Macro II', https://www3.nd.edu/~esims1/time_series_notes_sp13.pdf).
([5]) Pesaran, M., Y. Shin and R. P. Smith (2004), 'Pooled mean group estimation of dynamic heterogeneous panels,' ESE Discussion Papers 16, Edinburgh School of Economics, University of Edinburgh.

(Continued on the next page)

Box (continued)

non-stationarity and at the same time allows for heterogeneity in convergence speed. The model takes the following form (6):

$$\Delta^2(TFP^{TR})_{it} = c + \beta_{0i}[\Delta(TFP^{TR}_{it-1}) - \Delta(TFP^{TR}_{Lt-1}) - \alpha_i - \beta_2(SI_{it-1} - SI_{Lt-1})] + \beta_{1i}\Delta^2(TFP^{TR})_{Lt} + \varepsilon_{it} \quad (2)$$

Note that the structural variables enter our model in terms of their gap vis-à-vis the US as we believe that dynamics in structural indicators in EU member states with respect to the US can explain dynamics in TFP growth in EU member states with respect to the US. A positive coefficient would indicate that — on average across EU member states — the structural indicator SI_{it} is positively correlated with TFP growth. It would also indicate that upward (downward) convergence or divergence with the US in terms of the structural indicator implies upward (downward) convergence or divergence with the US in terms of TFP growth. Note that due to the importance of parsimony in our model (i.e. relatively short series as well as the presence of multicollinearity) it is not possible to capture both, short- and long-run effects of the structural variables. Structural variables should have long-run effects while their short-run effects are more debatable. For this reason we only model the long-run effects of structural variables. Even if there are short-run effects, their omission decreases the efficiency of the estimates, but does not bias them (note that the omission of a valid long-run effect would generally lead to a biased estimate).

The data

Trend TFP data is computed as the trend Solow Residual based on the production function methodology (see Havik et al 2014) and on AMECO data combined with ECFIN's Spring 2016 Forecast. It is available for the 28 EU Member States. Data for the EU-15 Member States is available from 1965-2017 and for the new Member States from 1995-2017. To match TFP data availability with the availability of the structural variables we cut the TFP sample to the period 1980-2014. The size of the dataset used for the respective regression results reported below varies depending on the availability of the explanatory variables we include.

The explanatory variables stem from various sources including OECD databases, the Labour Force Survey (LFS), the INTAN-INVEST project, Eurostat etc. Note that some of the data was interpolated in some cases or in some rare cases flatly extrapolated. More specifically,

- our measure of human capital is based on the quality of skills (OECD PISA (maths) scores; available 2000-2012);
- our measures of regulations include the OECD's Product Market Regulation (PMR) index (taken from the OECD; sub-indicators cover barriers to entrepreneurship, state control and barriers to trade and investment; available 1998-2013 (7)) and the OECD's Employment Protection Legislation (EPL) index (it consists of 8 indicators based on sub-indicators; available 1985-2015 (8));
- innovation is measured as business sector intangible capital (taken from the INTAN-invest database (9) and measured as investment in intangibles over Gross Value Added (GVA); data available for the business sector excluding dwellings and for 15 countries 1995-2013);
- public R&D spending (taken from Eurostat and measured as a percentage of GDP; available 1995-2014).
- for measuring trade openness we regress per country the sum of exports and imports on GDP and use the predicted error term for our analysis (data is taken from AMECO and is available for 1960-2017;
- ageing is measured by the share of older workers, i.e. the percentage of employed aged 55+ in the labour force aged 15-64 (taken from AMECO and available for 1981-2014).

(6) See equation (8) in Blackburne and Frank (2007).
(7) The PMR index is not available for Bulgaria, Cyprus, Croatia, Lithuania, Latvia, Malta and Romania.
(8) The EPL index is not available for Bulgaria, Cyprus, Croatia, Estonia, Lithuania, Latvia, Luxemburg, Romania and Slovenia.
(9) http://www.intan-invest.net/

Turning to the results in growth rates (Table IV.2 based on equation (2) in Box IV.1) we can see that there is evidence of co-integration (i.e. convergence) in the euro area. This is also the case forcase for the other groupings of EU countries though this result seems to be stronger for the

NMS-13 countries ([126]), in line with a priori expectations. This result may stem from the fact that growth rates in the NMS, which are typically higher than in the US, declined as a result of the economic crisis, leading to downward convergence (see section IV.2).

Table III.1: **Pooled mean group estimation of error-correction equation (3); long-run relationship in levels**

	EA-19	EU-28	EU-15	NMS-13
catching-up US	0.00945	-0.0224	-0.00743	-0.0445**
	(0.0226)	(0.0216)	(0.0204)	(0.0189)
spill-over US	0.974**	1.299***	1.093**	3.029***
	(0.439)	(0.343)	(0.496)	(0.711)
Constant	-0.0655	0.161	0.0678	1.012**
	(0.138)	(0.139)	(0.200)	(0.425)
Countries	19	28	15	13
Years (maximum)	33	33	33	20
Observations	541	754	510	244

Source: Commission services

Table III.2: **Pooled mean group estimation of error-correction equation (3); long-run relationship in growth rates**

	EA-19	EU-28	EU-15	NMS-13
TFP growth gap US	-0.115***	-0.103***	-0.0336*	-0.137***
	(0.0398)	(0.0263)	(0.0194)	(0.0468)
spill-over US	1.041**	0.781*	0.836**	0.874
	(0.461)	(0.417)	(0.385)	(0.774)
Constant	-4.25e-05	-0.000441	-0.000132	-0.00201**
	(0.000525)	(0.000305)	(0.000234)	(0.000798)
Countries	19	28	15	13
Years (maximum)	33	33	33	20
Observations	522	726	495	231

Source: Commission services

III.4.2. Adding explanatory variables

In Table IV.3 results are shown for the specifications including selected explanatory variables added to the baseline model of TFP convergence in growth rates. While a series of variables were tested in line with the literature review in Section IV.3, only the variables with the most robust results for each of the groups of determinants identified in Section IV.3 are presented, namely innovation, human capital, regulation, trade and globalisation, and ageing. The variables are added separately for reasons of multi-collinearity. This may, however, create an omitted variable bias.

Column (1) is simply the baseline model for the full EU sample. Results in column (2) indicate that the quality of education — measured by PISA maths scores — is positively associated with TFP growth, i.e. catching-up in terms of PISA maths scores vis-à-vis the US is consistent with closing a negative gap in TFP growth relative to the US (or increasing a positive gap). Increasing PISA maths scores relative to the US by 1 % is associated with an increase in TFP growth relative to the US by about 0.05 %. This finding supports some previous results showing that education may matter in levels rather than in percentage change. For instance, based on a theoretical model by Nelson and Phelps ([127]), Benhabib and Spiegel ([128]) show that human capital levels matter for TFP growth as they ensure a sufficient technology absorption capacity.

Results in column (3) show that increasing investment in innovative assets, measured by intangible assets ([129]) (as a share of GVA), relative to the US, by 1 % is associated with an increase in TFP growth, again relative to the US, by 0.05 %. Similarly, increasing public R&D spending relative to the US is associated with increased TFP growth (see column (4)).

Ageing seems to be negatively associated with TFP growth, as indicated by results in column (5). Results for regulation are mixed. For employment protection legislation (EPL) we find a negative relationship with TFP growth (see column (6)), while for product market regulation (PMR) the relationship is not significant. The latter finding is in contrast with theoretical literature on this issue and also with findings by the IMF. ([130]) The insignificance of the coefficient on the OECD's PMR indicator may be related to the fact that this data is only available every five years. Indeed, when testing the World Bank's Doing Business indicators — which are available annually, though only from 2004 onwards — some of them, notably the ease of dealing with construction permits, are

([126]) Notice that when we harmonise the time range across EU-15 versus EU-NMS also in growth rates the convergence for the EU-15 vanishes, which reflects the fact that the growth rate in the US was on average higher in recent years.

([127]) Nelson, R. and E. Phelps (1966), 'Investment in humans, technological diffusion and economic growth', *American Economic Review* 56, p. 69-75.

([128]) Benhabib, J., and M. Spiegel (2005), 'Human capital and technology diffusion' in Aghion, P, and S. Durlauf (eds) Handbook of economic growth, vol 4. North Holland, Elsevier, Amsterdam.

([129]) Following a commonly used definition by Corrado, C., Hulten, C., and D. Sichel (2005), 'Measuring capital and technology: an expanded framework' in Corrado, C., Haltiwanger, J., and D. Sichel. (eds.), Measuring capital in the new economy, Studies in Income and Wealth, Vol. 64, Chicago: The University Press, intangible assets include investment in employer provided training, R&D, market development, and organisational and management efficiency.

([130]) IMF (2015), 'World Economic Outlook', April.

Table III.3: **Pooled mean group estimation of error-correction equation (3), adding structural variables, EU-28**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP growth (US gap) (log)	-0.103***	-0.176**	-0.0935***	-0.131***	-0.106***	-0.146**	-0.0782**
	(0.0263)	(0.0686)	(0.0274)	(0.0320)	(0.0269)	(0.0607)	(0.0316)
Spill-over US	0.781*	2.056**	1.137***	1.183**	1.188	0.904	0.897**
	(0.417)	(0.876)	(0.427)	(0.518)	(0.758)	(0.662)	(0.416)
Long-run relationship							
PISA score maths (US gap) (log)(1)		0.0465***					
		(0.00168)					
Business sector intangible investment (US gap) (log)			0.0455***				
			(0.00512)				
Public R&D (US gap) (log)				0.0129***			
				(0.00120)			
Share of workers aged 55+ (US gap) (log)					-0.0450***		
					(0.00444)		
Employment protection legislation (US gap) (log)(2)						-0.00721***	
						(0.00119)	
Trade openness (US gap) (log)							0.0102**
							(0.00475)
Constant	-0.000441	0.000395	0.00146	-0.00137***	-0.00119	0.00105*	-0.00596**
	(0.000305)	(0.000776)	(0.000933)	(0.000468)	(0.000731)	(0.000638)	(0.00251)
Countries	28	15	15	28	23	21	28
Maximum available years across countries	33	15	20	20	33	29	33
Observations	726	225	300	560	639	603	726

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1 (1) for PISA scores also the science categories is significant (2) strictness of regulation on the use of fixed term and temporary work agency contracts; the indicator of strictness on dismissals on regular contracts is also significant
Source: Commission services

significantly correlated with TFP growth. Our findings somewhat confirm those of Dobbelaere and Vandercauteren (2015) that labour market regimes are more important than product market regimes for TFP growth (see Section V.3).

Finally, trade openness seems to be an important determinant of TFP growth as column (7) indicates.

III.5. Conclusion

This section focused on the dynamics of trend TFP concerning the US and potential determinants of trend TFP growth, in particular human capital, innovation, regulation, openness and demographics. While this analysis does not provide the answer to the widely discussed productivity puzzle, it sheds some light on factors that could play a role in determining the long-run dynamics of TFP growth in the euro area and beyond.

Overall, we find evidence for convergence in growth rates while we do not find strong evidence for catching-up in levels with the US. Convergence in growth rates can be explained by spill-overs stemming, for instance, from technology adoption or imitation and also by the global impact of the economic crisis. This finding is true for the euro area but also for other groupings of EU Member States. In particular, convergence seems to be strongest for the EU Member States that joined more recently. This result may stem from the fact that growth rates in the latter countries declined as a result of the economic crisis, leading to downward convergence. We also find that spill-over effects with the US are strong in the euro area as well as across other groupings of EU Member States.

Structural factors seem to play a role in determining trend TFP growth rates. Educational quality (measured by PISA scores), investment in intangible capital, public R&D expenditure, policies enhancing job transitions and self-employment, and trade openness are estimated to have a positive impact on TFP growth, while an older workforce could tend to have overall negative effects.