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Recent Trends and Structural Breaks in US and EU15 Labour Productivity Growth

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RECENT TRENDS AND STRUCTURAL BREAKS IN US AND EU15 LABOUR PRODUCTIVITY GROWTH

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By
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ABSTRACT/RÉSUMÉ

Recent trends and structural breaks in US and EU15 labour productivity growth

This paper examines shifts in labour productivity growth in the United States and in Europe between 1970 and 2007 based on econometric tests of structural breaks. Additionally, it makes use of time-series-based projected labour productivity growth up to 2009 in order to detect any recent break according to a central scenario as well as high and low scenarios, both derived from a 95% confidence interval. The identification of structural breaks in US labour productivity growth is far from obvious. A statistically significant break date is found in the late 1990s only if the upper scenario materialises in the future, which means that despite a clear pick-up in productivity growth in the second half of the 1990s, the size of the hump is not still large enough compared with past variation to make this change a statistically significant break. However, a significant breakpoint is detected in the mid-1990s for the difference in labour productivity growth between the United States and the EU15 based on observed data, which seems to be due to both the initial catch-up of Europe and the halt of the convergence process in the mid-1990s. Finally, European ICT-intensive countries are shown to have structurally performed better in terms of productivity growth than non-ICT-intensive countries.

JEL classification codes: E30; O47; O51; O52
Key words: labour productivity growth; structural break tests; ICT

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Tendances récentes et ruptures structurelles de la croissance de la productivité du travail aux États-Unis et dans UE15

Ce papier étudie les changements structurels dans la croissance de productivité du travail aux États-Unis et en Europe entre 1970 et 2007 à partir de tests de rupture de tendance. Il incorpore également des prévisions de la croissance de la productivité du travail jusqu'en 2009 afin de détecter des ruptures récentes selon un scénario central, ainsi que haut et bas tous deux définis à partir d'un intervalle de confiance à 95%. Premièrement, l'identification de ruptures structurelles dans la croissance de la productivité du travail aux États-Unis ne va pas de soi. Une rupture à la fin des années 1990 est mise en évidence seulement si le scenario haut est amené à se réaliser dans le futur, ce qui signifie que malgré la réelle hausse de la croissance de la productivité américaine dans la seconde moitié des années 1990, seuls des chiffres à venir élevés feraient de ce changement une rupture statistiquement significative au regard des variations passées. Cependant, sur la période observée, la différence entre les taux de croissance américain et européen de la productivité du travail présente une rupture significative au milieu des années 1990, qui semble due au rattrapage de l'Europe et à l'arrêt de la convergence au milieu des années 1990. Enfin, les pays Européens dont l'accumulation de capital dans les TIC a été plus intensive ont eu une croissance de la productivité structurellement plus forte que les pays dont l'investissement a été moindre.

Classification JEL : E30 ; O47 ; O51 ; O52
Mots-clés : croissance de la productivité du travail; tests de rupture structurelle ; TIC

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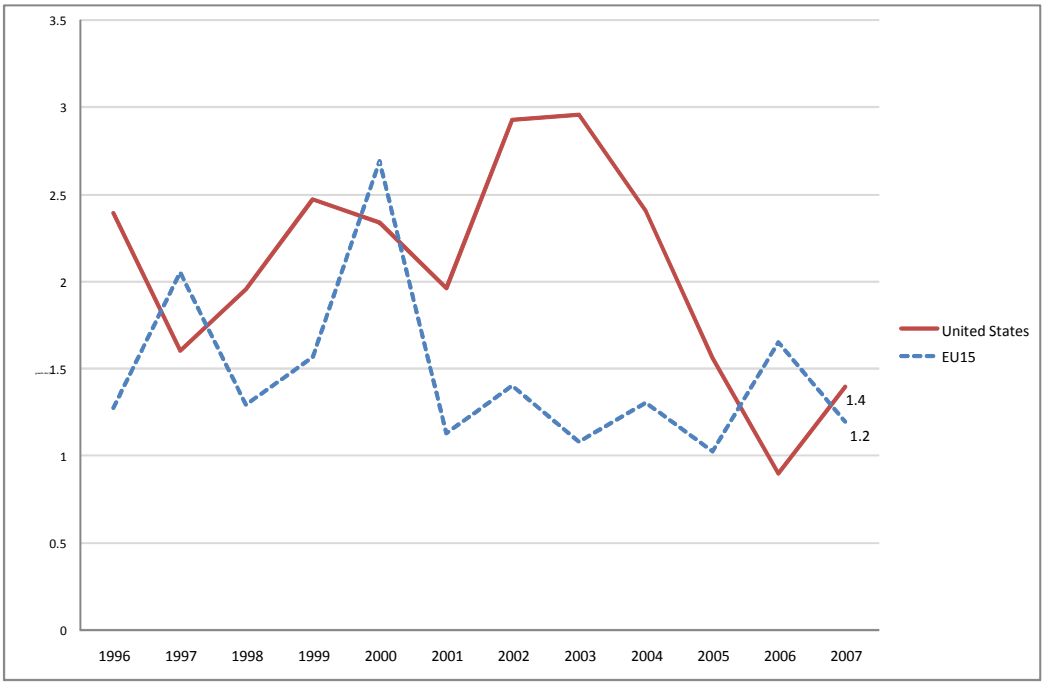
RECENT TRENDS AND STRUCTURAL BREAKS IN US AND EU15 LABOUR PRODUCTIVITY GROWTH

Laure Turner and Hervé Boulhol[1]

1. Introduction

1. The gap in hourly labour productivity growth between the United States and the EU15 was nearly closed by the second half of the 1990s. Since then, there has been a sharp turnaround, with labour productivity growing faster in the United States than in Europe. However, productivity growth in the United States has slowed since 2003, to reach 1.4% in 2007. In contrast, in conjunction with the cyclical recovery, a small acceleration in labour productivity occurred in the EU15 between 2004 and 2006. But productivity growth in the EU15 is estimated to have fallen from 1.7% in 2006 to 1.2% in 2007 (Figure 1).

Figure 1. Labour productivity growth in the United States and in Europe, 1996-2007



Note: The 2007 EU15 labour productivity growth figure is based on Economic Outlook 83 projections.

Source: OECD Productivity Database, Economic Outlook 83 Database for 2007 EU15 labour productivity growth, and BLS for 2007 US labour productivity growth rates in the non-farm business sector. 0.4 percentage point has been subtracted from the BLS data. This is the average difference between the means of the OECD Economic Outlook 83 and BLS series since 1970. This applies to the remaining of the figures using BLS data.

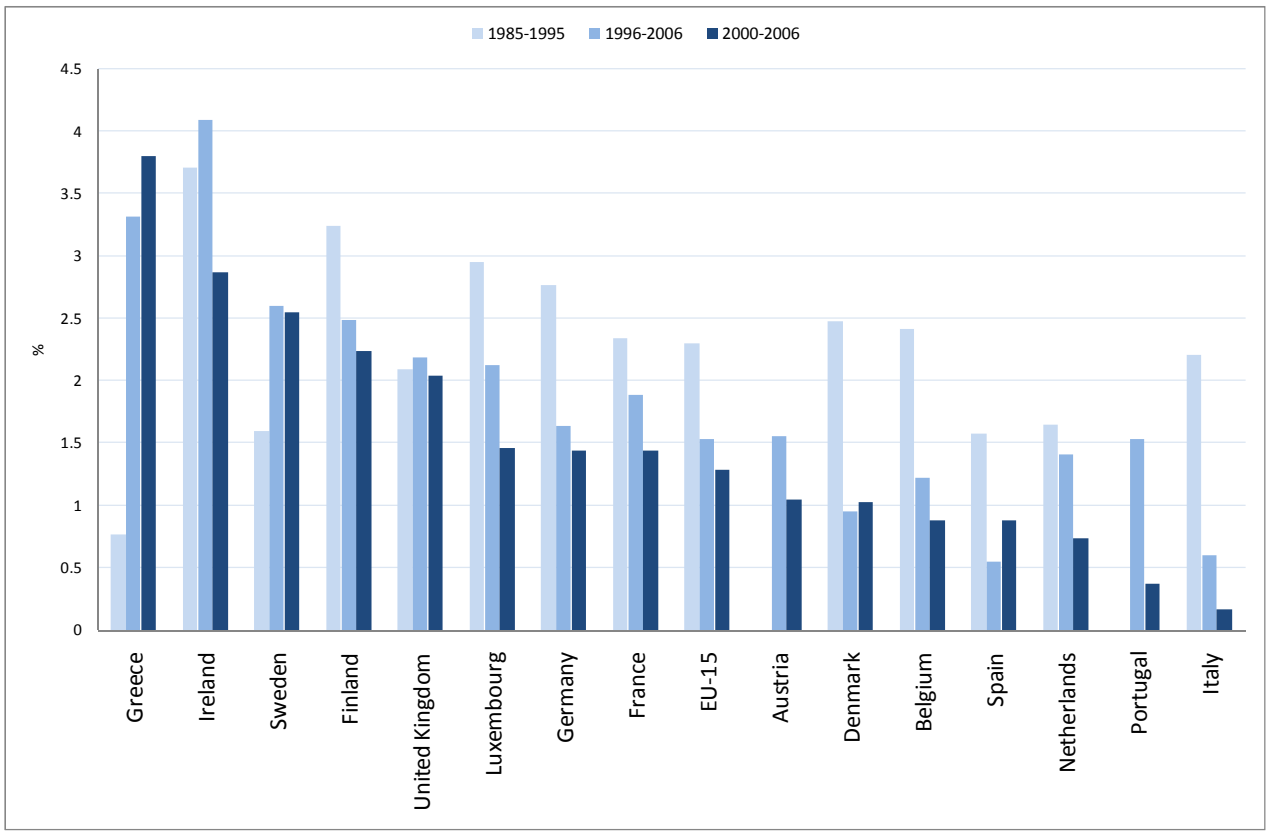
2. This paper aims at assessing the extent to which the recent changes in labour productivity growth in the United States and in Europe are structural as opposed to cyclical. First, for descriptive purposes, filtering techniques are employed on observed data to calculate the underlying trends in labour productivity growth between 1970 and 2007. Then, time series modelling is used to get forecasts of labour productivity

1. Laure Turner is an administrator at INSEE and Hervé Boulhol is an economist in the Structural Policy Analysis Division of the Economics Department. The authors would like to thank Sveinbjörn Blöndal and Jean-Luc Schneider for their valuable comments as well as Caroline Abettan for editorial support.

growth up to 2009 as well as a high and a low scenario. Identifying the trends of those scenarios gives an insight on the conditions under which structural changes might have recently taken place. Finally, the statistical significance of the breaks in labour productivity growth is assessed. Throughout the paper, "breaks" should be understood as induced by sudden shifts rather than by gradual changes or drifts.

3. The paper takes into account the heterogeneity between European countries. Over 2000-2006, the United Kingdom, Ireland, Finland and Sweden were in the upper range of labour productivity growth performance in Europe, whereas Italy, Spain, Portugal and the Netherlands were in the lower range (Figure 2). The latest forecast for the United Kingdom in 2007 is quite high at 2.8%.[2] In contrast, it is at 0.6% for France. The paper investigates whether this performance heterogeneity is due to different propensities of being ICT intensive in the recent past.

Figure 2. Labour productivity growth in Europe, 1985-2006



Source: OECD Productivity Database.

4. Well-known stylised facts are highlighted by the descriptive analysis:

a) Until the second half of the 1990s, the EU15 outperformed the United States in terms of labour productivity growth.[3] As from then, the United States experienced an increase in productivity growth, whereas EU15 labour productivity growth kept on decreasing. The trend in the

2. Based on OECD Economic Outlook 83 projections.

3. EU15 is defined as a weighted average based on each country's GDP at PPP. Throughout the paper EU15 is without Austria because of the lack of data on hours worked before 1990 for this country.

productivity growth gap between the United States and the EU15 reached a peak in the early years of the 2000s, and has decreased since then.

b) During the 1996-2006 decade, Spain and Italy have been driving down the European labour productivity growth trend, whereas Ireland, Finland, Sweden and the United Kingdom have been pushing it upwards.

c) During the 1996-2006 decade, European ICT-intensive countries have been performing better in terms of structural labour productivity growth than non-ICT-intensive countries.

5. This paper contributes to the literature that both identifies and dates breaks in labour productivity growth in the United States and in Europe, using statistic and econometric techniques, as in Benati (2007), European Commission (2007), Gomez-Salvador (2006), Hansen (2001) and Stiroh (2001). It also brings in new elements. First, it extends data time coverage and makes use of three labour productivity growth forecasts up to 2009 - an upper, a central and a low scenario.[4] Second, whereas few studies have concerned individual European countries, the current paper estimates the structural breaks in labour productivity growth on a country-by-country basis. It also provides the test and dating of structural breaks in the *difference* between US and EU15 labour productivity growth rates. Finally, it sheds some light on the contrasted patterns of the ICT and non-ICT groups of countries in terms of their labour productivity growth developments.

6. The main findings of the paper are the following:

a. Identification of structural break in US labour productivity growth is far from obvious at conventional test sizes. The tests for structural change over 1970-2007 fail to identify a break, with the exception of the manufacturing sector around 1993.

b. It is only if relatively high growth rates of labour productivity are reached in the future (upper forecast scenario) that a statistically significant break date is found around 1998 in the United States and the structural break, presumably due to ICT, is confirmed.

c. In Europe, statistically significant downward shifts in structural labour productivity growth are found around 1979 and at the end of 2000.

d. However, if future growth of labour productivity in Europe were consistent with the upper scenario, the slowdown after 2000 would not be identified as a structural shift.

e. A clear breakpoint is found in 1995 for the *difference* in labour productivity growth between the United States and the EU15, the estimated difference in annual growth rates jumping from -1.6 percentage points over 1970-1995 to 0.5 p.p. over 1996-2006. This breakpoint, however, disappears when controlling for the difference in lagged productivity levels. The latter finding suggests that the 1995 breakpoint is due to both the initial catch-up of Europe and the halt of the convergence process in the mid-1990s, rather than to different ICT performances. Moreover, the very recent decrease in the gap is not captured as a statistically significant structural break, emphasising that the 2004-2006 developments in both areas were mostly cyclical.

4. As described in the Annex 1, the data coverage is 1970-2006 for the EU15, and 1970-2007 for the United States. The forecasts are based on time-series analysis and on OECD Economic Outlook 83 projections.

f. Yet, the European countries that have similar timing of the structural shifts in their labour productivity growth are devoting comparable effort to ICT. This suggests that in Europe the accumulation of ICT capital is correlated to structural shifts in labour productivity.

g. In the United States, a structural increase of growth in ICT capital services is estimated to have taken place after 1995, followed by a strong fall after 2001. These breaks do not translate into breaks at the total economy level.

7. The paper is organised as follows. The next section presents a brief review of the literature. Section 3 deals with the nature — cyclical or structural — of the recent evolution of labour productivity growth in the United States and in Europe, as well as across European countries and across groups of countries based on their ICT intensity. Different scenarios based on forecast analysis are presented. The fourth section assesses the statistical significance of breaks in labour productivity growth. Results are provided for the United States and Europe, individual European countries, and high and low ICT intensity country groups in Europe. The data are described in the Annex 1.

2. Overview of the literature

8. The focus of this paper is the timing and extent of breaks in labour productivity growth rather than the identification of the determinants of labour productivity growth. An initial literature predominantly made use of growth decomposition techniques to document the sources of the shifts in labour productivity growth with specific attention placed on the role of ICT.[5] These studies have two shortcomings concerning the identification of the structural trends in productivity. First, they presume a breakpoint in 1995 in US labour productivity growth. While the average annual labour productivity growth has strongly increased after 1995, an *a priori* selection of the break date is not satisfactory from a statistical point of view. The break date should be estimated as the one for which the shift in trend is statistically significant. Secondly, as Hansen (2001) underlines, structural change has a meaning only in the context of a model, and occurs when the model's parameters change over time at some breakpoints.

9. The current paper overcomes these issues by relying on the econometrics of structural change, which allows for both the identification of multiple structural shifts in series and their dating with confidence intervals. The amount of work in this field is voluminous and surveyed by Perron (2006). In particular, substantial advances have been made by Bai and Perron (1998, 2003) to cover models at a high level of generality. Their methodology is now widely implemented in applied studies and is the one used in the current paper. The break tests are adequate for detecting sudden shifts. Conversely, such tests might have a low power to identify drifts when the underlying series is driven by too gradual changes (Benati, 2007).

10. For the United States, the results obtained in this literature depend upon the sectoral coverage (non-farm business, manufacturing, total economy) and the period under study (Table 1). For the non-farm business sector, Benati (2007) investigates changes in the growth of labour productivity using data from the Bureau of Labor Statistics (BLS) over 1947:1-2005:4. The Bai and Perron (1998, 2003) test for structural change fails to identify any statistical break for growth in output per hour. In an earlier paper, Stiroh (2001) uses one of the methodologies that served as a basis for the Bai and Perron (1998, 2003) test, which allows to estimate just one unknown break point and then test for the significance of the change. The data used in this study are from the Bureau of Economic Analysis (BEA) and cover 1974:1 to 2000:3. The

5. Gordon (2000, 2004), Jorgenson and Stiroh (2000), Jorgenson, Ho and Stiroh (2002, 2006, 2007), and Oliner and Sichel (2000, 2002). See Jorgenson, Ho and Stiroh (2007) for a comprehensive survey of this literature for the United States, as well as Gordon and Dew-Becker (2005) for a complementary analysis; see also Gust and Marquez (2000) for the other main industrialised countries.

result for the non-farm business sector fails to detect any statistically significant breakpoint. However, for the manufacturing sector, Stiroh (2001) estimates a breakpoint in 1993:3 which is statistically significant. Hansen (2001) also finds a breakpoint in 1997 in the manufacturing/durables sector with the Bai and Perron (1998, 2003) methodology. For the total economy, using the Groningen Growth and Development Center (GGDC) Total Economy Database over 1950-2006 and the same methodology, Gomez-Salvador *et al*. (2006) find two break dates in the United States labour productivity growth in 1973 and in 1995.

Table 1. Overview of the previous results

Paper	Data source and scope	Data period	Data frequency	Statistical approach	Break(s) identified
		UNITED STATES			
Benati (2007)	USA Non-farm business, BLS	1947:1-2005:4	quarterly	Bai and Perron (1998, 2003)	No break
Stiroh (2001)	USA Non-farm business, BEA	1974:1-2000:3	quarterly	estimation of one break date	No break
Stiroh (2001)	USA, Manufacturing, BEA	1974:1-2000:3	quarterly	estimation of one break date	1993:3
Hansen (2001)	USA Manufacturing/ durables, BLS	1947:1-2000:4	quarterly	Bai and Perron (1998) among others	1997
Gomez-Salvador *et al.* (2006)	USA, Total Economy, GGDC Database	1950-2006	annual	Bai and Perron (1998, 2003)	1973, 1995
		EUROPE			
Benati (2007)	Euro-zone, Total Economy, European Central Bank Area Wide Model Database	1970:1 – 2006:2	quarterly	Bai and Perron (1998, 2003)	2001:1
Gomez-Salvador et al. (2006)	Euro-zone, Total Economy, GGDC Database	1950-2006	annual	Bai and Perron (1998, 2003)	1973, 1979, 1995
EC (2007)	Euro-zone, Total Economy, Eurostat	1980:1 – 2006:4	quarterly	Bai and Perron (1998, 2003) on trend extracted by filter. BIC criteria.	1998:1

11. The case of Europe's labour productivity growth is documented by Benati (2007), Gomez-Salvador *et al*. (2006) and the European Commission (2007) (*Table 1*). Benati (2007) uses quarterly series of the euro-zone real GDP per worker from the European Central Bank Area Wide Model Database over 1970:1 – 2006:2. One breakdate is found in 2001:1 that leads to a period of lower labour productivity. Using the GGDC Total Economy Database over 1950-2006, Gomez-Salvador *et al*. (2006) find three break dates in the Euro Area annual growth of labour productivity per hour. The break dates reported are 1973, 1979 and 1995. All the structural changes identified give rise to a period of lower labour productivity growth. The European Commission (2007) studies structural breaks in labour productivity growth in

Europe using the private business sector Eurostat data over 1980:1 – 2006:4.[6] According to this estimation, one break is found for the euro area in 1998:1 (the mean of labour productivity growth that follows the break date is lower).

12. With respect to individual EU countries, the European Commission (2007) finds that Germany shows a break in 1987:1 (downwards) and France in 1998:2 (downwards). Italy shows two breaks, in 1983:2 (upwards) and 1997:2 (downwards), and Spain three breaks in 1985:1 (downwards), 1991:1 (upwards) and 1994:4 (downwards).

3. Standard Hodrick-Prescott filtering of the trends

13. The 2004-2006 acceleration of labour productivity in Europe from a low growth rate and the deceleration in the United States are closely related to the pace of economic activity, suggesting that they may be of cyclical nature.[7] To shed light on this issue, statistical techniques are used both to disentangle the trend and the cyclical components of labour productivity growth and to determine whether labour productivity growth has been subject to shifts.

Table 2. Trend/cycle breakdown of labour productivity growth
(annual data, Hodrick-Prescott filtering with lambda=30)

EU15

	Labour productivity growth	Trend	Cycle
1985-1995	2.1	2.1	0.0
1996-2006	1.5	1.5	0.0
2000-2006	1.2	1.4	-0.1
2000-2003	1.2	1.5	-0.2
2004-2006	1.3	1.3	0.0
2007*	1.2	1.2	0.0

United States

	Labour productivity growth	Trend	Cycle
1985-1995	1.2	1.4	-0.2
1996-2006	2.1	2.1	0.0
2000-2006	2.2	2.2	-0.1
2000-2003	2.7	2.3	0.3
2004-2006	1.3	2.1	-0.8
2007	1.4	2.0	-0.6

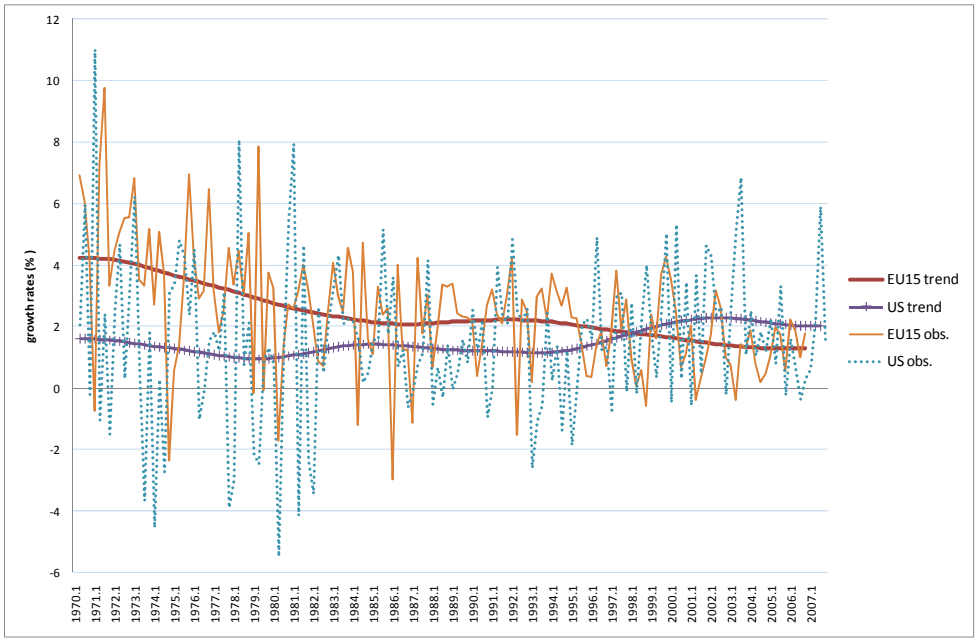
Source: OECD Productivity Database, *OECD Economic Outlook* 83
Database for 2007 EU15 labour productivity growth, and BLS for 2007

6. The methodology differs in that the series are first filtered before the Bai and Perron (1998, 2003) test for structural breaks are run on the extracted trend. Moreover, the criteria employed to select the number of breaks is the Bayesian information criteria (BIC) which is weaker than the sequential procedure of Bai and Perron (see simulation analysis in Bai and Perron, 2006). Model selection procedure based on information criteria cannot take into account potential heterogeneity across time segments unlike the sequential method and shows limits when serial correlation is present.

7. As a matter of fact, EU15 annual labour productivity growth is estimated to have fallen from 1.7% in 2006 to 1.2% in 2007 (on the basis of the three first quarters and without Austria, Portugal and Greece, OECD Economic Outlook 83 projections).

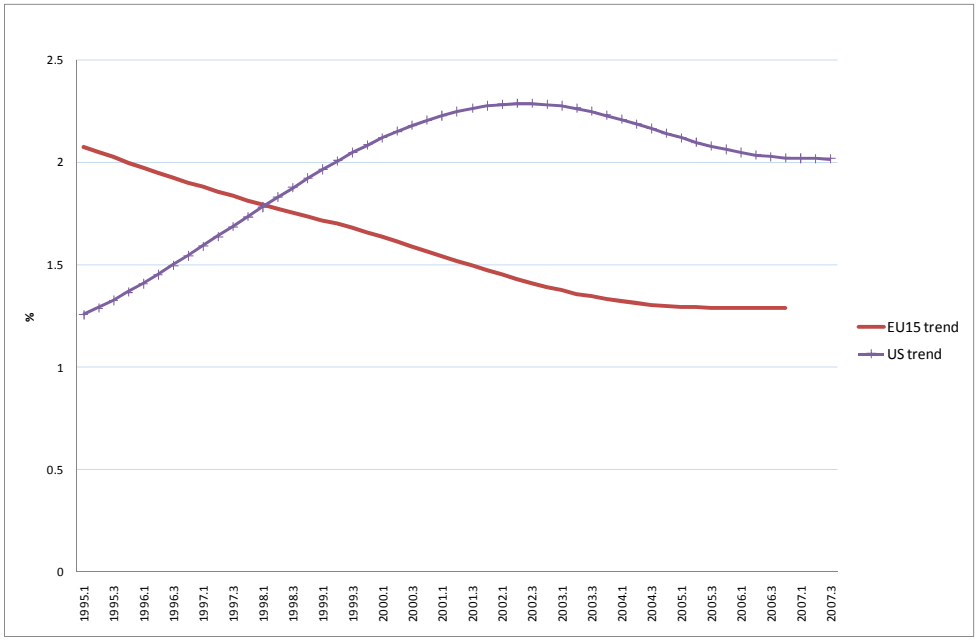
US labour productivity growth rates in the non-farm business sector.
Hodrick-Prescott filtering (lambda=30).
* The 2007 EU15 labour productivity growth figure is based on *OECD Economic Outlook* 83 projections.

Figure 3A. US and EU15 labour productivity growth rates, observations and trends, quarterly data, 1970:1 - 2007:4



Source: OECD Economic Outlook 83 Database, and BLS for 2007 US labour productivity growth rates in the non-farm business sector. Hodrick-Prescott filtering (lambda=7000).

Figure 3B. Zoom on US and EU15 labour productivity growth rate trends, quarterly data, 1995:1 - 2007:4



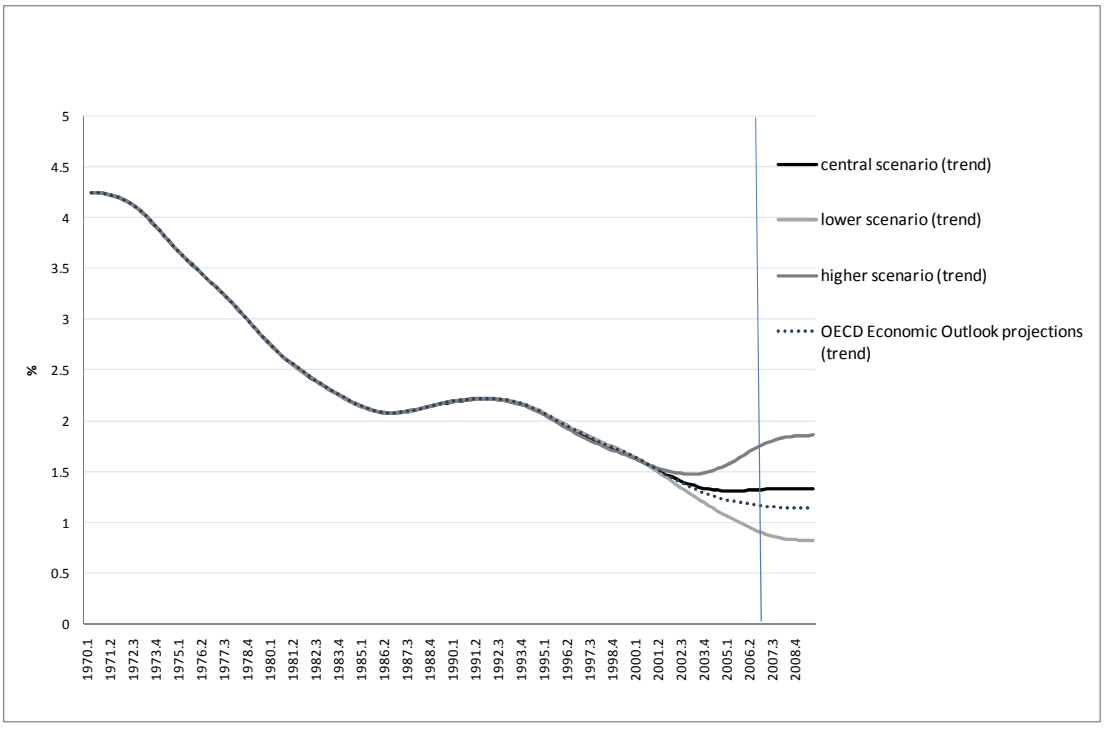
Source: OECD Economic Outlook 83 Database, and BLS for 2007 US labour productivity growth rates in the non-farm business sector. Hodrick-Prescott filtering (lambda=7000).

14. For descriptive purposes, Hodrick-Prescott (HP) filtering has been employed to identify trends in labour productivity growth. Figures 3a and 3b show the inversion in trends that occurred in the second half of the 1990s between Europe and the United States. Since then, the United States have outperformed the EU15 in terms of labour productivity growth. The trend gap between the United States and the EU15 reached a peak in the early years of the 2000s but has decreased since then. However, it can be noted from Table 2 that much of the decrease in US labour productivity growth over 2004-2006 could be cyclical.

15. To gain further insight into possible shifts in labour productivity growth in recent years, both in the United States and in Europe, a forecast for US and EU15 labour productivity growth up to 2009:4 is made using time series analysis methods, as well as a confidence interval for the forecast consisting of an upper and a lower scenario at the 95% confidence level. It gives three series of labour productivity growth consisting of the observed data supplemented by the forecasts, namely the central, the upper and the lower scenarios. All scenarios are then decomposed into structural and cyclical parts, in order to compute three alternatives in labour productivity growth. Figure 4 shows the central, upper and lower trend scenarios obtained for the United States and the EU15.[8,9]

Figure 4A. EU15 growth rate trends in labour productivity, quarterly data 1970:1 - 2006:4, and arima forecast to 2009:4

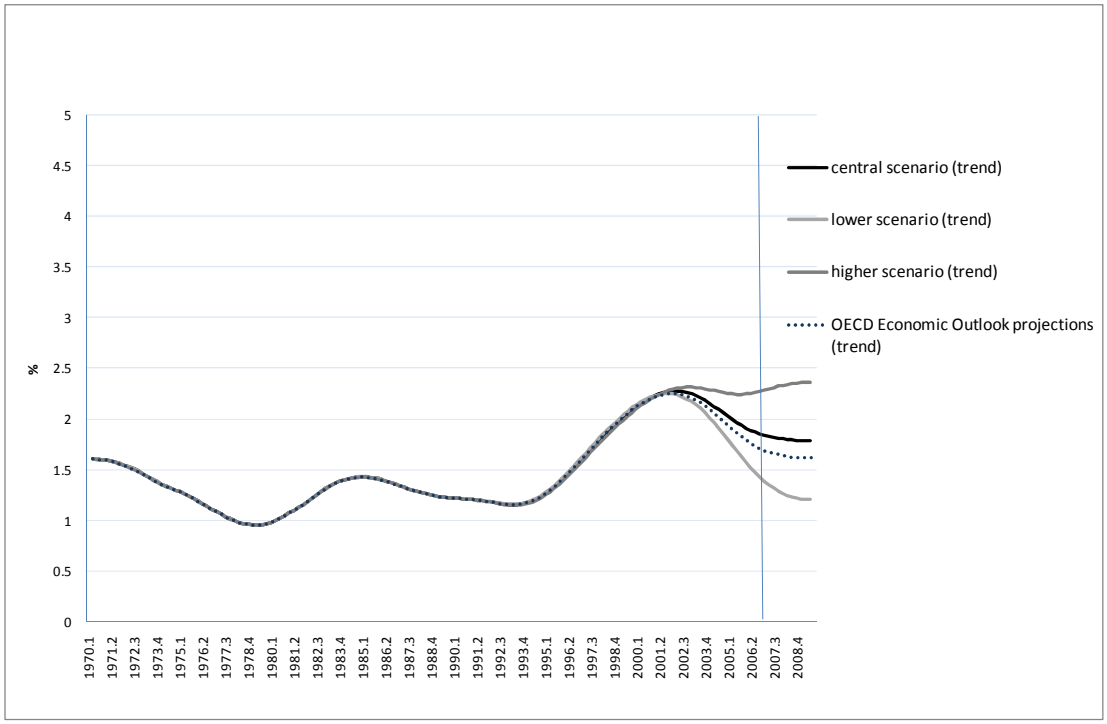
Central, upper and lower projected trends in labour productivity growth



8. These scenarios are based on ARIMA forecasts of the labour productivity series. The model that fits the EU15 is an ARIMA with differentiation parameter d=1, AR parameters p=9, 10, 11, 21, 22, 23 and MA parameter q=0, whereas the model for the USA is an ARIMA where d=1, p=9, 12 and q=0. The trends are robust to various specifications.

9. The HP trends based on the OECD Economic Outlook 83 projections for the US and EU15 labour productivity growth up to 2009:4 are shown in Figure 4 as well. The trend based on these projections is close to the central scenario based on ARIMA forecasts, albeit slightly below (but above the lower scenario). The purpose of using time-series-based forecasts is to get the upper and the lower scenarios.

Figure 4B. US growth rate trends in labour productivity, quarterly data 1970:1 - 2007:4, and Arima forecast to 2009:4



Source: OECD Economic Outlook 83 Database, and BLS for 2007 US labour productivity growth rates in the non-farm business sector. Hodrick-Prescott filtering (lambda=7000).

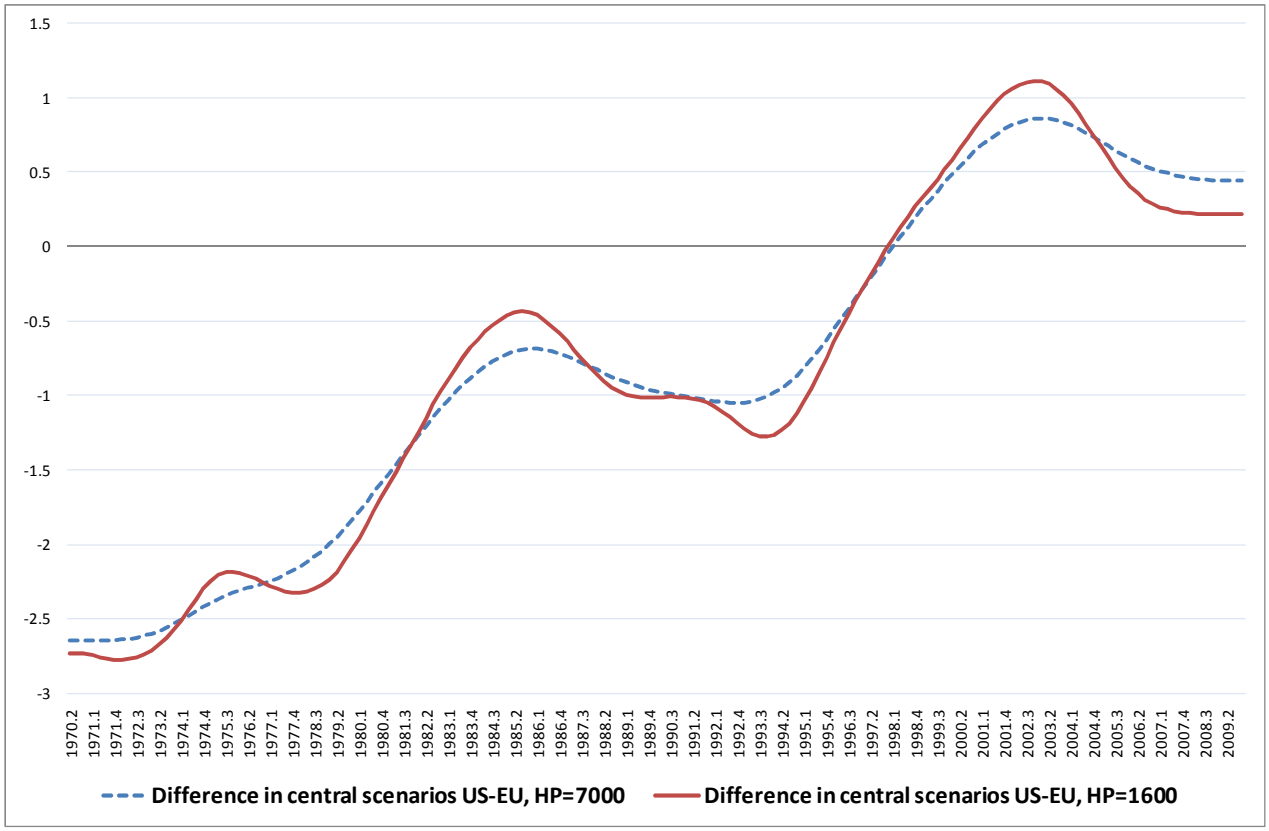
16. The robustness of the identified trends is subjected to two limitations that the tests reported in Section 4 partly overcome.

- One of the well documented drawbacks of the HP filter is that at the end of the sample, the filter becomes one-sided and the contemporaneous data are given a weight that is much greater than in the middle of the sample. This effect can be seen on Figure 4: the upper and lower scenarios are diverging from the central scenario as soon as 2003:4, even though values are forecasted from 2006:4 only and observed data used before.

- Trends are to some extent sensitive to the filtering parameter.[10] When using the lambda=1600 filter, the central prediction is that the post-1995 gap between US and EU15 labour productivity growth is shrinking quicker and reaching a lower level in 2009 than when using the lambda=7000 filter (Figure 5).

10. A filter should include around 90% of the short cycles amplitude in the cyclical component, and under this constraint, the percentage of the long cycles amplitude included in the cyclical component should be as low as possible. On this basis, HP filtering on annual data requires lambda=30 (Bouthevillain, 2002). Lambda=30 leads to a value of 91% of the short cycles amplitude included in the cyclical component and 41% of the long cycles amplitude included in the cyclical component. Lambda=100 – the value suggested by Hodrick and Prescott- leads to a value of 97% of the short cycles amplitude included in the cyclical component but to 70% of the long cycles amplitude included in the cyclical component. On quarterly data, lambda=7000 corresponds to lambda=30 on annual data. However, the usual value for international comparisons is lambda=1600 (which would correspond to lambda=7 on annual data). The different parameter specifications lambda=30 and lambda=100 have been studied on annual data as well as lambda=7000 and lambda=1600 on quarterly data.

Figure 5. Differences in central scenarios US *vs.* EU15, 1970:Q1 - 2009:Q4 according to the HP filtering parameter



Source: OECD Economic Outlook 83 Database up to 2006:4, and BLS for 2007 US labour productivity growth rates in the non-farm business sector. Arima forecasts to 2009:4.

17. The aggregate European labour productivity growth trend masks some heterogeneity between countries. During the 1996-2006 decade, Spain and Italy have been driving down EU15 labour productivity growth trend, whereas Ireland, Finland, Sweden and the United Kingdom have been pushing it upwards. These evolutions continue according to the 2007-2009 forecasts of labour productivity growth and the implied trend (Table 3).

18. Productivity developments differ systematically across countries depending on their propensity of being more or less ICT intensive over the recent past. Looking at the average growth in total capital services over 1996-2005 in the ICT sector, three groups of countries can be distinguished (Figure 6). An ICT-intensive group that includes Sweden, United Kingdom, and Ireland; a non-ICT-intensive group consisting of Germany, Italy, and Greece; an intermediary group with France, Finland, Belgium, Denmark, the Netherlands, Spain and Portugal.[11] It appears that the ICT-intensive group performed better since the mid-1990s (Figure 7). Table 3 shows that ICT-intensive countries are *structurally* performing better in terms of labour productivity growth than non-ICT-intensive countries since the trends in labour productivity growth are higher from 1996 onwards for the former countries.

11. No data on capital services in the ICT sector being available for Luxembourg, it is excluded from this country classification.

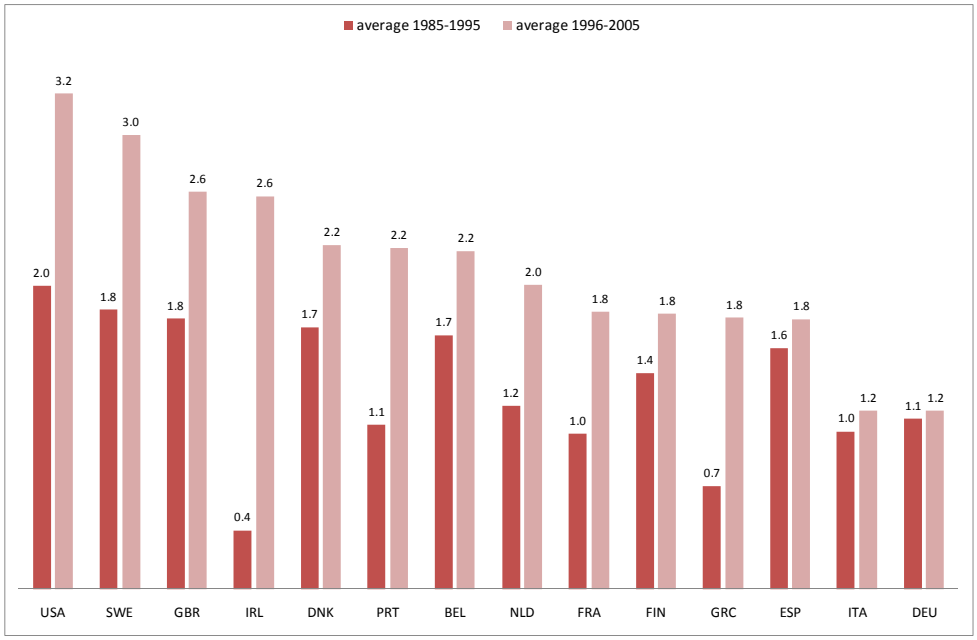
Table 3. Average growth rate of labour productivity (quarterly annualised)

	1985-1995			1996-2006			2000-2006			2007-2009*		
	LP	Trend	Cycle	LP	Trend	Cycle	LP	Trend	Cycle	LP	Trend	Cycle
BEL	2.2	2.2	0.0	1.4	1.4	0.0	1.1	1.3	-0.1	1.1	1.1	-0.1
DEU	2.7	2.7	0.0	1.7	1.6	0.1	1.6	1.4	0.2	1.0	1.3	-0.3
DNK	2.6	2.3	0.2	1.0	1.1	-0.1	1.0	1.0	0.0	1.3	1.0	0.3
ESP	1.8	1.8	-0.1	0.5	0.6	0.0	0.7	0.5	0.2	0.3	0.6	-0.3
FIN	3.2	3.2	0.1	2.6	2.4	0.2	2.6	2.3	0.3	1.8	2.4	-0.5
FRA	2.4	2.4	0.1	1.8	1.8	0.0	1.5	1.6	0.0	1.0	1.0	0.0
GBR	2.0	1.9	0.1	2.2	2.6	-0.4	2.0	2.8	-0.7	1.9	1.9	0.1
GRC	1.7	1.0	0.7	3.3	3.3	0.0	4.0	3.6	0.4	-	-	-
IRL	3.6	4.0	-0.4	4.3	4.0	0.3	3.0	3.4	-0.4	2.7	2.1	0.6
ITA	2.2	1.9	0.3	0.6	0.7	0.0	0.5	0.4	0.1	0.3	0.5	-0.2
LUX	3.0	3.0	0.0	2.0	1.7	0.2	1.8	1.7	0.1	0.9	1.4	-0.5
NLD	1.5	1.7	-0.2	1.3	1.4	-0.1	0.8	1.1	-0.4	1.3	0.9	0.4
PRT	3.0	2.6	-0.4	1.7	1.9	0.2	1.2	0.8	-0.3	-	-	-
SWE	1.6	1.6	0.0	2.5	2.3	0.2	2.5	2.2	0.3	0.4	1.4	-1.0
EU15	**2.1**	**2.1**	**0.0**	**1.5**	**1.5**	**0.0**	**1.2**	**1.4**	**-0.1**	**1.4**	**1.3**	**0.0**
ICT	2.4	2.5	-0.1	3.0	3.0	0.0	2.5	2.8	-0.3	2.8	2.4	0.5
Intermediary	2.3	2.2	0.1	1.7	1.7	0.0	1.6	1.5	0.0	1.1	1.2	0.0
non-ICT	2.5	2.3	0.2	1.2	1.2	0.1	1.1	0.9	0.2	0.7	0.9	-0.3

Source: OECD Economic Outlook 83 Database. Hodrick-Prescott filtering (lambda=7000).

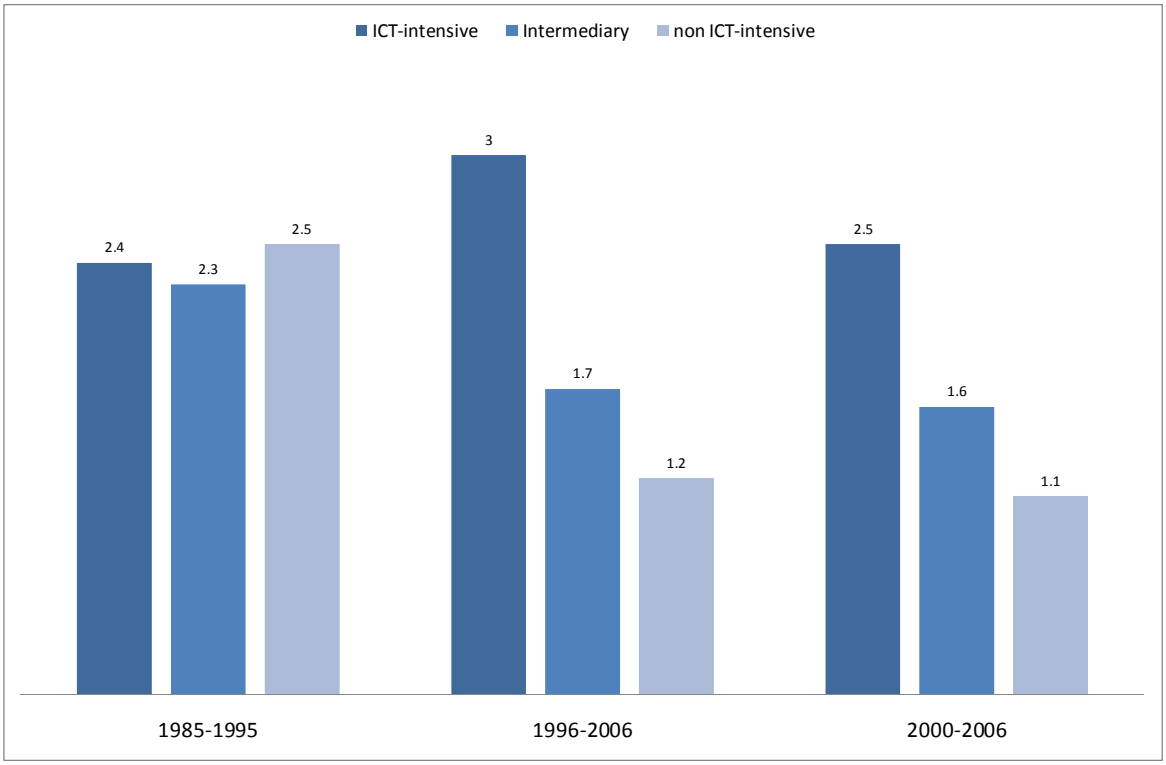
* Based on OECD Economic Outlook 83 projections for countries and on the central ARIMA projection for EU15 (see Section 3). No forecasts are available for Portugal or Greece.

Figure 6. Annual growth rate of total capital services (in %), ICT sector, United States and Europe, 1985-2005



Source: OECD Capital-Services Database. No data are available for Luxembourg.

Figure 7. Unweighted average of labour productivity growth rates (annualised) across ICT European country groups, 1985-2006



Source: OECD Economic Outlook 83 Database.

4. An econometric assessment of structural breaks in labour productivity growth

19. This section investigates the existence and importance of multiple breaks in labour productivity growth since 1970 using the segmented trend approach developed in the context of the econometrics of structural change and more specifically the Bai and Perron (1998, 2003) test. This section is organised as follows. The next subsection describes briefly the methodology. Subsection 4.2 presents the results from the Bai and Perron sequential procedure for the EU15. Subsection 4.3 focuses on the United States, and subsection 4.4 gives the results for the difference between the United States and EU15. The last subsection deals with the European countries and groups of countries based on their ICT intensity.

4.1 Methodology

20. The econometrics of structural change provides statistical answers to the questions of the existence, number and dates of structural shifts in labour productivity growth and has the advantage to date the breaks without any *a priori* hypothesis about the length of the economic cycles. It also indicates how statistically significant the shifts are. Therefore it overcomes these two limits of the HP filtering.

21. Breaks in labour productivity growth being the issue of interest, the estimation concerns the shifts in the mean of the labour productivity growth. The model used for testing structural change and estimating the number of break dates is the following, for *m* breaks at dates T_m:

$$\Delta y_t = \beta_1 + \sum_{k=1}^{m} \beta_{k+1} I(t > T_k) + v_t$$

where Δy_t is labour productivity growth, $(\beta_1, \ldots, \beta_m)$ the parameters, and v_t the error term.

The Bai and Perron (1998, 2003) method of estimation of the candidate break dates is based on the least-squares principle and uses grid-search.[12] The methodology covers models at a level of generality that permits numerous practical applications. In particular, it allows for autocorrelation and heteroskedasticity in the residuals and different distribution for the data and for the errors across segments. The results of the test are reported at conventional test sizes of 5% or 10%.

12. For each *m*-partition *(T1, ..., Tm)*, the associated least squares estimates of the parameters *(β1, ..., βm)* are obtained by minimising the sum of squared residuals. Substituting the resulting estimates in the objective function and denoting the resulting sum of squared residuals *S(T1, ..., Tm)*, the estimated break points $\left(\hat{T}_1,\ldots,\hat{T}_m\right)$ are the solution of the minimisation of *S(T1, ..., Tm)* over all partitions. Then, the stability tests are implemented. The procedure is sequential. First, stability of the trend is tested against the hypothesis of one break. If stability is rejected, then one break date is imposed on the model, and the hypothesis of one break is tested against the hypothesis of two breaks. The second break date is obtained by testing all the possible models with two breaks knowing the first break date against the one break model. The procedure is repeated until the number of breaks and the corresponding break dates are determined. A maximum of 5 breaks have been allowed for this study. In the remaining of the text, the results of the sequential procedure are reported at the 5% or 10% significance level.

4.2 Results for the EU15

22. Testing for structural change on quarterly data over 1970-2006 gives two break dates in 1979:2, and in 2000:2.[13] After each break, the estimated average growth of labour productivity is lower (Table 4). These results are in line with the literature reviewed above. Additional tests applied to the difference in the US and EU15 series, and reported in sub-section 4.4, suggest that these structural shifts found for the EU15 might be due to a convergence effect towards the steady state having fostered growth in the catch-up phase. This convergence has remained incomplete as the catch-up stopped in the mid-1990s.

23. It is interesting to investigate whether adding forecasted values up to 2009:4, according to the central, upper and lower scenarios seen in Section 3 alters the results. Testing multiple structural breaks in either the central or lower scenario does not modify the results, whereas it does in the upper scenario. A break is always found in 1979. Another break is found at the end of 2000 in the central and in the lower scenarios, as when the data are limited to 2006. But if future productivity growth were consistent with the upper scenario, the slowdown after 2000 would not be identified as a structural break (Table 4).

Table 4. Results of the Bai-Perron sequential test at significance level of 5% - EU15

Data 1970q1-2006q4		Central scenario up to 2009q4		Lower scenario up to 2009q4		Higher scenario up to 2009q4	
Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity
70q1-79q2	4.1***	70q1-79q2	4.1***	70q1-79q2	4.1***	70q1-79q2	4.1***
79q3-00q2	2.1***	79q3-00q2	2.1***	79q3-00q2	2.1***	79q3-06q4	2.0***
00q3-06q4	1.2***	00q3-06q4	1.3***	00q3-06q4	1.0***		

*** indicates that estimates are significant at the 1% level

4.3 Results for the United States

24. For the United States, the outcome differs according to whether the non-farm business sector or the manufacturing sector is considered. The results are the following, as reported in Table 5.

a. For the non-farm business sector, the test on data covering 1970-2007 gives no statistically significant break dates in US labour productivity growth even at the 10% level. Adding forecasted values up to 2009:4 according to the central, upper and lower scenarios seen in Section 3provides an additional insight. It is only if relatively high growth rates of labour productivity were reached in the future, *i.e.* consistent with the upper scenario, that the structural break of the mid-1990s, presumably due to ICT, would be confirmed. With the upper scenario, a statistically significant break date is found in 1998:3. This means that in the central scenario, although there has been a clear pick-up in productivity growth in the second half of the 1990s, the size of the hump is not large enough compared with past variation to make this change a statistically significant break.

13. On annual data over the same period, the break points found are 1979 and 1995. Quarterly data show more variation than annual data. On the other hand, they provide more observations. Consequently, results obtained on annual or quarterly data can differ.

b. For the manufacturing sector over 1987:2 to 2007:4, a break is found in 1993:3.[14,15]

c. In order to gain more insight on the structural evolution of labour productivity in the United States, breaks in some of the series related to labour productivity growth – capital deepening growth, multifactor productivity growth, labour quality growth and ICT capital accumulation – have been studied between 1970 and 2006. The results are reported in Annex 2. The finding is a structural acceleration of growth in ICT capital services after 1995, followed by a sharp fall after 2001. This analysis implies that these breaks do not translate into breaks at the total economy level.

Table 5. Results of the Bai-Perron sequential test at significance level of 5% - United States

Data 1970q1-2007q4		Central scenario up to 2009q4		Lower scenario up to 2009q4		Higher scenario up to 2009q4	
Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity	Periods identified by the BP test	Estimated average growth rate of labour productivity
Non-farm business sector							
Non-significant	_	non significant	_	non significant	_	70q1-98q3 98q4-09q4	1.3*** 2.4***
Manufacturing							
87q2-93q3 93q3-07q4	2.5*** 4.3***	n.a	n.a	n.a	n.a	n.a	n.a

*** indicates that estimates are significant at the 1% level

4.4 Results for the difference in the US and EU15 series

25. One advantage of looking at the difference between the US and EU15 series of labour productivity growth is to control for the effect of global shocks impacting both zones. Studying the difference in the US and EU15 series of labour productivity growth over 1970:1-2006:4 leads to the identification of a structural increase in the gap in labour productivity growth between the two areas after 1995:2. The results are reported in Table 6.

26. The recent decrease in the gap is not captured as a structural break, which emphasises that the 2004-2006 developments in both areas were mostly cyclical.

14. This result is obtained at the test significance level of 10% (instead of at 5% as in the rest of the text). No forecast scenarios are made due to the time span of the data.

15. As discussed earlier, for the total economy, using the Groningen Growth and Development Centre (GGDC) Total Economy Database over 1950-2006, Gomez-Salvador *et al*. (2006) finds two break dates in the United States labour productivity growth in 1973 and in 1995. Those breaks are not found using the BLS data at the non-farm business sector level over the same period. In order to understand the result of Gomez-Salvador *et al*. (2006), the structural change test was ran for the same sectoral coverage of data, *i.e.* the total economy, using the OECD Economic Outlook 83 database. The period covered could not be greater than 1960-2006 due to data availibility. The result of the test gives a break date in 1968. Over the same period of 1960-2006, the GGDC data also support a similar unique break date in 1966. This means that the results of Gomez-Salvador *et al*. (2006) depend both on the sectoral coverage (total economy versus non-farm business) and the starting date (1950 versus 1960).

27. Adding time-series-based forecasted values up to 2009:4, according to the central, upper and lower scenarios, does not change the result.

Table 6. Results of the Bai-Perron sequential test at significance level of 5% - Difference between United States - EU15

Data 1970q1-2006q4		Central scenario up to 2009q4		Lower scenario up to 2009q4		Higher scenario up to 2009q4	
Periods identified by the BP test	Estimated difference in growth rates	Periods identified by the BP test	Estimated difference in growth rates	Periods identified by the BP test	Estimated difference in growth rates	Periods identified by the BP test	Estimated difference in growth rates
70q1-95q2	-1.6***	70q1-95q2	-1.6***	70q1-95q2	-1.6***	70q1-95q2	-1.6***
95q3-06q4	0.6	95q3-06q4	0.6	95q3-06q4	0.5	95q3-06q4	0.6

*** indicates that estimates are significant at the 1% level

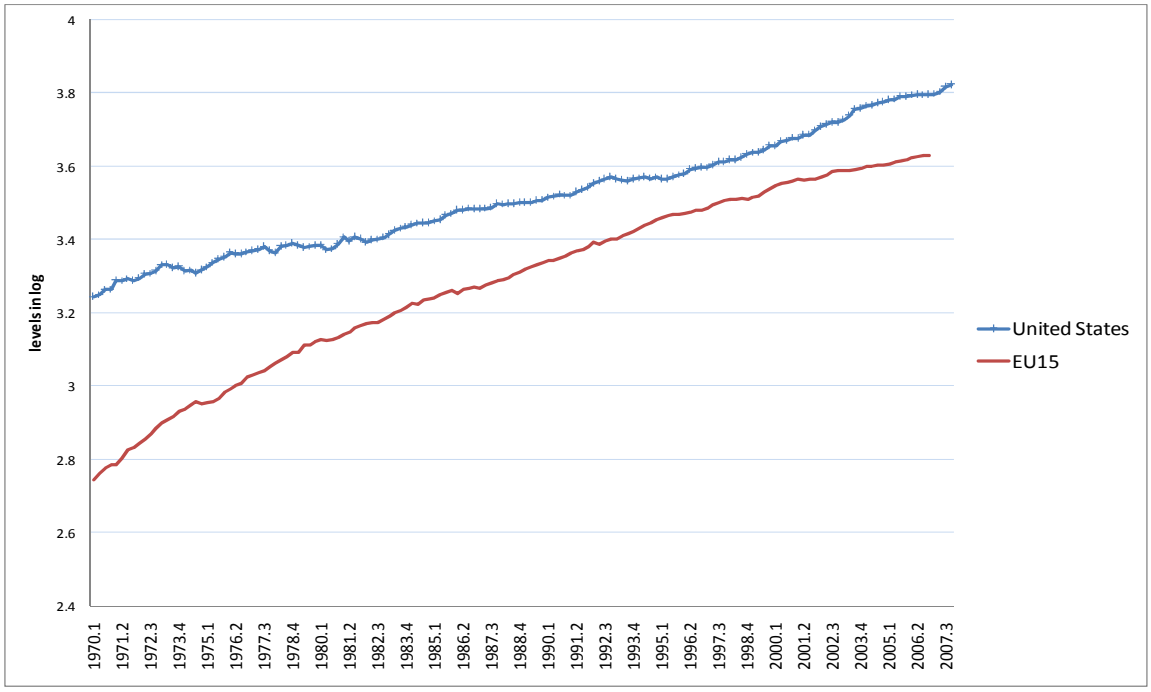
28. Before 1995, the over-performance of Europe in terms of labour productivity growth might be due to a convergence effect towards the US level. Figure 8 displays the stronger EU15 labour productivity growth until the mid-1990s, while the United States evolved on a more steady growth path at higher labour productivity levels. In order to explore this hypothesis of a convergence effect, the test for structural change is run controlling for the difference in the levels of labour productivity (in logarithms). Within the Bai and Perron (1998, 2003) framework, the model used is the following:

$$\Delta x_t = \beta_1 + \sum_{k=1}^{m} \beta_{k+1} I(t > T_k) + \delta x_{t-1} + v_t$$

where Δx_t is the difference in US and EU15 labour productivity growth, x_{t-1} the difference in US and EU15 labour productivity levels (in logarithms), $(\beta_1, \ldots, \beta_m, \delta)$ the parameters, and v_t the error term.

29. The estimation points to no break but to a convergence effect with an estimated annual speed of convergence of 9.3%. This observation suggests that the identified break in 1995:2 could be mostly explained by the interruption of the convergence process, despite remaining large level differences, rather than by the effect of ICT. This seems to imply that the pattern of the gap evolution is mainly driven by the EU15 growth rate changes, which, in turn, might explain why no break is found when focussing on the US series only.

Figure 8. Labour productivity levels in the United States and in Europe, 1970:1 - 2007:4 at 2000 PPP, USD



Source: OECD Economic Outlook 83 Database.

4.5 Results for the European countries and the ICT groups of countries

30. Finally, heterogeneity in Europe across countries and across ICT groups of countries has been taken into account. The results are summarised in Tables 7 and 8. The European countries that have similar timing of the structural shifts in their labour productivity growth are also part of the same ICT group. This suggests that in Europe the accumulation of ICT capital is correlated to structural shifts in labour productivity.

a. As for the United States, no significant break is found for the United Kingdom, Sweden, and Ireland. Those countries are all part of the ICT- intensive group.

b. Italy and Germany experienced a structural change (downwards) in the labour productivity growth around the end of 1979 according to the tests. Both countries are part of the non-ICT-intensive group.

c. The break (downwards) in France and Spain is estimated to have occurred around the late 1980s. Both countries are part of the intermediary ICT group.

Table 7. Results of the Bai-Perron sequential test at significance level of 5% for selected countries

Countries	Periods identified by the BP test	Estimated average growth rate of labour productivity
FRA	1970:Q1- 1989:Q4	3.5***
	1990:Q1- 2006:Q4	1.8***
ESP	1970:Q1- 1986:Q2	4.4***
	1986:Q3- 2006:Q4	1.0***
DEU	1970:Q1- 1979:Q2	4.6***
	1979:Q3- 2006:Q4	2.1***
ITA	1970:Q1- 1979:Q4	4.3***
	1980:Q1- 2006:Q4	1.3***
GBR	non significant	_
SWE	non significant	_
IRL	non significant	_

*** indicates that estimates are significant at the 1% level

31. The study of the *difference* in labour productivity growth between Europe-ICT and Europe non-ICT[16] over 1970:1-2006:4 gives a break point at the end of 1990, indicating that labour productivity has structurally grown faster in Europe ICT than in Europe non-ICT after this point.

Table 8. Results of the Bai-Perron sequential test at significance level of 5 % - Difference between Europe ICT and Europe non-ICT

Periods identified by the BP test	Estimated difference in growth rates
1970q1-1990q4	-0.5*
1991q1-2006q4	1.0**

** indicates that estimates are significant at the 5% level, * at the 10% level.
Europe-ICT and Europe non-ICT labour productivities are unweighted averages.

5 Conclusion

32. This paper aimed at assessing the existence and extent of structural shifts in US and EU15 labour productivity growth since 1970. Four main conclusions emerge from the econometric tests. First, there seems to have been a structural slowdown in EU15 labour productivity growth around 1979 and again around 2000. Second, the pick-up in United States labour productivity growth, presumably due to ICT, would be statistically measured as a break only if relatively high growth rates of labour productivity were reached in the future. Third, a clear breakpoint is found in 1995 for the *difference* in labour productivity growth between the United States and the EU15. However, this breakpoint disappears when controlling for a convergence effect of Europe towards United States levels. Moreover, the 2004-2006 changes in labour productivity growth rates in Europe and in the United States are not captured as structural breaks, which suggest that these developments were mostly cyclical. Fourth, looking at individual European countries,

16. Europe ICT consists of the European countries in the ICT-intensive group, and Europe non-ICT of the European countries of the two other groups, non-ICT-intensive and intermediary.

the paper shows that ICT-intensive countries have been structurally performing better in terms of labour productivity growth since 1990.

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ANNEX 1: DATA

1. Labour productivity is defined as GDP per hour. Annual data for the European countries come from the OECD Productivity Database and cover 1970 to 2006. Quarterly data come from the OECD Economic Outlook 83 database and cover 1970:1 to 2006:4. The data are available at the aggregate country level. They cover the total economy.

2. For the United States, the OECD Economic Outlook 83 database is used between 1970 and 2006 for the total economy and updated for 2007 using the Bureau of Labour Statistics (BLS) numbers. The non-farm business sector is the one studied. However, the BLS also provides historical series of annual labour productivity growth for the non-farm business sector from 1948 as well as a quarterly series for manufacturing from 1987. Section 4 makes use of those data in order to allow comparison of results with the existing literature.

3. Also, in Section 4, in order to gain more insight about the structural evolution of labour productivity in the United States, capital deepening, multifactor productivity growth and labour quality have been studied, as well as ICT capital trends. The data on capital deepening (capital services divided by hours) are the annual data of the BLS between 1970 and 2006, and the quarterly data of the OECD Economic Outlook 83 database on capital stock in volume divided by hours between 1970:1 and 2006:4. Multifactor productivity growth is provided by the BLS on an annual basis between 1970 and 2006. Finally, the BLS provides annual data on labour composition between 1970 and 2006. Labour composition measures the effect of shifts in the experience, education, and gender composition of the work force. It is the ratio of labour input to hours of all persons, where labour input is a Tornquist aggregate of hours of all persons (classified by education, work experience and gender) using hourly compensation to determine weights. Two series of data were used to study the ICT capital trends over 1970-2006. Jorgenson and Stiroh (2007) have built a dataset which contains IT capital services' values and prices from 1948 to 2006. The ratio of these series, which approximate the quantity of IT capital services, is taken as the first series. The second data series considered is the BLS calculation of the contribution of IT capital intensity to aggregate productivity growth (growth rate of information processing equipment and software capital services per hour times its share in total costs) available also from 1948 to 2006.

ANNEX 2: BREAKS IN SOME COMPONENTS OF US LABOUR PRODUCTIVITY GROWTH

Periods identified by the BP test	Estimates
Capital deepening growth, 1970 – 2006	
1970 – 2006	2.9[1]
Multifactor productivity growth, 1970 – 2006	
1970 –2006	0.9[1]
Labour composition, 1970 – 2006	
1970 – 1979	0.0***
1980 – 2006	0.5***
ICT capital services growth, 1970-2006	
1970 – 1995	15.6***
1996 – 2001	21.4***
2002 – 2006	9.3***

*** indicates estimates at significant at the 1% level

Labour composition measures the effect of shifts in the experience, education, and gender composition of the work force. It is the ratio of labour input to hours of all persons, where labour input is a Tornquist aggregate of hours of all persons (classified by education, work experience and gender) using hourly compensation to determine weights.

The results reported for the ICT capital services growth rely on Jorgenson and Stiroh (2007) dataset. They were confirmed using the BLS dataset.

1. No break date is found. This figure is the average over 1970-2006.

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