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TRABAJO DE FIN DE GRADO

TÍTULO: *Why is productivity slowing down in the US and even further in the EU?*

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ABSTRACT

The purpose of this paper is to explain two stylized facts observed in the US and the EU data: (i) the slowdown in Total Factor Productivity (TFP) in both regions and (ii) the widening gap between the US and the EU Total Factor Productivity growth. We estimate two separate models and examine the long-run and short-run determinants of TFP growth for each region. We find that those variables which are closely related to technological changes brought about the Third Industrial Revolution play a crucial role in explaining TFP variability. The slowdown in high-technology patenting activity and the deceleration of ICT investment play a key role when explaining TFP dynamics and the gap between the US and the EU. However, we are not able to assert a decisive role of R&D expenditure and human capital when determining cross-country differences in TFP growth, since the effect of the variables related to the Third Industrial Revolution usually overwhelms that of the traditionally considered as typical determinants of TFP.

1. INTRODUTION

Total Factor Productivity (TFP) has been considered the crucial variable in economic growth models. It is usually defined as the efficiency with which the other production inputs (i.e.- labour and capital) are applied to the production process. In such a way, growth economists have shown the close relationship between TFP and income per capita growth[1] for developed countries, this factor accounting for most of the long-run change in output. In this way, the contribution of TFP to economic growth explains half of total growth in developed economies (OECD)[2]

The neo-classical growth model, as advocated by Solow (1956), conceives TFP mainly as technological change and innovation. This view has influenced most of authors after him[3] who have placed an extreme importance on changes in the parameter 'A' in the classical production function, which traditionally stands for technological change and innovation. Different paths for these parameter lead to differences in income and consumption per capita among countries, as well as on their growth rate. In this way, a new wave of technological change should bring about positive consequences on economic growth and TFP. In this context, the Third Industrial Revolution has played a key role in innovation during the last decades. It has been mainly characterized by the expansion of Information and Communication Technologies (ICT) and the development of high technology inventions such as nano and bio-technologies.

Nonetheless, the III Industrial Revolution and its innovations coincide with a period where TFP growth has actually faded. Table 1.1 reflects the TFP evolution for the US and the EU and the growing gap between both due to the higher deceleration of growth in the European Union since the 70s. The situation is cumbersome for the United States as well, as the growth rate of TFP during the last decade has slowed down dramatically (for the period 2004-2014). This TFP gap has excised its influence on the turndown of GDP per capita, which is a growing concern among Western institutions.

[1] Christenson, Cummings and Jorgenson (1980) demonstrate this for OECD economies before the productivity slowdown. Dougherty (1991) proves it including the turndown period.
[2] see Easterly, W. and Levine, R. (2001)
[3] see Aghion, P. and Howitt, P. (1998), Grossman, G. and Helpman, E. (1991)

Table 1.1. Average TFP growth

	1975-1984	1985-1994	1995-2004	2005-2014
US	0.9%	1.0%	1.3%	0.4%
EU	1.2%	1.1%	0.7%	0.05%

Source: European Commission

Table 1.1 illustrates two stylized facts that will be the subject of study in this paper. These are:

- *Stylized fact #1: TFP growth is declining in the US and the EU.*
- *Stylized fact #2: There is an increasing gap in TFP growth between both regions in detriment of the European Union.*

These two facts have raised concern among economists[4] and institutions. When it comes to Europe, there are two main views about the problem. The first one advocates that the EU is not be able to shift resources between sectors and still specializes in products where member countries have had comparative advantages since decades[5]. On the other hand, another view contemplates the EU as a region in transition and that the decline in TFP is temporary and due to lagged effects of the implementation of technologies[6].

The fact that the slowdown in TFP coincides with the expansion of the Third Industrial Revolution raises questions on the effects of the latter on the former. Even if the US has also decreased the rate of growth of TFP and the period 1950-1969 has not been matched by any period after, EU's case is even more worrisome. There is a growing consensus regarding the view that implementation of ICTs has been one of the factors behind the growing TFP gap between EU and the US[7]. Industry-level studies carried out in developed countries, mainly the US and EU, show that the increase in TFP can be explained through a bulk of market services that have had a big influence of ICT investment on the development of the sector[8]. In such a way, the paper will address the way in which ICT devices have affected the TFP gap between both regions.

[4] see Havik, K., et al. (2008)
[5] see Sapir et al., (2003); Van Ark, B., et al. (2003)
[6] see Blanchard, O. (2004)
[7] see Inklaar, R. and van Ark, B. (2007, 2008); Maudos et al. (2008)
[8] see Vecchi, M. and O'Mahony, M. (2003); van Ark, B. (2001)

Albeit its theoretical and empirical relevance, ICT is not the only variable considered to assess the effects of the Third Industrial Revolution. We will also refer to Patents of those technologies that have played a role in the new cohort of inventions (i.e.- nano and bio-technologies, medical and optical equipment or pharmaceuticals). Thus, we will try to explain the puzzle of a declining TFP growth in spite of its time correlation with the Third Industrial Revolution. Lastly, we have included two variables which account for the determinants that are 'traditionally' considered as drivers of TFP. These two variables are Human capital and R&D, which are widely regarded as factors determining TFP.

The paper will analyze this puzzle through the use of a structural econometric model. Section 2 of the paper analyzes the stylized facts that characterize the variables considered in the model. These will be two variables traditionally considered as determinants of TFP (R&D and Education) and other two variables which try to capture the effect of the Third Industrial Revolution (ICT investment and high technology patents). Section 3 and 4 will develop the model *per se*. This model will use an Error Correction Mechanism (ECM) which will allow us a long and short-run assessment of the determinants of TFP. Section 5 gathers the Conclusions of the paper.

2. PLAUSIBLE DETERMINANTS OF TFP GROWTH

Following the arguments discussed in the introduction, to analyze the phenomenon of the slowdown in TFP growth both in the EU and the US, and the widening gap between both regions, we will test four explanatory variables. On one hand, two variables that try to capture the Third Industrial Revolution and the influence of its innovations in TFP and the growth differential: (i) the number of high technology Patents, in particular nanotechnologies, biotechnologies, medical equipment and pharmaceuticals, and (ii) the gross fixed ICT capital formation. On the other hand, we also select two 'control' variables which are classically considered as determinants of TFP: (iii) R&D, measured through expenditures in real terms, and (iv) Education, measured through the number of tertiary students per 100,000 inhabitants. As widely advocated by other authors[9] the last two variables presumably play a fundamental role when explaining TFP and long-run economic growth, so we will include them as part of the possible structural changes explaining the different TFP evolution in both regions. In addition, the two of them can reflect changes that have resulted on more or less innovation on behalf of these regions, contributing or hindering the expansion of the ICT revolution.

Table 2.1.Average growth of the potential determinants of TFP

	EU			**US**		
	1985-1994	**1995-2004**	**2005-2014**	**1985-1994**	**1995-2004**	**2005-2014**
ICT Investment	4.7%	4.0%	1.3%	3.4%	4.7%	1.4%
High technology patents	23.1%	9.2%	1.4%	24.9%	7.8%	0.4%
R&D expenditure	2.7%	1.7%	2.5%	2.3%	4.3%	2.6%
Tertiary students	3.7%	1.2%	0.8%	0.4%	0.7%	0.6%
TFP	**1.1%**	**0.7%**	**0.1%**	**1.0%**	**1.3%**	**0.5%**

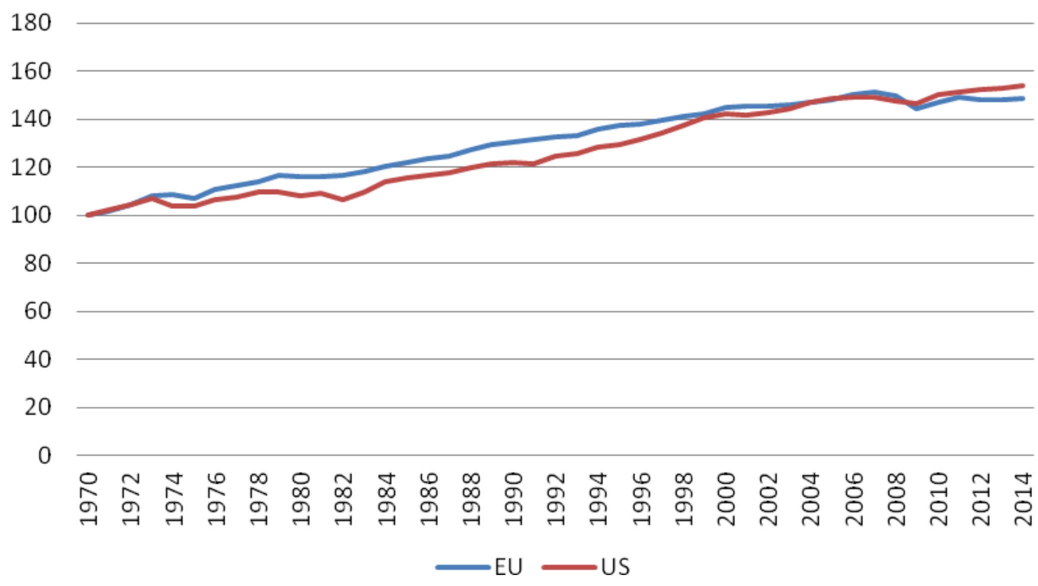
Source: Eurostat, European Commission, OECD and World Bank

As observed in Table 2.1 and Figure 2.1, TFP growth was almost the same in both regions during the mid-80s and early 90s. Nevertheless, during the following twenty years TFP lagged behind in the European Union, being its growth in the last decade close to 0. Regarding the potential explanatory variables there are certain differences. The evolution in the case of ICT investment is quite similar to that of TFP:

[9] see Barro, R. (1998); Aghion, P. and Howitt, P. (1992)

European countries performed better in the first period while divergence with respect to the US deepens in the following decades. Regarding patents it happens otherwise; Western European countries grow faster during the last two decades. Human capital demonstrates a better evolution than that of the US, but departing from much lower levels (specifically, this variable was more than 2 times higher for the US than for the EU by 1985). Lastly, R&D expenditure goes in hand with the evolution of ICT and TFP; convergence in the first period and divergence in the following two. In this section we will address individually each of these four variables.

Figure 2.1. TFP (1985=100)



Source: European Commission

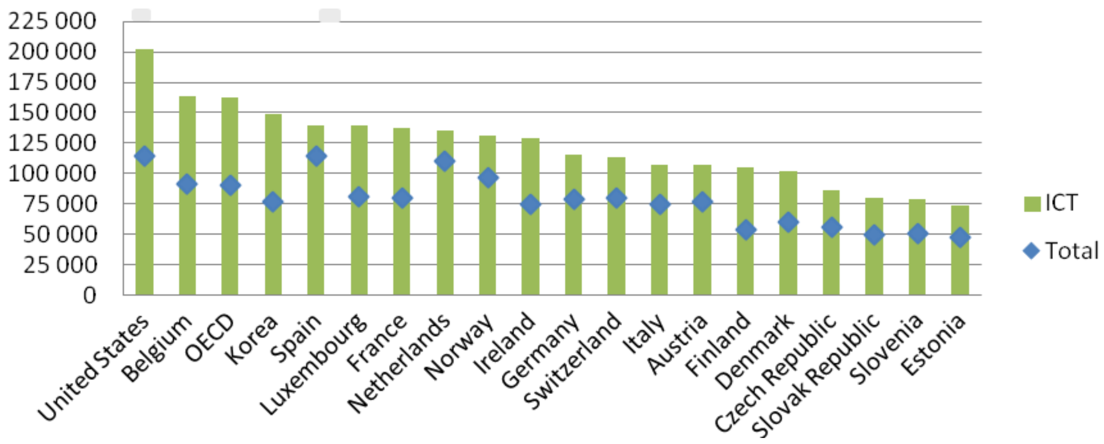
2.1. ICT investment

As exposed by other authors mentioned above[10], sectors implementing ICT devises to a higher extent are those which have experienced a higher growth in TFP during the last decades. According to these authors[11], this bulk of sectors have been the main drivers of TFP growth. Other papers focus on the effect of ICT on labour productivity rather than multifactor productivity. Nevertheless, there is indeed a strong correlation between both. In this way, from Figure 2.2, we can see that ICT-related sectors have performed much better in terms of productivity than the rest of the economy. Curiously enough, countries which show a higher productivity in the ICT

[10] see van Aark, B. et al. (2008)
[11] see Havik, K. et al. (2008)

sector also show higher productivity figures for the rest of the economy, with the US topping the chart.

Figure 2.2. Output per worker (USD current PPP), 2013.



Source: OECD

Despite the better performance of the US during the last two decades, as illustrated in Table 2.1, the overall growth in ICT investment has been higher for the EU. In this way, out of the 10 countries of the European Union selected for our study, only Italy and Germany had lower growth rates of investment on ICT than the US. However, according to van Aark (2008) and others, the relationship between the *amount* of ICT capital and TFP is not very clear. These studies include industry-level comparisons across countries and they conclude that ICT investment *per se* does not have a significant role when explaining TFP, but those sectors which are more intensive on ICT and R&D are the ones with higher TFP gains. In fact, a difference between both regions is that the EU achieved increases in TFP in those sectors which *manufacture* ICT equipment but fail to achieve these increases in the sectors that *use* ICT equipment. An interesting paper studies the effect of ICT capital in US multinationals firms in non-US environments[12] and the result was that American firms succeeded to enjoy the spill-over effects of ICT investments even outside their own country. This was not the case for the EU, suggesting that the key change introduced by ICT capital resides in expanding the *organizational capital* of companies inside the country. This organizational capital is defined as the expenditures that companies make in order to change their structure and organization. OECD data shows that R&D expenditures devoted to ICT innovation in the private sector in the EU underperform the US.

[12] see Bloom, N. et. al. (2012)

Particularly interesting are the cases of big economies, such as Germany, which have a relatively poor performance.

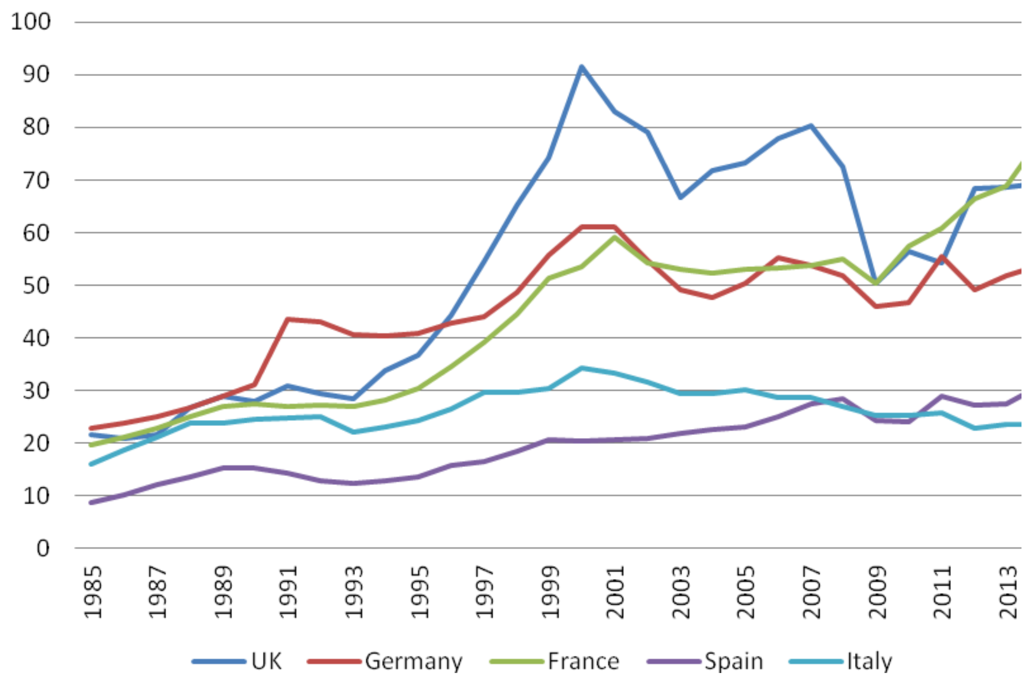
As opposite to those theories, some 'pessimistic' authors think that the slowdown in TFP during the Third Industrial Revolution should not be surprising as the huge increases in welfare from the first and second industrialization waves are hard to match[13]. It is true that the inventions from previous technological waves affected primary necessities, so that the increase in welfare was huge when the expansion of railways or fertilizers took place. The role that household appliances had in the entry of women in the labour force is hardly comparable to that of the expansion of the Internet. Our material world has not changed, we still *produce* almost the same things we did 50 years ago. Nevertheless, the *way* we do things has drastically changed. Thus, it seems that the EU has focused on the increase of ICT production, in line with the strategy followed throughout the First and Second Industrial Revolutions, while the US has focused on ICT implementation, assuming another strategy towards this new wave of technological change.

Regarding the evolution of ICT investment, the main fluctuations are the following; rapid acceleration of growth, particularly during the dot-com bubble (late 90s) and a huge slowdown from then onwards which is slightly recovered in the Great Moderation. However, the global financial crisis finished ICT positive growth and the level of 2000 has not been achieved by the average European economy since then (while the US recovered that level by 2012). Since we use weighted averages for the European Union, its evolution is more influenced by the biggest countries and the trend has been, in general, radically different among them. The UK is the leader regarding ICT investment (despite lower levels of non-residential investment), and its evolution has been particularly bad following the dot-com bubble (see Figure 2.3). The biggest European economy, Germany, has performed rather discreetly in ICT capital formation (2014 investment was approximately twice that of 1985). By contrast, in Spain the ratio between investment in 2014 and 1985 was three. Italy and Spain have been involved in a process of convergence, in which the latter has been catching up with its bigger neighbour up to the crisis period. After the crisis, Spain surpassed the Italian economy and became the fourth investor by importance within the EU. Finally, France had a peculiar evolution; very rapid growth before the dot-com bubble, slowdown (almost no

[13] see Gordon, R. (2000)

growth) during the 'between-bubbles' era, and rapid growth after the crisis, surpassing Germany and the UK during the Great Recession.

Figure 2.3. ICT Gross Fixed Capital Formation, real (billion €).

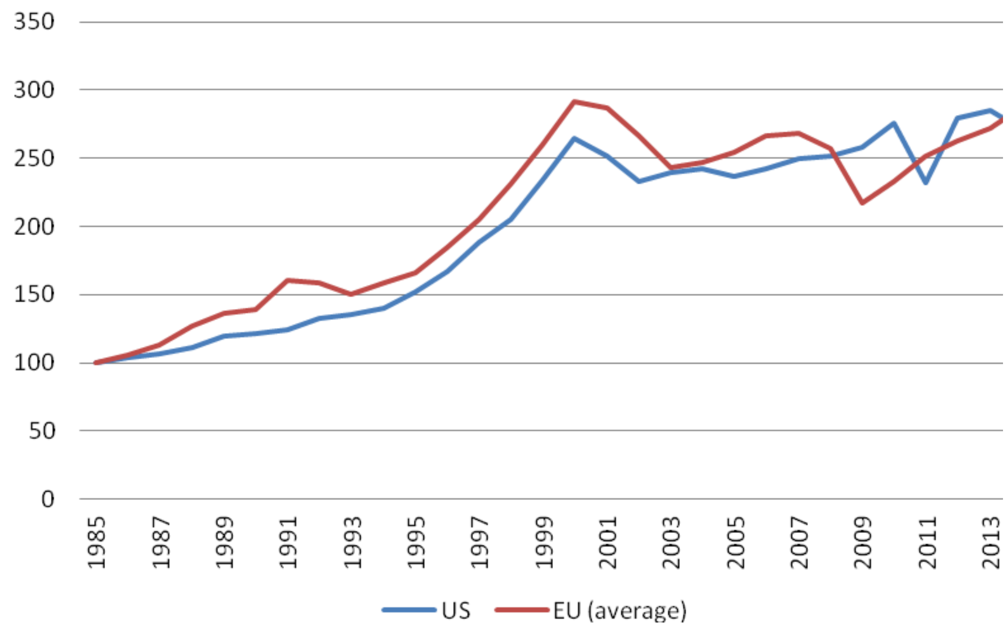


Source: OECD, Eurostat and European Commission

When it comes to the US, the evolution has been in accordance with TFP. However, as we can observe in Figure 2.4, the overall evolution for the average European economy has been slightly better than that of the US. This is mainly because of the good performance of the biggest economies in the period before the dot-com bubble. After that, the US grew moderately recovering the 2000 level of capital formation by 2010. By contrast, the EU stagnated and ICT investment growth declined dramatically with respect to previous decades. However, there has not been such a huge difference in the evolution of both variables for the US and the EU as to explain such a TFP growth differential. In fact, the evolution has been almost constant for both countries until the 2008 financial crisis, but the consequences of the crisis have been deeper in the EU.

This evolution reinforces the idea that we have mentioned. It is not about *how much* ICT capital is invested but rather *where* it is invested. In this way, it seems like the US has better understood the role of ICT in the economy than the EU, having a key role in the organizational investment of companies which has allowed them to adapt to the new technological wave faster than the EU.

Figure 2.4. ICT Investment (1985=100)



Source: Eurostat, European Commission and OECD.

2.2 R&D expenditure

In order to assess R&D expenditure, we shall start with Gershenckron's Theory of catch-up (1962). This theory advocates that countries with a technological gap will grow faster from implementation of foreign technologies than from innovation itself. Other extensions of the model suggest that the speed of convergence depends as well on the capacity of the follower to absorb leader's changes[14]. In this way, R&D expenditures could help to reduce the gap and increase the absorptive capacity of a country. It is widely assumed that expenditures on R&D in a country foster technological innovation and can help to reduce the technological gap between regions[15]. In these papers, the authors demonstrate that R&D's effect on the stock of knowledge have a positive and direct effect on TFP, even when controlling for other variables like human capital.

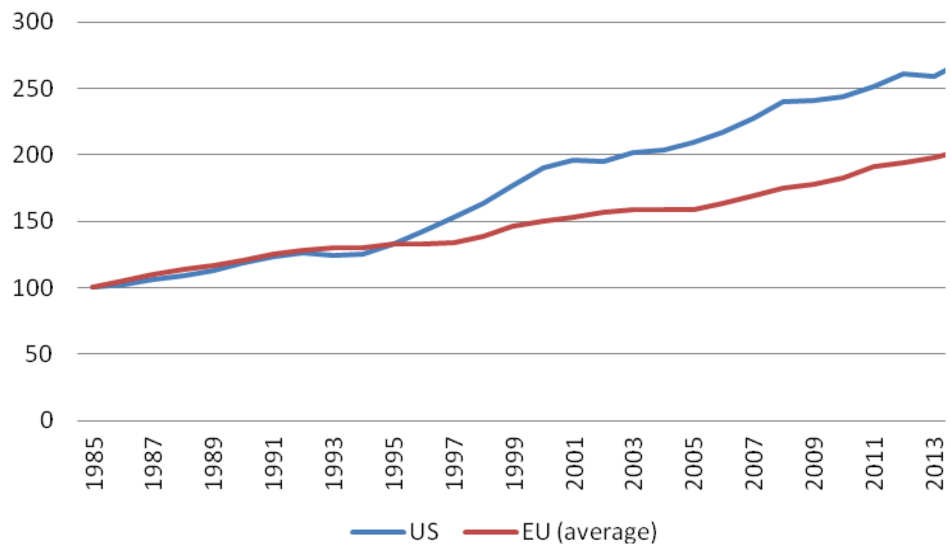
As exposed in the Lisbon Agenda (2000), the EU lags behind the US in terms of innovation. The Agenda intended that countries should achieve a 3% of GDP on R&D

[14] see Nelson, R. and Phelps, E.(1966); Benhabib, J. and Spiegel, M. (2005)
[15] see Coe, D. and Helpman, E. (2008)

expenditure. Nevertheless, this target has been far from being achieved. Out of the 28 countries of the European Union, only the Scandinavian countries (Sweden, Finland and Denmark) have fulfilled the objective and are above the target. Germany slightly outperforms the US. In general, the EU is far behind the 2.8% of GDP ratio that the US spends on R&D (for instance, the UK spent 1.6%, Spain 1.2%, Italy 1.3% or France 2.2% by 2014) and the trend has not improved neither. As exposed in the Sapir Report (2003), "*the EU is longer taking advantage of the implementation of existing technologies, and should increase its investment in R&D and education so that long-run growth depends more on innovation and a knowledge-based economy*".

Regarding intraregional differences, German expenditures have grown much faster than those of other European countries. It is one of the few countries who outperform the US in terms of research expenditures as a percentage of GDP. These expenditures have increased in a very steady way for the biggest European economy. Another case is that of the UK, albeit with a less regular pattern; expenditures stagnated until the mid-90s, followed by a rise during the dot-com bubble, with the corresponding slowdown after its burst, and a rise during the pre-crisis period matched by a fall from 2008 onwards. France has evolved steadily, without big fluctuations, while Italy and Spain show a similar pattern to that of investments in ICT. The Spanish economy caught up with Italy, but the 2008 Recession broke this trend. Nonetheless, on average the US has evolved faster than the EU. As illustrated in Figure 2.5, the American economy showed a higher pace in R&D, especially during the late 20th century.

Figure 2.5. R&D expenditures (1985=100).



Source: Eurostat

Given this, since R&D potentially plays a role in determining TFP, it would be reasonable to think that there is certain scope for attributing part of the increasing productivity gap to the developments in R&D investment. Recent studies[16] show that there is indeed a strong positive relationship between an increasing expenditure on R&D and the TFP gap. We will test this hypothesis below.

However, our model will not only account for the effect of *how much* is spent, but we want to account for *the results* of what is spent. This is the reason for including the flow of high-technology patents, in order to reflect the changes introduced by other sectors affected by the Third Industrial Revolution, besides ICT equipment.

2.3 High technology patents and TFP

In order the assess the effectiveness of expenditure on R&D, we have tracked the evolution of patents in the European Union and the US. We have included only those of the technologies with a higher R&D intensity and, when referring to patents, we will strictly stick to this narrow definition. These industries have played an important role in the evolution of the III Industrial Revolution. Nano and biotechnologies, together with pharmaceuticals and medical equipment have had an enormous impact on their respective sectors. Table 2. 2 classifies industries according to R&D intensity (i.e.- R&D expenditures over sales). As we can observe, the patents that we have selected stand for the considered as 'high technology' patents, those which are more intensive in R&D.

Table 2.2 R&D intensity among industries (1999)

Industry name	Total R&D-intensity (in % of sales)
Biotechnology and Pharmaceuticals	10.5
Aircraft and spacecraft	10.3
Medical, precision & optical instruments	9.7
Radio, television & communication equipment	7.5
Average	**6**

Source: OECD

The evolution of high technology patents has experienced a very rapid growth during the first two decades of the period under consideration but its pace slowed down

[16] see López-Bazo, E. and Manca, F. (2014)

to almost no growth during the 2000s. This evolution has been similar in all the European countries and the US as we have seen in Table 1.1 above.

Previous studies on the effect of patenting activity on the economy have concluded different results. Patents affect innovation in the same way as R&D expenditures do: they increase the stock of knowledge.

However, patents have two kind of additional effects: a negative short-run monopoly power and a positive incentive for further R&D expenditure. In this way, there are doubts regarding their final effect on TFP. Recent studies referred to similar countries to those of this work[17] show that both domestic and foreign patents do have effects on TFP. Guo (2015) studies the effect of patents on TFP in Japan and finds a direct relationship between both. Park and Ginarte (1997) show a positive relation between patents and R&D for developed countries. In this way, we want to account for the effect of R&D expenditure *and* patenting on the efficiency with which labour and capital are applied.

If we concentrate on the evolution of this variable, is easy to observe that the slowdown of TFP coincides with a stagnation in the high technology patenting activity of the countries under consideration. As far as timing is concerned, the deceleration of patents takes place at the same time as TFP starts decreasing more severely for both regions. Even though, the slowdown of TFP is a long process, patents decline more abruptly when TFP growth is the lowest in the studied period, as illustrated in Figure 2.6.

Nevertheless, it is interesting to see that while R&D expenditures have risen, in general, for most European countries its patenting activity, that is, the usufruct of R&D expenditure, has experienced a dramatic drop in growth.

As observed in Figure 2.6, the US has performed better in general terms. This is consistent with the widening gap between both regions, and therefore this high technology indicator could allow us to test another link of TFP with the Third Industrial Revolution.

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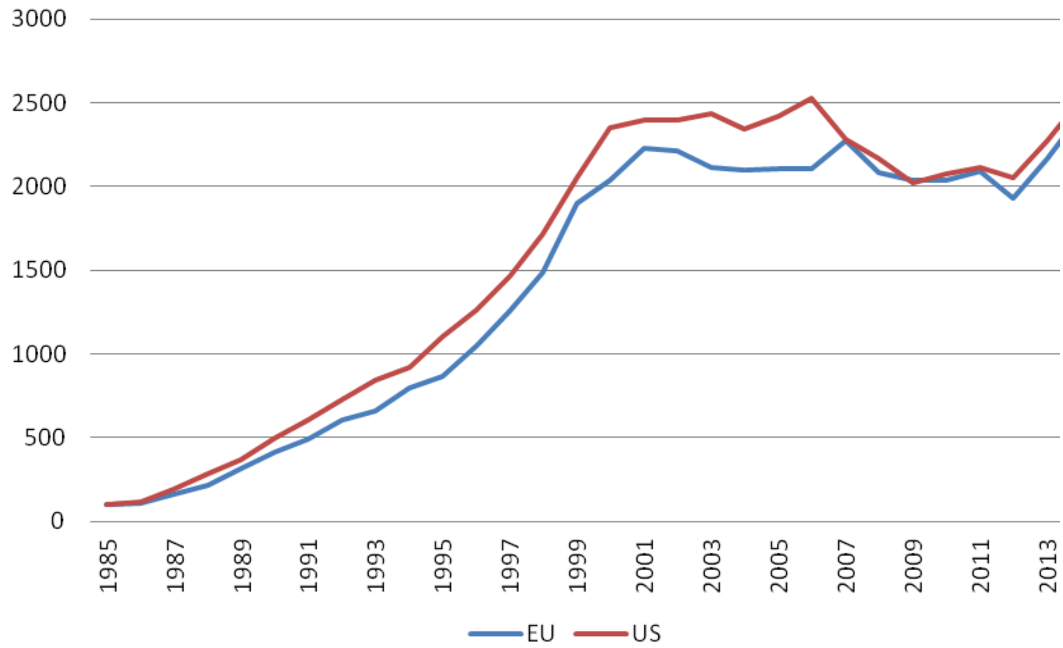
[17] see Cubel, A. et al. (2014)

Figure 2.6. Number of patents per year[18] (1985=100)



Source: OECD

2.4 Human capital and the technological gap

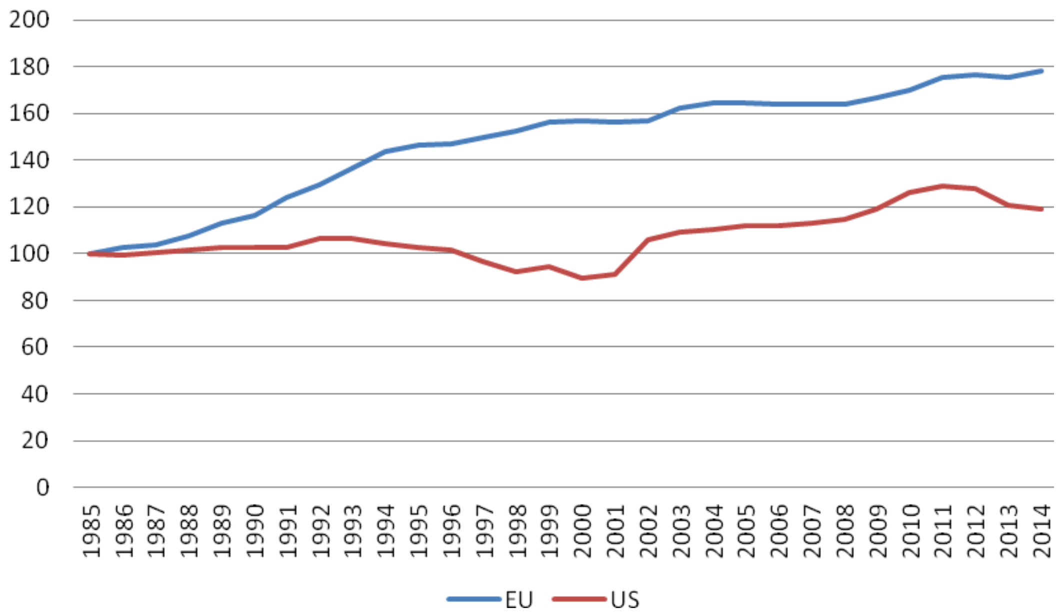
Human capital, together with R&D, have been considered in our study as part of the 'traditional' explanations for TFP. The effect of increases in human capital upon economic growth and productivity have been largely discussed by scholars, with different results but which, generally speaking, lead to similar conclusions: years of schooling and income per capita are positively related[19]. Krueger and Lindhal (2001) find that education is only significantly and positively correlated with economic growth for those countries with starting lower levels of education. Here, it would be important to emphasize the composition of education. Different educational levels have dissimilar outcomes on productivity and economic growth. In this way, there are mainly two effects of human capital on TFP according to some economists[20]: a level effect, which directly enhances economic growth, and a composition effect, which can has a positive or negative effect depending on the study. These two effects have their origin in the dual explanation of technological progress shown in studies carried out in the OECD. One of them is imitation of existing technologies, and the other one is the pure invention. It

[18] Includes nanotechnologies, biotechnologies, ICT, medical equipment and pharmaceuticals. ICT has been taken out in the model to avoid colinearity problems with ICT investment.
[19] see Benhabib, J. and Spiegel, M. (1994); Barro, R. and Sala-i-Martin, X. (1995)
[20] see Aghion, P. et al. (2004)

looks like early educational levels (primary and secondary education) play a more crucial role for imitation while tertiary education helps to create completely new inventions. In this way, if a country is far from the frontier, the main growth driver in technology is imitation. Nevertheless, as the country gets closer to the frontier, imitation-led growth fades away and innovation-led growth takes a more important role.

Consistently with these results, we want a variable which at the same time, captures the level and the composition effect. We have selected the number of tertiary students per 100,000 inhabitants to reflect the state of human capital in the selected countries. The time evolution of the variable has been radically different for both regions. While the European Union has doubled its proportion of tertiary students per inhabitant, the United States has lagged behind. This evolution would favour the TFP of the EU with respect to the United States. However, the theoretical framework exposed above can provide an explanation for the different evolution in TFP and human capital. Since the EU is farther away from the technological frontier, imitation should have a larger effect on the growth of TFP. The studies mentioned above and many others prove that investments in elementary education are more effective when approximating the technological frontier. On the other hand, the US, while being closer to the frontier, has had a lower increase in the number of tertiary student and this could explain the slowdown in TFP growth for the American economy.

Figure 2.7. Tertiary students per 100,000 inhabitants (1985=100)



Source: World Bank.

In addition, despite the numerous works where human capital shows a positive relationship with TFP growth, there are also different papers which fail to demonstrate the benefits of human capital on productivity. According to a report gathered by the UN Industrial Development Organization (2007) on the determinants of TFP: '*In a literature review, Isaksson (2002) concludes that empirical results linking human capital and economic growth vary, in particular, with respect to statistical significance (significant or not), magnitude (small or large) and sign (positive or negative) of the estimated parameter. The tendency seems to be that the statistical relationship between growth and human capital weakens and the parameter sign switches over time, an effect that is mainly attributed to the advancement of statistical methods. Another conclusion is that, to the extent human capital is significant, marginal returns to human capital are high for countries where it is scarce, although the issue of causality remains unresolved.*'.

3. THE MODEL

In this section, we develop a model which will allow us to disentangle the main determinants behind the TFP slowdown and the growth differential between the US and the EU. We will use a time series approach for the 1985-2014 period[21]. The countries selected for the EU represent almost 85% of the total GDP for the EU, which permits us to make statements on the general evolution of, at least, Western Europe. In order to aggregate their indicators, we have used weighted averages, so results from the US are compared to the data from an 'average' European economy.

The chosen methodology tries to analyze cyclical changes but retaining the information from long-run trends. This target will be achieved through the use of the Error Correction Mechanism[22]. Twofold, first we use the Engle and Granger 2-step approach[23], where once we select a long-run relationship in levels, we will include the lagged deviations from this relationship in the short-run regression. Later, we will also use the 1-step procedure as a complementary tool simultaneously estimating the long-run and short-run coefficients. Both procedures help us to deal with co-integration between variables avoiding spurious relationships. Thanks to this criteria we will select the most plausible long-run trend for our model, which later on will be used to estimate the short-run variations. As exposed by Granger and Newbold (1974), when economic variables are regressed in levels, a regression characterized by absence of co-integration between variables will exhibit high R^2 and low Durbin-Watson statistics, as well as a high significance of coefficients. In such a way, the ECM will provide information for economic analysis and will avoid the co-integration problem of regressions in levels.

In order to assess the long-run relationship, we will use the expression shown in Table 3.1 and estimate all its different combinations of explanatory variables. On the other hand, Table 3.2 represents the general model to be estimated for the short-run, in which we have included all the first differences of the variables in levels as well as their second differences (i.e.- growth rates and their acceleration).

[21] The sample for the European Union includes the five biggest economies (Germany, France, the United Kingdom, Italy and Spain) as well as the Netherlands, Finland, Denmark, Ireland and Austria.
[22] see Sargan, D. (1964)
[23] see Engle, R. and Granger, C. W. J. (1987)

Table 3.1. Theoretical long-run model[24]

$\ln TFP_{it} = \alpha_{i1} + \beta_{i1} \ln ICT_{it} + \beta_{i2} \ln Pat_{it} + \beta_{i3} \ln H_{it} + \beta_{i4} \ln R\&D_{it} + ECM_{it} \quad [1]$	
$\ln TFP_{it}$ *: Natural log of TFP*	$\ln H_{it}$ *: Natural log of number of tertiary students per 100,000 inhabitants*
$\ln ICT_{it}$ *: Natural log of ICT investment*	$\ln R\&D_{it}$ *: Natural log of R&D expenditure*
$\ln Pat_{it}$ *: Natural log of patents*	ECM_{it} *: Long-run residual. Error Correction Mechanism*

Table 3.2. Theoretical short-run model

$\Delta \ln TFP_{it} = \gamma_{i1} + \theta_{i1} \Delta \ln x_{it} + \theta_{i2} \Delta^2 \ln x_{it} + \theta_{i3} ECM_{it-1} + \varepsilon_{it} \quad [2]$	
$\Delta \ln TFP_{it}$ *: First difference of the natural log of TFP*	x_{it} *: Vector with the four explanatory variables of Table 3.1*
$\Delta \ln x_{it}$ *: First difference of the variables*	$\Delta^2 \ln x_{it}$ *: Second difference of the variables*
ε_{it} *: Short-run residual*	ECM_{it-1} *: Long-run residual. Error Correction Mechanism*

[24] *i=EU,US t=1985-2014*

4. THE RESULTS

4.1 THE ESTIMATED MODEL FOR THE UNITED STATES

4.1.1. The long-run

We use TFP as the dependent variable, estimating separated models for the US and the EU. Such a procedure will allow us to identify which regressors better explain long-term variations in each region separately. The most significant and co-integrated relationship will be selected for our long-run model, and its residuals will be used later on to estimate one of the versions of the short-run model via the 2-step approach.

Following that procedure, as mentioned in Section 2 we consider two variables strongly related to the Third Industrial Revolution and two other variables which are 'traditionally' considered, as closely related to technological developments. The sign of the coefficients is expected to be positive in all of the cases, as all of them are *a priori* regarded as contributors of TFP growth. However, estimates will allow us to *ex post* select which of them are the most appropriate explanatory variables for each region.

The results of the long-run model show that the variables which are closely related to the recent Industrial Revolution have played an important role when determining the trend of the TFP level in the US. Thus, the level of ICT investment proves to be significant when explaining the US long-run TFP trend even when accounting for the effects of human capital and R&D. In addition, the highest co-integration relation is found when ICT is introduced individually as a regressor in the model (see Table 4.1, Regression 1). The Durbin-Watson (DW) and other statistics worsen in the rest of regressions, being the worst the one with human capital alone. However, when ICT investment is combined with R&D expenditure, human capital or patents, co-integration results worsen but the R^2 improves, mainly for the cases of human capital and patents (see Regressions 5 and 7, respectively). Moreover, when adding more variables to the model, the traditional selection criteria do not seem to improve greatly. In any case, these difficulties to select the long-run relationship will be overcome with the estimation of the short-run model under the 1-step procedure, which will confirm the selection of ICT investment as a key determinant of the TFP long-run behaviour.

Table 4.1. Long-run models for the US

Dependent variable: $\ln TFP_{US,t}$										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
C	3.03 (0.05)	3.69 (0.07)	1.02 (0.11)	-	1.78 (0.28)	1.78 (0.28)	2.41 (0.3)	1.52 (0.13)	1.52 (0.51)	1.47 (0.25)
$\ln ICT_{US,t}$	0.24 (0.01)				0.20 (0.02)	0.09 (0.03)	0.23 (0.01)			
$\ln Pat_{US,t}$		0.09 (0.01)			0.02 (0.01)			0.02 (0.0)	0.08 (0.01)	
$\ln R\&D_{US,t}$			0.28 (0.01)			0.17 (0.04)		0.23 (0.01)		0.30 (0.01)
$\ln H_{US,t}$				0.52 (0.15)			0.08** (0.04)		0.26 (0.06)	-0.08** (0.04)
DW R^2	0.89 0.96	0.11 0.84	0.5 0.97	0.09 0.32	0.78 0.97	0.61 0.98	0.85 0.97	0.84 0.99	0.25 0.9	0.74 0.98

All variables significant for 1% except:
** statistically significant for a 10% level of significance*
*** statistically significant for a 5% level of significance*

Patents do not exhibit a strong co-integration relation with TFP when assessed individually. Despite this fact, when combined with other variables it proves to be quite significant in the long-run. In the 8 regressions where we find an acceptable co-integration relationships, patents are statistically significant in all of them. This result is only outperformed by ICT investment, since human capital and R&D expenditure are statistically less significant in the 15 regressions that we have estimated to assess the long-run.

R&D expenditure is individually significant and positive in all the long-run regressions. Despite the fact that Regression 3 has a better DW statistic than Regressions 2 and 4, when combined with other variables the effect of R&D on co-integration is usually detrimental. In fact, it seems that R&D expenditure performs particularly well when we take into account the effect of patents, but without them, co-integration statistics usually worsen, as well as the global significance of the models. In the same way, human capital behaves inconsistently through the model. Human capital is the variable which presents a lower individual significance across the different models and we disregard it as a long-run contributor to TFP growth in the US. In this way, the 'traditional' variables appear to be less significant when explaining the long-term TFP trend than the variables reflecting the new cohort of inventions.

In summary, the variables chosen to reflect the Third Industrial Revolution prove to be a good explanation for TFP long-run growth in the US. On the contrary, classical determinants of TFP, such as R&D expenditure and human capital display a poor explicative power for the TFP growth in the US.

$$\ln TFP_{US,t} = \underset{(0.28)}{1.78} + \underset{(0.02)}{0.2} \ln ICT_{US,t} + \underset{(0.01)}{0.02} \ln Pat_{US,t} + \varepsilon_{US,t} \qquad [3]$$

This equation corresponds to regression 5 in Table 4.1. Moreover, as we will show later, this long-run trend proves to be systematically significant when introduced in the short-run model.

Table 4.2. Contributions to long-run TFP change in the US

TFP change 1985-2014*		**Contributions**	
Actual	Estimated	ICT	Patents
28.6%	28.7%	23.5%	5.2%

**Accumulated*

Table 4.2 illustrates the ability of our model to explain the long-run growth of TFP has been quite appropriate. As shown in the table, the change in ICT accounts for most of the variation in TFP between 1985 and 2014, actually explaining more than 80% of the total change. Thus, ICT investment has had a key relevance when shaping the long-run TFP in the US. Changes in the number of patents has had some explanatory power but lags behind ICT in importance and significance.

4.1.2 The short-run

In this section we will estimate the short-run model which will help us to understand the changes in TFP growth in the US. The short-run model has been helpful not only to explain the dynamics of TFP but also to confirm which is the best long-run relationship. Estimating the short-run model for the US has been more difficult given the higher volatility of TFP as compared to the EU. Nevertheless, we have relatively succeeded to find a short-run relation which allow us to track this high volatility of the American series.

As in the long-run model, ICT investment proves to be highly significant in the short-run. Disregarding the selected long-run variables, the short-run is clearly determined by ICT investment in the US. In fact, any short-run model[25] that does not include ICT investment will lose a lot of explanatory power. In such a way, when ICT capital is absent Durbin-Watson and R^2 statistics significantly deteriorate. Given the available data, we would assert that ICT investment has played a very important role when determining TFP level and growth. This is a very powerful result whose implications we will developed below.

However, ICT investment cannot explain by itself all the dynamics in US TFP growth. In this way, we have checked for other candidate variables that help us to explain the short-term TFP deviations from its long-run trend. We have found that the first difference of the number of patents and the second difference of R&D expenditures prove to be significant, when considered separately. However, both variables seem to be substitutes.

Table 4.3 presents the selected short-run model. The three best models include the first difference of patents, the second difference of R&D expenditure and both are quite similar from a statistical point of view. However, Model 2 has the higher individual significance for each coefficient. For this reason, we have selected the acceleration of R&D as one of the explanatory variables for the short-run.

Table 4.3. Short-run regressions

	1	**2**	**3**
C	0.01*** (0.0)	0.01*** (0.0)	0.01*** (0.0)
$\Delta \ln ICT_t$	0.06*** (0.02)	0.06*** (0.02)	0.06*** (0.02)
$\Delta \ln Pat_t$	0.01 (0.01)	-	0.01 (0.01)
$\Delta^2 \ln R\&D_t$	-	0.09* (0.05)	0.08 (0.05)
ECM_{t-1}	-0.24*** (0.09)	-0.31*** (0.09)	-0.28*** (0.09)
DW ***R^2*** ***Prob (F-statistic)*** ***Dummy (1991)***	1.52 0.49 0.002 Yes	1.49 0.52 0.002 Yes	1.58 0.54 0.003 Yes

[25] Number of short-run models for the US: 82
Number of short-run models for the EU: 104

As we mentioned at the beginning of the section, we will re-estimate the short-run model not imposing the coefficients of the Error Correction Mechanism, as we did in Table 4.3, but allowing data to simultaneously estimate the short-run and long-run coefficients. This is what we have called '1-step' procedure and it will help us to corroborate not only the short-run coefficients but to confirm long-run determinants as well.

The results are presented in Table 4.4 (1-step column) and are compared to those of the selected 2-step model presented in Table 4.3. We are able to confirm that the coefficients for the short-run variables are very similar in both cases. In addition, the coefficient of the ECM in the 2-step procedure should be similar to that of the lagged TFP of the 1-step procedure as shown in Table 4.4. Finally, the coefficients of the long-run variables (ICT investment and number of patents) in the 1-step approach should be approximately the product of the coefficients of the estimated long-run model and the coefficient of the ECM. It can be easily checked that this condition is fulfilled and corroborates the statistical significance of patents and ICT investment as determinants of TFP in the long-run

Table 4.4. The short-run model for the US

	$\Delta \ln TFP_t$	
	1-step	**2-step**
C	0.98*** (0.0)	0.01*** (0.0)
$\Delta \ln ICT_t$	0.05*** (0.02)	0.06*** (0.02)
$\Delta^2 \ln R\&D_t$	0.08 (0.05)	0.09* (0.05)
ECM_{t-1}	-	-0.31*** (0.09)
$\ln TFP_{t-1}$	-0.3*** (0.09)	-
$\ln ICT_{t-1}$	0.05*** (0.02)	-
$\ln Pat_{t-1}$	0.01* (0.0)	-
DW $\boldsymbol{R^2}$ ***Prob (F-statistic)*** ***Dummy (1991)***	1.52 0.49 0.002 Yes	1.49 0.52 0.002 Yes

Table 4.5 shows the average contributions of the selected variables to changes in TFP growth in the US. As we observe, the role of ICT has been more important when explaining TFP growth on average than R&D expenditure. However, we notice by looking at the raw data that there is a slight downward trend in the contribution of ICT to TFP growth. In such a manner, R&D expenditure increases its contribution in the last decade, playing a role in TFP slowdown for the US.

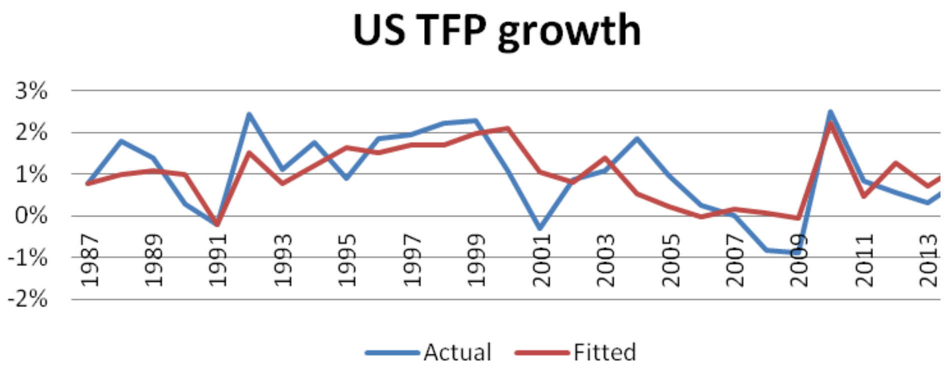
Table 4.5. Average contributions to TFP growth in the US (1985-2014)

TFP growth		**Average contribution**	
Actual	Explained	ICT growth	R&D acceleration
1.0%	1.0%	65%	35%

In summary:

- In the long-run, strictly technological variables prove to have a higher influence on the trend followed by the TFP in the United States. In particular, ICT investment is systematically significant through the sample followed by high technology patents. This indicates that the new wave of inventions has played a role when shaping TFP in the US.
- In the short-run, ICT investment growth proves to be consistently significant across different models, even when accounting for the 'traditional' determinants and high technology patents. The latter prove to be significant in some cases but its individual significance is much lower than that of ICT. The acceleration in the rate of change of R&D expenditure ($\Delta^2 \ln R\&D_t$) also plays a role given the high volatility of TFP in this period. Thus, in our model it is not the growth rate of R&D expenditure which influences the TFP long-run but it do so in explaining short-run fluctuations.

Figure 4.1. Actual and fitted values for the US short-run model



4.2. THE ESTIMATED MODEL FOR THE EUROPEAN UNION

4.2.1. The long-run

Following the same procedure, we select the variables that determine the TFP long-run trend in the EU. Contrary to the United States, ICT investment does not seem to play such a key role in explaining the trend behaviour of European TFP. In a single variable basis, the highest co-integration relation includes either human capital or the number of patents, but ICT investment shows a very low co-integration relation with TFP, and so does R&D expenditure. As observed below in Table 4.6, long-run models for the European Union exhibit poorer statistics than those of the US. In this way, the selection of a long-run model has been more difficult than in the case of the US, in which long-term TFP was clearly explained by ICT investment.

All in all, we have observed that Patents are a recurrent variable in those long-run models which are statistically significant according to co-integration criteria. We should recall that, when considered on an individual basis, the highest co-integration was including ICT in the US. By contrast, EU's pattern does not resemble the US. In fact, human capital, which was clearly not co-integrated for the US, seems to play a not negligible role when shaping long-run TFP evolution. By contrast, R&D expenditure is not statistically significant when we account for the effect of the other traditional variable (human capital).

Table 4.6 Long-run models for the EU

$\ln TFP_t$										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
C	3.88 (0.03)	4.13 (0.02)	1.37 (0.23)	1.68 (0.14)	4.02 (0.05)	2.90 (0.22)	2.69 (0.22)	3.17 (0.23)	3.07 (0.48)	1.47 (0.25)
$\ln ICT_t$	0.19 (0.01)				0.08** (0.03)	0.13 (0.02)	0.09 (0.02)			
$\ln Pat_t$		0.06 (0.0)			0.04** (0.01)			0.05 (0.0)	0.04 (0.01)	
$\ln R\&D_t$			0.3 (0.02)			0.12 (0.03)		0.11 (0.02)		0.06 (0.04)
$\ln H_t$				0.35 (0.02)			0.19** (0.04)		0.15** (0.07)	0.29** (0.05)
DW	0.33	0.48	0.23	0.53	0.37	0.43	0.47	0.75	0.55	0.52
R^2	0.93	0.95	0.87	0.94	0.96	0.97	0.97	0.97	0.95	0.95

*All significant for 1% except for: *Significant for 10% **Significant for 5%*

Even though not very strongly, when patents are included in the model, co-integration statistics considerably improve. This is observed in Regressions 2, 8 and 9. On the other hand, the best performing 'classical' variable is Human capital when analyzed individually, and it also works well when combined with patents. The other 'traditional' variable, R&D expenditure, also proves to improve co-integration tests, when combined with patents. Nevertheless, the models where R&D is included usually do not improve nor significance nor co-integration tests. Hence, in order to justify our selection, we must use results of the short-run estimates. The results indicate that patents alone, on one hand, or patents combined with human capital, work well when used as long-run relationship in modelling the ECM. Therefore, the 2 long-run models are given by:

$$Model\ 1:\ \ln TFP_{EU,t} = \underset{(0.02)}{4.13} + \underset{(0.0)}{0.06} \ln Pat_{EU,t} + \varepsilon_{EU,t} \qquad [4]$$

$$Model\ 2:\ \ln TFP_{EU,t} = \underset{(0.48)}{3.07} + \underset{(0.01)}{0.04} \ln Pat_{EU,t} + \underset{(0.07)}{0.15} \ln H_{EU,t} + \varepsilon_{EU,t} \qquad [5]$$

Using both expressions in Table 4.7 we analyze the long-run contributions to EU's TFP growth as we did for the US. When analyzed together with human capital, we see that Patents' contribution is higher (despite having a lower coefficient). This gives us a hint about the predominant long-run relationship. Nonetheless, the forthcoming short-run specification will allow us definitely to choose between these two models.

Table 4.7. Contributions to long-run TFP change in the EU

	TFP change*		**Contributions**	
	Actual	Explained	Patents	Human capital
Model 1	20.1%	20.6%	20.6%	-
Model 2	20.1%	20.8%	11.9%	8.9%

**Accumulated*

4.2.2 The short-run

One of the difficulties that we found in American data was volatility of TFP. For the EU it is lower, probably because we are aggregating the behaviour of 10 different countries. This could have a smoothening effect on the evolution of the variables. In any case, lower volatility has helped us to establish a short-run relation which fits nicely the actual data.

When we analyze the short-run for the EU, the outstanding result is the great importance of ICT investment in explaining the dynamics of TFP. This is inferred from the high significance of the variable $\Delta \ln ICT_t$ in the short-run specification. This result is robust when tested for different long-run relationships others than the ones selected in the section above. The second result is that not only the first difference of ICT matters, but also the second difference. Thus, we need to consider the acceleration of ICT investment ($\Delta^2 \ln ICT_t$) and by doing so we discover a new good explanatory variable in our model. This is a powerful result for our research purposes, as ICT investment in the US has played an important role as well when shaping TFP, both in long and short terms. Hence, the new wave of inventions should have had something to do with the increasing growth gap between both regions.

Moreover, the second variable selected to represent the effect of the Third Industrial Revolution, the number of high technology Patents, also demonstrates to be significant in our model. The effect is somewhat lower if we also consider ICT investment, but positive and strongly significant even when traditional determinants of TFP are included in the regressions. Human capital and R&D show some inconsistencies. Despite the positive effect of the former on the long-run, its sign and significance varies when we include different long-run Error Correction Mechanisms. In addition, R&D expenditure is systematically insignificant once we take into account the effect of ICT or patents.

In this way, following our 1-step and 2-step procedures, we have identified a model which could explain short-run determinants of TFP growth. As we can observe in Table 4.8, Model 1 represents the regression with only patents in the long-run, while Model 2 presents an ECM with human capital as well.

Table 4.8. Short-run models for the EU

	$\Delta \ln TFP_t$			
	Model 1		**Model 2**	
	1-step	**2-step**	**1-step**	**2-step**
c	0.53 (0.31)	0.005*** (0.0)	0.54 (0.32)	0.005*** (0.0)
$\Delta^2 \ln ICT_t$	0.04*** (0.01)	0.04*** (0.01)	0.04** (0.02)	0.04** (0.01)
$\Delta \ln Pat_t$	0.03* (0.02)	0.03*** (0.01)	0.03* (0.02)	0.03*** (0.01)
ECM_{t-1}		-0.13* (0.07)		-0.13 (0.08)
$\ln TFP_{t-1}$	-0.13 (0.07)		-0.12 (0.09)	
$\ln Pat_{t-1}$	0.01 (0.01)		0.01 (0.01)	
$\ln H_{t-1}$			-0.01 (0.03)	
DW $\mathbf{R^2}$ **Dummy (2009)**	2.1 0.82 Yes	2.11 0.82 Yes	2.13 0.82 Yes	2.03 0.81 Yes

Interestingly enough, coefficients for both models do not vary much from one another. Nonetheless, the best long-run relationship is the one that just includes high technology patents (Model 1). The variables representing the long-run Model 2 are less significant, under both procedures. In fact, human capital, proves to be very insignificant when introduced in the short-run (p-value of its t-statistic=0.87). Thus, we reject the regression including both human capital and patents in the long-run in favour of that one containing only patents (Model 1).

The results for the short-run model in the European Union also give us scope to infer a statistical relevance of the variables related to the Third Industrial Revolution. The number of high technology patents as well as ICT investment demonstrate to be significant in the long-run and the short-run.

Table 4.9 illustrates the average contributions of the selected variables to total TFP growth in the EU. As we can observe, here the pattern is different to that of the US since ICT has a lower contribution to growth than the number of patents. In spite of the lower percentage that ICT investment exhibits, this contribution becomes stronger during the last decades, in detriment of patent activity. We find that this in contrast to the American economy, where the contribution of ICT is dropping in favour of R&D expenditure. In such a way, the average contribution of ICT investment to TFP growth in the EU has been 25.9% higher during the last decade than in the first decade under examination (increasing from a 28.3% in the 1985-1994 decade to a 54.2% in 2005-2014).

Table 4.9. contributions to TFP growth in the EU (1985-2014)

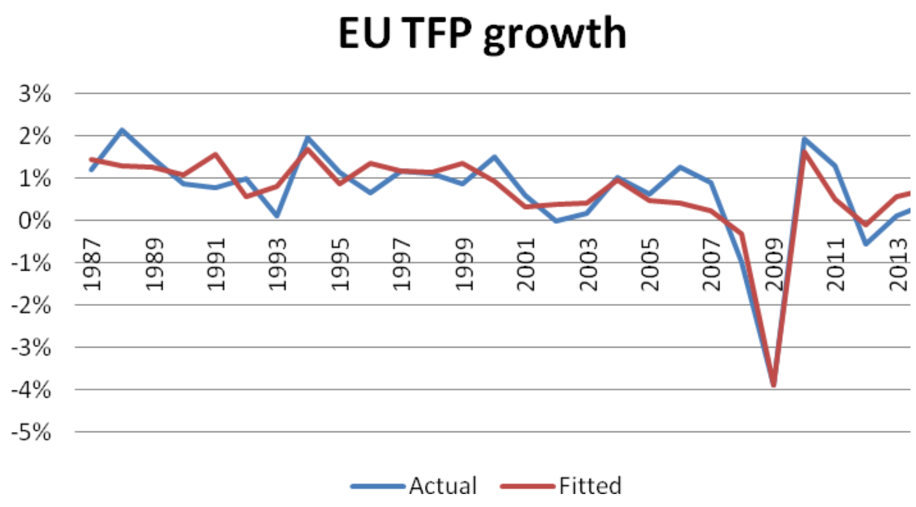
TFP growth		**Average contribution**	
Actual	Explained	ICT acceleration	Patent growth
0.7%	0.7%	41%	59 %

In summary:

- In the long-run, patents have an important role to explain TFP trends in the EU and, to a lesser degree, so does human capital. As for the US, we find that patents appear to be an explanatory variable for the evolution of the long-run. The close connection between TFP and the number of inventions related to nano and bio-technologies, medical and optical equipment and pharmaceuticals, which represent the new wave of inventions, indicates that technology has been one of the most important factors behind TFP evolution.
- In the short-run, the acceleration of ICT investment ($\Delta^2 \ln ICT_t$) and the growth of patents ($\Delta \ln Pat_t$) plays a role when shaping the dynamics of TFP. Thus, we find ICT capital accumulation as playing a role in the both regions. Despite rejecting $\Delta \ln Pat_t$ for the US, it showed some significance across the sample. Thus, the variables selected to represent the Third Industrial Revolution play a role when shaping the short-run as well.

Figure 4.2 below illustrates the actual and fitted values of TFP growth in the EU. As already mentioned, the smoothening effect of the averages allows to track the evolution of the EU quite authentically:

Figure 4.2. Actual and fitted values



4.3. EXPLAINING THE SLOWDOWN IN TFP

In this section we break the sample into two sub-periods in order to assess the recent TFP growth slowdown. Thus, we will compare the first and the last decades of our sample in order to disentangle the slowdown puzzle. Tables 4.10 and 4.11 provide us with two results: (i) the weights of each variable in explaining TFP growth in the US and the EU, as well as their evolution through time and (ii) the negative evolution of the variables, given the fall in TFP growth in both regions since their coefficients are always positive and constant in our model. These two facts will help us to evaluate the slowdown.

Table 4.10. Short-run contributions for the US

	TFP growth		**Average contributions**	
	Actual	Explained	ICT growth	R&D acceleration
1987-96	1.2%	1.0%	68%	32%
2005-14	0.5%	0.6%	59%	41%

Table 4.11. Short-run contributions for the EU

	TFP growth		**Average contributions**	
	Actual	Explained	ICT acceleration	Patent growth
1987-96	1.1%	1.1%	28%	72%
2005-14	0.1%	0.05%	54%	46%

In Table 4.10 the US exhibits a higher average contribution of ICT investment growth for both periods. In this way, according to our model more than half of its slowdown in TFP growth is attributed to the slowdown in ICT investment. Actually, the weight of R&D expenditure today is higher than that of the first decade. If we look at the data, this is because the slowdown in R&D expenditure has been lower than that of ICT investment. Hence, ICT investment growth was approximately a 40% lower the last decade than the first one. Meanwhile, average R&D expenditure acceleration was 20% lower than in the mid-80s. This fact explains the shift in both contributions.

On the other hand, Table 4.11 shows a shift in the importance of the variables from one period to the other for the EU. Growth in the number of high technology patents was the main contributor in the first period. However, it explained less than half of total growth in the recent subperiod. By looking at the data, we are able to explain this contribution through a massive drop in the growth of patenting activity. The average growth of the number of high technology patents is a 93% lower today than it was 30 years ago. By contrast, the average acceleration of ICT investment is only a 21% lower today than it was the first decade. In such a way, the dramatic fall in the growth of Patents explains the shift of contributions and the slowdown in TFP growth in the EU.

4.4 EXPLAINING THE TFP GAP BETWEEN THE US AND THE EU

Table 4.12 classifies the explanatory variables according to their influence when shaping the TFP widening gap between the US and the EU. As we can observe, the role of ICT has had a great deal of importance in explaining this gap. Despite the fall in ICT investment growth in the US, it continues being positive. This fact, together with the smaller effect of ICT in the EU, explains more than half of the total gap in TFP growth between both regions. If the slowdown in ICT investment in the US had been matched by an acceleration of ICT investment in the EU, the evolution of ICT would have had a narrowing effect on the gap. However, the fall in ICT investment growth in the US has been matched with a deceleration of ICT investment growth in the EU, contributing to widen the gap.

Table 4.12. Contributions to TFP growth gap 2005-14

TFP growth gap		**Average contributions**		
Actual	Explained	ICT growth	Patent growth	R&D acceleration
0.4%	0.6%	58.9%	16.7%	24.4%

Regarding the other two variables we find a similar pattern. R&D expenditure decelerates in the US but keeps having a positive sign. This slowdown *ceteris paribus* should narrow the gap between both regions. Nevertheless, the further slowdown of the growth in the number of high technology patents in Europe, has contributed to widen the gap.

In summary, we are able to assert that all the explanatory variables have slowed down everywhere. However, the variables which had a higher explanatory power in the European Union have had a more negative evolution: the deceleration of ICT investment and the dramatic fall in patenting activity in the EU have outperformed the deceleration of R&D expenditure and the fall in ICT investment growth in the US. For this reason, the gap is widening as the slowdown in both regions is deepening.

5. CONCLUSIONS

Our main purpose in this paper is to explain two stylized facts: the worlwide slowdown in TFP and the widening gap between the US and the EU in TFP. We pays special attention to the role of the Third Industrial Revolution in such a performance. We estimate an Error Correction Mechanism model which has allowed us to identify long-run and short-run explanatory variables for each region.

Regarding the US, we obtained a relevant role of technology-related variables (ICT and number of patents) when shaping the evolution of the TFP, both in the long and in the short-run. In the slowdown in TFP growth in this country, we conclude that the fall in ICT investment growth has played a key role. To a lesser extent, R&D expenditure deceleration has played a role in explaining short-run dynamics.

As for the EU, the technology-related variables also play a key role when shaping short and long-run changes in TFP. But in the long-run ICT investment does not play such a fundamental role for the US. By contrast, the number of high technology patents takes the relevant role. Although human capital appeared to have certain influence in the EU TFP long-run behaviour, the model finally rejected such a hypothesis. However, the short-run is clearly determined both by ICT investment and the number of patents. Therefore, the huge slowdown in patenting activity of the last decade has accounted for most of the slowdown in TFP growth in the EU.

Regarding the US-EU productivity slowdown advantage, the bigger slowdown in the explanatory variables in the EU, particularly that of patents, explains most of the widening gap. The fall in ICT investment growth in the US, which explains its slowdown in TFP growth, has been matched with an even sharper decrease of patenting activity in the EU. In this way, we are able to attribute both the slowdown and the increasing gap in between these two regions to changes in the dynamics of the Third Industrial Revolution, in detriment of traditional TFP explanatory variables, such as R&D and Human capital investment.

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