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THE BREAKS IN PER CAPITA PRODUCTIVITY TRENDS IN A NUMBER OF INDUSTRIAL COUNTRIES

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Résumé

L'objet de cette note est d'étudier les mouvements tendanciels de la productivité par employé dans divers grands pays industrialisés. L'analyse est d'abord menée à partir de données annuelles sur une période longue, couvrant l'ensemble du vingtième siècle pour les Etats-Unis, la France et le Royaume-Uni. Par la suite, les évolutions de la productivité sont étudiées sur une période plus courte, en données trimestrielles, pour les Etats-Unis, la France, le Royaume-Uni, l'Allemagne, le Japon, l'Espagne et les Pays-Bas. Les études de ce type sont déjà nombreuses dans la littérature, mais elles se limitent souvent à présenter des taux de croissance moyens de la productivité sur des périodes choisies de manière ad hoc. Une méthode statistique robuste est ici utilisée afin de déterminer de manière endogène d'éventuelles ruptures de tendances de la productivité par tête. Cette méthode, élaborée par Bai et Perron (1998), permet d'extraire plusieurs faits marquants :

- aux Etats-Unis, la productivité par employé connaît une accélération consécutive à une rupture située au début des années 1920, puis un ralentissement à partir de la fin des années 1960. Ce résultat se rapproche sensiblement de la « grande vague » évoquée par Gordon (1999, 2002) pour décrire les mouvements tendanciels du taux de croissance de la productivité américaine au XX^{ème} siècle.

- Le début du rattrapage du niveau de productivité des Etats-Unis par la France ou le Royaume-Uni se situe peu après la fin de la seconde guerre mondiale.

- La plupart des pays considérés enregistrent un ralentissement de leur productivité tendancielle dans la première moitié des années 1970. Pour les Etats-Unis, cette rupture intervient dès 1966, ce qui diffère de certaines analyses existantes qui ont fait ressortir la date de 1974.

Les pays européens et le Japon connaissent un ralentissement de leur productivité tendancielle au cours des années 1990, tandis que la productivité américaine accélère au cours de cette période.

Mots-clés : tendances de la productivité, ruptures structurelles, méthode de Bai et Perron.
Classification JEL : O47, C12, N10.

Abstract

The purpose of this article is to study the trends in per capita productivity in several major industrialised countries. The analysis is first based on annual data over a long period spanning the entire 20th century for the United States, France and the United Kingdom. Productivity trends are then studied over a shorter period, using quarterly data, for the United States, France, the United Kingdom, Germany, Spain, Japan and the Netherlands. There are already a large number of studies of this kind, but they are too often focused on presenting average productivity growth rates for given periods chosen on an ad hoc basis. In this article, we use a robust statistical method to endogenously identify possible breaks in per capita productivity trends. This method, developed by Bai and Perron (1998), brings out the following salient features:

– in the United States, per capita productivity growth accelerated following the trend break at the start of the 1920s, then slowed down at the end of the 1960s. This finding is in line with the "Big Wave" concept developed by Gordon (1999, 2002) to describe the trends in US productivity growth throughout the 20th century.

– French and UK productivity started catching up with that in the United States around the end of the Second World War.

– Most of the countries under review recorded slower trend productivity growth in the first half of the 1970s. In the United States, this break occurred in 1966. This finding differs from that of other existing analyses, which point to 1974.

– Trend productivity growth in Europe and Japan slowed in the 1990s, whereas US productivity gained momentum over the same period.

Keywords : Productivity trends, structural breaks, Bai and Perron method
JEL classification : O47, C12, N10

Résumé non technique :

Les différentes études réalisées sur les évolutions de la productivité sur le long terme ont mis en évidence quelques faits stylisés sur les données américaines et européennes. En particulier, les travaux de Gordon ont analysé les grandes phases du taux de croissance de la productivité américaine depuis le début du XXème siècle et l'évolution du rattrapage des niveaux de productivité américains par les économies européennes.

Gordon (1999) est à l'origine de l'expression « grande vague » pour caractériser la croissance de la productivité globale des facteurs américaine : l'auteur place le « démarrage américain » autour de 1913. Le taux de croissance de la productivité ne va cesser de s'accroître jusqu'au milieu des années 1960. De 1964 au début des années 1990, le taux de croissance va retomber pour atteindre des niveaux inférieurs à ceux connus durant l'entre-deux guerres.

Gordon (2002) constate que le retard du niveau de productivité européen, qui était apparu au milieu du XIX^{ème} siècle, s'est accru jusque vers le milieu des années 1950, période à laquelle s'est amorcé le rattrapage des Etats-Unis par les économies européennes. Ce rattrapage s'est poursuivi jusqu'au début des années 1990 et n'a pas été interrompu par le choc pétrolier de 1973.

Certaines analyses (cf. Basu, Fernald et Shapiro, 2001, Hansen, 2001, Gust et Marquez, 2002, Lecat, 2003) ont complété ces travaux en s'intéressant aux mouvements de la productivité américaine ou européenne dans les années 1990. Ces études mettent en évidence l'interruption du rattrapage des Etats-Unis par l'Europe au milieu des années 1990 : vers 1995 approximativement, l'économie américaine connaît à nouveau des taux de croissance de la productivité proches de ceux des années 1950, tandis que les taux de croissance européens et japonais chutent.

Toutefois, on peut s'interroger sur la robustesse des faits stylisés mentionnés ci-dessus. Ces études n'utilisent généralement pas, à l'exception de Hansen (2001), une technique statistique suffisamment rigoureuse. Par exemple, Gordon se contente de faire des moyennes des taux de croissance de la productivité sur des périodes choisies de manière ad hoc. Notre objectif dans la présente analyse est donc de détecter si les grandes phases énoncées ci-dessus de l'évolution des productivités américaine, européenne et japonaise sont validées au moyen d'un test de ruptures de tendance.

Les multiples objectifs de ce papier nécessitent de recourir à une méthode permettant de déterminer de façon endogène à la fois le nombre et la datation des points de ruptures. Nous utilisons la technique récemment proposée par Bai et Perron (1998), nettement plus efficiente que les méthodes précédentes. L'approche ici retenue est purement statistique. Elle ne propose pas de lecture économique des ruptures détectées.

Pour chaque pays, cette étude est menée sur deux types d'échantillons de productivité par tête:

- un échantillon long couvrant le XXème siècle en données annuelles ;
- un échantillon postérieur à la seconde guerre mondiale en données trimestrielles.

Il convient de souligner la fragilité de certaines données mobilisées, particulièrement sur période longue où sont articulés diverses sources et bases comptables. Il convient donc de rester prudent dans l'interprétation des résultats.

L'utilisation de la méthode de Bai et Perron (1998) pour construire une composante tendancielle de la productivité apparente du travail nous a permis d'extraire plusieurs faits marquants :

- certaines des conclusions de Gordon (1999, 2002) sont confirmées. Nous retrouvons bien la vague séculaire dont parle l'auteur dans les mouvements tendanciels du taux de croissance de la productivité américaine ; le test place également le début du rattrapage des Etats-Unis par la France ou le Royaume-Uni peu après la fin de la seconde guerre mondiale ;

- le test montre que la plupart des pays considérés ont connu un ralentissement de leur productivité tendancielle autour du choc pétrolier des année 1970 ; pour les Etats-Unis, cette rupture intervient dès 1966 (pour la productivité par tête comme pour la productivité horaire), ce qui diffère de certaines analyses existantes qui ont abouti à la date de 1974 ;
- enfin, les résultats de cette étude ont permis de montrer que l'interruption du rattrapage des Etats-Unis par les économies européennes constatée au milieu des années 1990 est présente dans les mouvements tendanciels de la productivité de ces pays ; les pays européens et le Japon connaissent un ralentissement de leur productivité tendancielle au cours des années 1990, tandis que la productivité américaine accélère dans les années 1980 ou 1990 (selon que l'on considère la productivité par tête ou la productivité horaire).

Ce dernier résultat, qui concerne la période la plus récente, est certainement le plus susceptible d'intéresser des décideurs chargés de conduire la politique économique. Il met en évidence, bien sûr, la capacité qu'a eu l'économie américaine au cours des dernières années à relever sa productivité du travail, notamment grâce au développement des nouvelles technologies de l'information et de la communication. Cependant, il montre également la nécessité pour les pays européens et notamment la France de soutenir des politiques structurelles visant à renforcer la productivité du travail.

Non-technical summary:

The various studies on long-term productivity trends have provided a couple of findings on American and European data. In particular, Gordon has analysed in his research papers the main phases of the American productivity growth since the beginning of the XXth century and the catching up of American productivity levels by European economies.

Gordon (1999) launched the expression "Big Wave" to describe total factor productivity growth in the United States. He set the "US take-off" at around 1913. Productivity growth rose continuously until the mid-1960s, then declined from approximately 1964 to the start of the 1990s, to reach a lower rate than that recorded during the inter-war period.

Gordon (2002) showed that the gap between European and US productivity growth, which appeared in the middle of the XIXth century, widened until the mid-1950s, when Europe started catching up with the United States. This catching-up process continued until the early 1990s and was not interrupted by the oil price shock in 1973.

Some studies (see Basu, Fernald and Shapiro, 2001, Hansen, 2001, Gust and Marquez, 2002, Lecat, 2003) went a step further by focusing on US and European productivity trends in the 1990s. These studies highlight the fact that the catching up process ended in the mid-1990s. Around 1995, productivity growth rates in the United States were close to those recorded in the 1950s, while European and Japanese growth rates were on a downturn.

However, the robustness of these stylised facts is questionable. Indeed, the statistical techniques used are generally not sufficiently rigorous, expect in the case of Hansen's (2001). For example, Gordon merely calculates average productivity growth rates for given periods chosen on an ad hoc basis. The purpose of this study is therefore to determine whether the above-mentioned phases of US, European, and Japanese productivity growth can be validated using a trend break test.

Given our many objectives, we require a method which will enable us to endogenously determine both the number and the date of the trend breaks. We have recourse to a technique recently put forward by Bai and Perron (1998), which is much more efficient than the

methods previously used. The approach adopted in this paper is purely statistical. It does not put forward any economic interpretation of the identified trend breaks.

For each country, the study is conducted using two samples of per capita productivity:
- a long sample of annual data covering the 20th century;
- a short sample of quarterly data covering the post-war period.

It appears necessary to emphasise the weakness of some of the data, in particular long data which are derived from several accounting databases and sources. Caution should therefore be exercised when interpreting the results.

Using the Bai and Perron method to highlight the trend component of apparent labour productivity enabled us to bring out the following salient points:
- some of Gordon's conclusions (1999, 2002) were confirmed. We were able to identify the centennial wave brought to light by Gordon and to establish that France and the United Kingdom started catching up with the United States shortly after the Second World War.
- The test showed that most of the countries under review experienced slower trend productivity growth at the time of the oil price shock in the 1970s. In the United States, this break occurred around 1966 (both in terms of per capita productivity and hourly productivity). This finding contrasts with that of other existing analyses, which point to 1974.
- Lastly, we were able to establish that the end of the catching up process in the mid-1990s was part of the trend in productivity growth in these countries. European countries and Japan posted slower trend productivity growth in the 1990s, whereas US productivity gained momentum in the 1980s or 1990s (depending on whether one considers per capita productivity or hourly productivity).

This last result, which concerns the recent period, is certainly likely to be of interest to decision makers in charge of conducting monetary policy. It highlights the capacity of the US economy in recent years to raise its labour productivity, in particular via the development of new information and communication technologies (ICT). However, it also shows the need for European countries, in particular France, to foster structural policies designed to improve labour productivity.

I Introduction

The various studies on long-term productivity trends have provided a couple of findings on American and European data. In particular, Gordon has analysed in his research papers the main phases of the American productivity growth since the beginning of the XXth century and the catching up of American productivity levels by European economies.

Gordon (1999) launched the expression "Big Wave" to describe total factor productivity growth in the United States. He set the "US take-off" at around 1913[1]. Productivity growth rose continuously until the mid-1960s, then declined from 1964[2] to the start of the 1990s, to reach a lower rate than that recorded during the inter-war period.

Gordon (2002) showed that the gap between European and US productivity growth widened until the mid-1950s[3], when Europe started catching up with the United States. This catching-up process continued until the early 1990s and was not interrupted by the oil price shock in 1973.

Some studies (see Basu, Fernald and Shapiro, 2001, Hansen, 2001, Gust and Marquez, 2002, Lecat, 2003) went a step further by focusing on US and European productivity trends in the 1990s. These studies highlight the fact that the catching up process ended in the mid-1990s. Around 1995, productivity growth rates in the United States were close to those recorded in the 1950s, while European and Japanese growth rates were on a downturn.

However, the robustness of these stylised facts is questionable. Indeed, the statistical techniques used are generally not sufficiently rigorous, expect in the case of Hansen's (2001). For example, Gordon merely calculates average productivity growth rates for given periods chosen on an ad hoc basis. The purpose of this study is therefore to determine whether the above-mentioned phases of US, European, and Japanese productivity growth can be validated using a trend break test. For each country, the study is conducted using two samples of per capita productivity:

- a long sample of annual data covering the 20th century;
- a short sample of quarterly data covering the post-war period.

The first sample enables us to detect possible trend breaks before the Second World War. We are therefore able to test whether the US take-off brought to light by Gordon (1999) corresponds to a productivity trend break.
More generally, we are able to check whether the trend break test enables us to identify Gordon's Big Wave. Furthermore, these tests make it possible to date the start of the catching up process.

The second sample enables us to test the existence of possible trend breaks at the time of the oil price shock and in the 1990s. Concerning this last point, Hansen (2001) highlighted a pronounced positive break in the US productivity trend between 1992 and 1996. Our objective is to determine whether this upswing corresponds to a fall in European and Japanese productivity growth.

1 This date depends on the respective weightings of capital and labour in the calculation of total factor productivity.

2 This date is subject to debate: theoretical literature generally places the US slowdown at around the time of the oil crisis in 1973.

3 Europe had been lagging behind the United States since the middle of the 19th century.

By comparing the results obtained in both samples, we are able to compare the current US and European trend growth rates with those prior to the Second World War, and, like Gordon, establish whether the growth rates at the end of the Big Wave are comparable to those at the start of the period.

Given our many objectives, we require a method which will enable us to endogenously determine both the number and the date of the trend breaks. We have recourse to a technique recently put forward by Bai and Perron (1998), which is much more efficient than the methods previously used. The approach adopted in this paper is purely statistical. It does not put forward any economic interpretation of the identified trend breaks. Furthermore, it appears necessary to emphasise the weakness of some of the data, in particular long data which are derived from several accounting databases and sources. Caution should therefore be exercised when interpreting the results.

The paper is structured as follows. In the next section, we present the econometric method and the data we use. Third section is divided in two parts : results on long samples are displayed in the first one, and results on short samples, as well as comments on the structural breaks detected in the 1970s and 1990s, are presented in the second one. Then, productivity trends computed on the period before World War II are compared to trends computed on short samples. Finally, last section concludes briefly.

II - Chosen approach

1) The Bai and Perron method

Econometrics has increasingly focused on trend breaks over recent years. In the initial work on structural change (see Perron, 1989), modelling only allowed for a single trend break, for which the date of occurrence would be determined by econometrics. Andrews (1993) proposed a general method for endogenously determining the date of the break. However, this method had the same drawback: it only allowed for a single trend break. Since then, several methods for measuring the number of break points have been developed. The use of information criteria (AIC, BIC) has been largely criticized. The method for a sequential estimation of break dates elaborated by Bai and Perron (1998) has appeared to be much more efficient, given the fact that the AIC or BIC approaches tend to overestimate the number of breaks.

Four commonly used specifications are implemented in this study to detect trend breaks. Specifications 1 and 2 are written as follows :

SPECIFICATION 1

$$Y_t = \mu + \beta_1 .\mathrm{t} + \sum_{k=1}^{m} \beta_{k+1}(t - T_k) I(t > T_k) + u_t$$

SPECIFICATION 2

$$Y_t = \mu + \beta_1 .\mathrm{t} + \sum_{k=1}^{m} \beta_{k+1}(t - T_k) I(t > T_k) + \sum_{i=1}^{p} c_i Y_{t-i} + u_t$$

for t=1,…, T where T is the sample size. I(.) denotes the indicator function. For both specifications, productivity (Y_t) is expressed in log form. u_t is a residual term with a zero average. μ is a constant. β_i (i=1, …,m) is the trend growth rate on the i^{th} segment. And, c_i (i=1,…,p) are the autoregressive term coefficients. For the first specification, we use the method developed by Den Haan and Levin (2000) to estimate the variance-covariance matrix of the parameters (VARHAC method). For the second specification, the residual autocorrelation problem is solved by including autoregressive terms. The optimal number of lags p is calculated using the Perron method (1989).
Our objective is to assess the number (m) and the dates (T_k, k=1,…,m) of possible breaks in the trend. β (slope of the trend) is the only parameter to be subject to a break; the other parameters μ and c_i are assumed to be stable.

Specifications 3 and 4 are written as follows:

SPECIFICATION 3

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

SPECIFICATION 4

$$\Delta Y_t = \beta_1 + \sum_{k=1}^{m} \beta_{k+1} . I(t > T_k) + \sum_{i=1}^{p} c_i \Delta Y_{t-i} + u_t$$

This time, we are measuring the per capita productivity growth rate (ΔY is the variation in the logarithms of productivity levels). The definitions of β_i and c_i are the same as in the first two specifications.
In specification 3, we run a regression of productivity growth rates on a constant subject to a random number of breaks. Here again, β is the only parameter subject to a break. Once more, we use Den Haan and Levin's VARHAC method to estimate the long-term variance-covariance matrix of the parameters. In specification 4, the autocorrelation problem is solved by using autoregressive terms.

Once the number and the dates of the breaks are determined, each specification is estimated. For specifications 1 and 3, we use the VARHAC method again to evaluate the significance of the parameters. We use the analytic formulas given by Bai and Perron (2001a, 2001b) to estimate the confidence intervals associated with the break points. 95% or 90% confidence intervals are usually too wide to bring any information[4]. Therefore, 66% confidence intervals are displayed in the result tables in annexes (Cf Stock and Watson, 2000).

4 This appears to be a common problem in the literature.

2) Presenting and processing the data

a) long sample

The long sample includes data which go back to the start of the 20th century, or even the end of the 19th century. In this case, the only data available are for France, the United States and the United Kingdom; employment and gross domestic product (GDP) data for Germany and Japan are not available over a sufficiently long period to enable us to use the Bai and Perron method [5].

The sources from which the data for France, the United States and the United Kingdom are derived are presented in Appendix 1. The data in long time series are less homogenous and robust than those in short time series. Pre-war data are highly volatile. Several factors account for this lack of homogeneity. First, data in long time series are drawn from a wide range of sources (censuses, industrial tribunals, trade unions, statistical surveys, etc). Second, the methods used for constructing series have changed considerably, in particular with regard to GDP deflators. Third, accounting conventions have also been considerably amended over time, for example with regard to the classification of farm workers[6] or the switch from national product to domestic product. Lastly, changing borders also account for the heterogeneity of the data. This problem occurs in the case of France (Alsace-Lorraine was not part of France prior to 1918) and the United Kingdom (Southern Ireland was included in the United Kingdom before 1920). For these three countries, the most recent data are drawn from the Groningen Growth and Development Centre (GGDC) database[7] (see Appendix 1). The older data are taken from Villa[8] for France, from Feinstein (1976) for the United Kingdom and from Mitchell (1998) for the United States. Villa presents single long time series both for employment and GDP data. He makes the assumption of a variable territory but reprocesses the data in order to ensure that concepts and nomenclatures remain constant. Feinstein and Mitchell, on the other hand, present discontinuous time series, which vary according to territory, source and methodology. The various employment and GDP series put forward by both authors have the particularity of always having a date in common. For example, in the case of the United Kingdom, some employment and GDP series including Southern Ireland extend until 1920 and others excluding Southern Ireland start in 1920.

The two world wars, for which there are either no data or unreliable data, were processed successively by interpolation and through the use of buffer variables. Because both methods yielded the same results, we only present the interpolation method. The French sample deliberately runs up until 1990, as the short sample of French data is broken in the 1990s (see below). This break cannot be detected using annual data, because it is too close to the end of the sample. At the same time, it is likely to distort the results for the rest of the sample[9].

5 Employment data for Germany are only available from 1921 onwards (Mitchell) and exclude the Second World War. In the case of Japan, the earliest available data go back to the 1930s.

6 In France, all persons living on farms who neither went to school nor had a job were automatically considered as farm workers until 1946. Today, only persons who declare themselves as farm workers are considered as such.

7 University of Groningen and The Conference Board, GGDC Total Economy Database, July 2003, http://www.eco.rug.nl/ggdc

8 *Http://www.cepii.fr//francgraph/bdd/villa.htm*

9 This problem is well-covered in econometric literature on trend breaks.

b) short sample

The countries under review in the short time series covering the post war period are the United States, France, the United Kingdom, Germany, Japan, Spain and the Netherlands. We use quarterly series for all countries except for the Netherlands, where half-yearly series are used. These series have two advantages compared with the long time series: the data are more homogeneous and, unlike in the case of the annual series, we are able to test the presence of possible trend breaks in the 1990s.

The series used are mainly derived from the macroeconomic database of the Bank for International Settlements (BIS). This database is fed by various national bodies, such as national statistical institutes and central banks. We also used data from Villa for France, Eurostat data for Spain and data from the Organisation for Economic Cooperation and Development (OECD) for the Netherlands. These various sources are presented in Appendix 1. We derived the productivity series from real GDP and employment series, except in the case of Germany, where we directly used per capita productivity series. All of the series were already seasonally-adjusted, with the exception of an employment series for the United Kingdom, which was adjusted for seasonality by the authors.

The problem posed by German reunification was handled in two stages. The same tests as those performed on the other countries under review were carried out on West Germany. However, we were unable to apply the Bai and Perron sequential procedure in the case of reunified Germany, as the available data sample was too short. We assumed that there could not be more than one break in this sample. In this case, there would be no sequential procedure and the test to be performed would be that of Andrews (1993).

III – Results

1) Long sample

Table A brings together all of the results obtained from the long sample. With annual time series, the autoregressive terms in specifications 2 and 4 are generally not significant. For this reason, only specifications 1 and 3 are included in Table A. As regards the United States, we were able to identify the Big Wave brought to light by Gordon (1999). Productivity growth showed a positive trend break in 1922 or 1933 (depending on the chosen specification) and starts slowing in 1967. The date of the US "take-off" is slightly later than that identified by Gordon, while the date of the slowdown is roughly the same[10]. However, a number of economists set the US slowdown at 1974 (see Zivot and Andrews, 1992). As we will see in the following section, the starting date of the US slowdown is not very different if one uses hourly productivity instead of per capita productivity.

Positive trend breaks occurred in the United Kingdom and France in 1943 and 1945 respectively. The date of the trend break in France corresponds to the start of the catching up process with the United States (According to Gordon, 2002, the catching-up process began in 1950). The average growth rate in France stood at 5.4%, compared with 2.5% or 3% in the United States (depending on the chosen specification). France posted a negative productivity trend break in 1970, but this break did not interrupt the catching up process: the trend

10 NB: Gordon uses total factor productivity series, whereas we use per capita productivity series.

productivity growth rate in France was almost twice as high as that in the United States after 1970. It appears that this break corresponds to a GDP break (Le Bihan, 2002, finds a negative GDP break for France around 1973 by applying the Bai and Perron method).

Table A: Trend productivity growth (GDP/employment) using long time series (annual) – results from the Bai and Perron method

For specifications 1 and 3, the table shows the dates of the breaks and the average annual productivity growth rate for each period, in %.

A.1. United States

Spec.1	**1890**	**1922**	**1967**	**2002**
	1.3%	2.5%	1.3%	
Spec.3	**1890**	**1933**	**1967**	**2002**
	1.1%	3.0%	1.3%	

A.2. France

Spec.1	**1890**	**1945**	**1970**	**1990**
	0.6%	5.4%	2.4%	
Spec.3	**1890**	**1945**	**1970**	**1990**
	0.6%	5.4%	2.4%	

A.3. United Kingdom

Spec.1	**1875**	**1943**	**2002**
	0.7%	1.9%	
Spec.3	**1875**	**1943**	**2002**
	0.7%	1.9%	

Sources: Authors' calculations

It is also worth pointing out that the United Kingdom did not experience a trend break at the time of the oil price shock of 1973 (this result will be partly confirmed in the following section).

2) Short sample

The results, presented in Table B, confirm that there are never more than two breaks, irrespective of the country. These breaks can be divided into two clusters, around 1970 and in the 1990s (except in the case of the United States).

All of the countries under review, with the exception of the United States and the United Kingdom, posted a significant negative productivity trend break between 1972 and 1976, irrespective of the specification[11]. These results therefore confirm those obtained from the long sample. In the case of France, this productivity trend break coincides once again with a GDP break (Le Bihan, 2002). In the absence of any significant break in the employment trend over this period, the downturn in productivity can therefore be attributed to the break in GDP trend growth.

The United Kingdom only posted a negative productivity trend break, albeit very small, for specifications 1 and 2. These results are in line with those of Broadberry and Crafts (2003), who identified a pronounced slowdown in British productivity around 1973 for the manufacturing sector, but a much smaller slowdown for the economy as a whole. The United States experienced a sharp fall in labour productivity growth in the first quarter of 1966. This date is robust to the chosen specification. This may be surprising given that the economic literature generally sets the negative break at around 1974 (see the work of Zivot and Andrews on US GDP, for example).

11 Excluding the third specification applied to West Germany.

Table B: Trend productivity growth (GDP/employment) using short time series (quarterly except for the Netherlands) – results from the Bai and Perron method

NB: For each specification, the table shows the break dates and the average annual productivity growth rate for each period

B.1. United States – per capita GDP

Spec.1	**1948Q1**	**1966Q1**	**1983Q1**	**2002Q4**
	2.8%	0.7%	2.0%	
Spec.2	**1948Q1**	**1966Q1**	**1983Q1**	**2002Q4**
	2.8%	0.7%	2.0%	
Spec.3	**1948Q1**	**1966Q1**		**2002Q4**
	2.8%	1.3%		
Spec.4	**1948Q1**	**1966Q1**		**2002Q4**
	2.8%	1.3%		

B.2. United States – hourly productivity

Spec.1	**1964Q1**	**1967Q4**	**1995Q3**	**2002t4**
	3.2%	1.4%	2.2%	
Spec.2	**1964Q1**	**1967Q4**	**1995Q3**	**2002t4**
	3.2%	1.4%	2.2%	
Spec.3	**1964Q1**	**1968Q1**	**1995Q3**	**2002Q4**
	2.6%	1.5%	2.2%	
Spec.4	**1964Q1**	**1968Q1**	**1995Q3**	**2002Q4**
	2.6%	1.5%	2.2%	

B.3. France

Spec.1	**1959Q1**	**1973Q3**	**1991Q2**	**2002Q4**
	5.0%	2.1%	1.1%	
Spec.2	**1959Q1**	**1973Q1**	**1991Q1**	**2002Q4**
	4.9%	2.2%	1.1%	
Spec.3	**1959Q1**	**1973Q2**	**1990Q1**	**2002Q4**
	5.0%	2.2%	1.1%	
Spec.4	**1959Q1**	**1973Q2**	**1990Q1**	**2002Q4**
	5.0%	2.2%	1.1%	

B.4. United Kingdom

Spec.1	**1955Q1**	**1972Q2**	**2002Q4**
	2.7%	1.9%	
Spec.2	**1955Q1**	**1972Q2**	**2002Q4**
	2.7%	1.9%	
Spec.3	**1955Q1**		**2002Q4**
	2.2%		
Spec.4	**1955Q1**		**2002Q4**
	2.2%		

B.5. Japan

Spec.1	**1961Q1**	**1973Q2**	**1990Q3**	**2002Q4**
	8.0%	2.9%	1.2%	
Spec.2	**1961Q1**	**1973Q2**	**1990Q3**	**2002Q4**
	8.0%	2.8%	1.2%	
Spec.3	**1961Q1**	**1973Q2**	**1990Q3**	**2002Q4**
	8.0%	2.9%	1.2%	
Spec.4	**1961Q1**	**1973Q2**	**1990Q3**	**2002Q4**
	8.0%	2.8%	1.1%	

B.6. West Germany

Spec.1	**1960Q1**	**1973Q4**		**1998Q4**
	4.1%	1.9%		
Spec.2	**1960Q1**	**1973Q4**		**1998Q4**
	4.1%	1.9%		
Spec.3	**1960Q1**	**1969Q4**		**1998Q4**
	4.3%	2.2%		
Spec.4	**1960Q1**	**1973Q1**		**1998Q4**
	4.2%	2.0%		

B.7. Reunified Germany

Spec.1	**1991Q1**	**1997Q3**	**2002Q4**
	1.9%	0.8%	
Spec.2	**1991Q1**	**1997Q3**	**2002Q4**
	1.9%	0.8%	
Spec.3	**1991Q1**	**1997Q3**	**2002Q4**
	2.2%	0.8%	
Spec.4	**1991Q1**	**1997Q3**	**2002Q4**
	2.1%	0.8%	

B.8. Spain

Spec.1	**1970Q1**	**1985Q4**	**1996Q1**	**2003Q2**
	3.3%	1.5%	-0.4%	
Spec.2	**1970Q1**	**1985Q4**	**1996Q1**	**2003Q2**
	3.3%	1.5%	-0.4%	
Spec.3	**1970Q1**	**1994Q1**		**2003Q2**
	2.9%	-0.1%		
Spec.4	**1970Q1**	**1994Q1**		**2003Q2**
	2.9%	-0.1%		

B.9. Netherlands (half-yearly)

Spec.1	**1960S1**	**1976S1**	**2003S1**
	4.1%	1.4%	
Spec.2	**1960S1**	**1976S1**	**2003S1**
	4.1%	1.4%	
Spec.3	**1960S1**	**1976S2**	**2003S1**
	3.7%	1.3%	
Spec.4	**1960S1**	**1976S2**	**2003S1**
	3.7%	1.3%	

Sources: Authors' calculations

To corroborate our results, we carried out the same tests on hourly productivity in the United States. Our objective was to estimate whether using the number of hours worked per employed person would alter our conclusions (the data series was supplied by the Bureau of Labour Statistics (BLS). The date of the break (last quarter of 1967 or first quarter of 1968 depending on the specification) is very close to that obtained using the productivity per employed person. The US slowdown can therefore not be attributed to the number of hours worked per employed person. The discrepancy between the results put forward in this article and those in the literature probably stems from our choice of method (*multiple break test*). The Zivot and Andrews test (1992), on the contrary, only allows for a single break.

The end of the catching up process can also be attributed to the fact that three countries, France, reunified Germany and Japan (see Gust and Marquez, 2002), experienced a negative labour productivity trend break in the 1990s. In France, it occurred in 1990 or 1991 depending on the chosen specification. The French trend growth rate dropped by approximately half. Unlike the 1973 break, this productivity trend break was not due to a GDP break (Le Bihan, 2002, rejects the hypothesis of a second GDP break in France). Instead, it can probably be attributed to the sharp rise in the employment growth rate in France at the start of the 1990s (in particular after the slump in 1993). We obtain similar results for Germany and Japan. Spain is a special case, since it experienced a negative trend productivity growth rate following the trend break in the mid-1990s.

Once again, the United Kingdom and the United States are in sharp contrast with the other industrialised countries under review. The United Kingdom and the Netherlands did not experience a productivity trend break in the 1990s. The fall in productivity growth around 1996-1997 is probably too close to the end of the sample and not sufficiently pronounced to be interpreted as a trend break. This slight fall may also correspond to a cyclical movement. It is also worth pointing out that, although the United Kingdom did not experience a negative trend break in the 1990s, it lagged further behind the United States than the other European countries (see Lecat, 2003).

In contrast to the other countries, the United States experienced an upward break in 1983. However, it is not very robust to the chosen specification, as it only appears when using productivity levels. This result is in line with the findings of Bassanini and Scarpetta (2002), according to whom US productivity growth started accelerating in the mid-1980s. Conversely, Hansen (2001) sets this acceleration in the mid-1990s. The reason for this is that Hansen uses hourly productivity in the manufacturing sector. By extending Hansen's analysis based on hourly productivity to the whole of the economy, we are able to confirm the presence of a positive trend break in 1995. Results obtained using hourly productivity are statistically more reliable than those obtained using per capita productivity, since they are robust to the chosen specification, which is not the case of the results based on per capita productivity[12]. This leads us to set the acceleration in the US growth rate at around 1995, rather than 1983.

This finding points to the end of the catching up process. For specifications 1 and 2, following the positive trend break in 1983, the United States posted a higher trend labour productivity growth rate than the other countries. This is also the case for specifications 3 and 4 if the United Kingdom is excluded from the sample. The widening gap between US and European

12 We were unable to repeat this exercise for Europe, as quarterly data on hours worked were not available.

and Japanese productivity therefore cannot be attributed to a cyclical movement, but, on the contrary, to shifts in productivity trends.

By bringing together the results derived from the long and short samples, we are now able to compare the growth rates before and after the Second World War. In the case of France, average per capita productivity growth before the war is significantly lower than that after the war, including the period following the slowdown of the early 1990s. Since 1991, the French trend growth rate has been twice as high as that recorded in the first half of the century. This also holds true for the United Kingdom, whose average per capita productivity growth after the Second World War is roughly three times as high as that recorded before.

The situation in the United States is markedly different. Average productivity growth before the 1930s was higher than that between the oil price shock and the economic recovery in the 1980s. On the other hand, it stands below the current trend productivity growth rate.

IV – Conclusion

Using the Bai and Perron method to highlight the trend component of apparent labour productivity enabled us to bring out the following salient points:

- some of Gordon's conclusions (1999, 2002) were confirmed. We were able to identify the centennial wave brought to light by Gordon and to establish that France and the United Kingdom started catching up with the United States shortly after the Second World War.
- The test showed that most of the countries under review experienced slower trend productivity growth at the time of the oil price shock in the 1970s. In the United States, this break occurred around 1966 (both in terms of per capita productivity and hourly productivity). This finding contrasts with that of other existing analyses, which point to 1974.
- Lastly, we were able to establish that the end of the catching up process in the mid-1990s was part of the trend in productivity growth in these countries. European countries and Japan posted slower trend productivity growth in the 1990s, whereas US productivity gained momentum in the 1980s or 1990s (depending on whether one considers per capita productivity or hourly productivity).

This last result, which concerns the recent period, is certainly likely to be of interest to decision makers in charge of conducting monetary policy. It highlights the capacity of the US economy in recent years to raise its labour productivity, in particular via the development of new information and communication technologies (ICT). However, it also shows the need for European countries, in particular France, to foster structural policies designed to improve labour productivity.

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APPENDIX 1

Description of the series used

Quarterly series

FRANCE

	long time series	series used	Starting date : 1959 Q1	Source	Description
Employment	emplong_fr	emptot_fr	1978 Q1	BIS (INSEE)	Total employment, quarter-end, sa
		emptotecb_fr	1959 Q1	BIS (INSEE)	Total employment, excl. conscripts (ECB proxy), sa
GDP	gdplong_fr	gdpvol95_fr	1978 Q1	BIS (INSEE)	GDP at market prices (SEC 95), 1995 prices, adjusted for seasonal and working-day variations
		gdpvol80_fr	1970 Q1	BIS (INSEE)	GDP at market prices (SEC 95), 1980 prices, sa
		gdpvol70_fr	1963 Q1	BIS (INSEE)	GDP at market prices, 1970 prices, sa
		gdpv_fr	1946 Q1	Villa	Market GDP, in FRF millions, 1980 prices, sa by P. Villa using Census

UNITED STATES

	long time series	series used	Starting date : 1947 Q1	Source	Description
Employment	emplong_us	emptot_us	1948 Q1	BIS (BLS)	Civilian employment, sa
GDP	gdplong_us	gdpchaine_us	1947 Q1	BIS (BEA)	GDP at market prices, in 1996 dollar terms, chained, sa

UNITED KINGDOM

	long time series	series used	Starting date : 1950 Q2	Source	Description
Employment	emplong_uk	emptotnsaecb_uk	1978 Q2	BIS (Office for national statistics)	Total employment (annual business enquiry) (ECB definition), quarter-end, sa
		emptot2nsa_uk	1950 Q2	BIS (Office for national statistics) + BdF seasonal adjustment	Total employment, quarter-end, BdF seasonal adjustment by Census
GDP	Gdplong_uk	gdp2_uk	1956 Q1	BIS (Office for national statistics)	GDP at market prices, 1995 prices, sa

GERMANY

	long time series	series used	Starting date : 1960 Q1	Source	Description
Productivity	pdt_de		1991 Q1	BIS (Bundesbank)	GDP per employee, 1995 prices (SEC 95) (ECB definition), sa
	pdtwest_de (until 1998 Q4)		1960 Q1	BIS (Bundesbank)	GDP per employee, 1991 prices (GFR) (ECB definition), sa

JAPAN

	long time series	series used	Starting date : 1961 Q1	Source	Description
Employment	emplong_jp	emptot_jp	1961 Q1	BIS (Economic planning agency)	Employees, sa
GDP	gdplong_jp	gdpv95_jp	1980 Q1	BIS (Economic	GDP at market prices (SNA 93), 1995

				planning agency)	prices, sa
		gdp90_jp	1955 Q2	BIS (Economic planning agency)	GDP at market prices (SNA 68), 1990 prices, sa

SPAIN

	long time series	series used	Starting date : 1970 Q1	Source	Description
Employment	emplong_es	empmin_es	1976 Q1	Ministerio de Economia y Hacienda	Employees, sa
		empbri_es	1964 Q1	BIS (Inst. Nacional de estadistica)	Total employment (excl. conscripts), sa
GDP	gdplong_es	gdpvolest_es	1980 Q1	Eurostat	GDP (SEC 95), 1995 prices, sa
		gdpvolbri_es	1970 Q1	BIS (Inst. Nacional de estadistica)	GDP at market prices (SEC 79), 1986 prices, sa

NETHERLANDS

	long time series	series used	Starting date : 1960 S1	Source	Description
Employment	emplong_pb	emptot_pb	1960 S1	OECD (Economic Outlook)	Total employment
GDP	gdplong_pb	gdpvol_pb	1960 S1	OECD (Economic Outlook)	GDP at constant prices

Annual series

FRANCE

	long time series	series used	Starting date : 1890 (excl. wars)	Source	Description
Employment	emplong_fr_a	empocde_fr_a	1959	GGDC	Civilian employment
		empv_fr_a	1890 (excl. wars)	Villa (SERLONG database)	Total employment
GDP	gdplong_fr_a	gdpinsee_fr_a	1978	INSEE	GDP, 1995 prices
		gdpocde_fr	1950	GGDC	GDP, 1990 Geary-Khamis dollars
		gdpv_fr_a	1890	Villa (PROD database)	Total real output, GDP excl. import duties and taxes, 1938 FRF billions

UNITED STATES

	long time series	series used	Starting date : 1890	Source	Description
Employment	emplong_us_a	empocde_us_a	1959	GGDC/BLS	Civilian employment
		empmitch_us_a	1890	Mitchell	Employment (using unemployment rate + number of unemployed in thousands)
GDP	gdplong_us_a	gdpbea_us_a	1978	BEA (GGDC as from 1950)	GDP at market prices, in 1996 chained dollar terms, sa
		gdpmitch_us_a	1890	Mitchell	Real GDP (1938 = base 1)

UNITED KINGDOM

	long time series	series used	Starting date : 1875	Source	Description
Employment	emplong_gb_a	empocde_gb_a	1959	GGDC	Civilian employment
		empfeinstein_gb_a	1875	Feinstein	Civilian employment
GDP	gdplong_gb_a	gdpocde_gb_a	1950	GGDC	GDP, 1990 Geary-Khamis dollars
		gdpfeinstein_gb_a	1875	Feinstein	GDP at factor cost

APPENDIX 2

Tables 1 to 11 : productivity trends – complete results of the Bai and Perron method

Table 1 : United states (1890-2002), long sample (yearly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1922 1967	1907 – 1937 1963 – 1969	5 % 1 %	1.30 % 2.54 % 1.34 %
Specification 3	1933 1967	1915 – 1951 1962 – 1971	5 % 1 %	1.05 % 3.00 % 1.34 %

Reading guide : for each specification, the table provides the break dates detected with the Bai and Perron method, the 66% confidence interval corresponding to this date, the significance associated with each break date and the average growth rate of productivity (GDP/employee) before and after each date (e.g. for specification 1, 1.30 % from 1890 to 1922, 2.54 % from 1922 to 1967 and 1.34 % from 1967 to 2002).

Table 2 : France (1890-1985), long sample (yearly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1 :	1945 1970	1943 – 1947 1968 – 1972	1 % 1 %	0.64 % 5.42 % 2.51 %
Specification 3 :	1945 1970	1935 – 1955 1943 – 1997	1 % 1 %	0.63 % 5.42 % 2.51 %

Table 3 : United kingdom (1875-2002), long sample (yearly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1943	1940 – 1946	5 %	0.68 % 1.88 %
Specification 3	1943	1934 – 1952	5 %	0.68 % 1.88 %

Table 4 : United states (1948-2002), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1966(1) 1983(1)	1962(1) – 1970(1) 1975(1) – 1991(1)	5 % 5 %	2.81 % 0.70 % 2.02 %
Specification 2	1966(1) 1983(1)	1962(2) – 1969(4) 1973(1) – 1993(1)	5 % 10 %	2.81 % 0.70 % 2.02 %
Specification 3	1966(1)	1957(4) – 1974(2)	5 %	2.81 % 1.33 %
Specification 4	1966(1)	1958(1) – 1974(1)	5 %	2.80 % 1.34 %

Table 5 : France (1959-2002), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1973(3) 1991(2)	1973(1) - 1974(1) 1990(4) – 1991(4)	1 % 5 %	4.98 % 2.12 % 1.15 %
Specification 2	1973(1) 1991(1)	1972(1) – 1974(1) 1990(3) – 1991(3)	1 % 10 %	4.93 % 2.15 % 1.15 %
Specification 3	1973(2) 1990(1)	1972(2) – 1974(2) 1986(1) – 1994(1)	1 % 5 %	4.99 % 2.22 % 1.12 %
Specification 4	1973(2) 1990(1)	1971(1) – 1975(3) 1976(1) – 2001(1)	1 % 5 %	4.97 % 2.23 % 1.09 %

Table 6 : United kingdom (1955-2002), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1972(2)	1971(4) – 1972(4)	5 %	2.74 % 1.86 %

Specification 2	1972(2)	1971(4) – 1972(4)	5 %	2.72 % 1.86 %
Specification 3	No break			2.17 %
Specification 4	No break			2.17 %

Table 7 : Japan (1961-2002), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1973(2) 1990(3)	1972(4)– 1973(4) 1980(3) – 2000(3)	1 % 10 %	7.98 % 2.88 % 1.19 %
Specification 2	1973(2) 1990(3)	1972(4)– 1973(4) 1980(3) – 2000(3)	1 % 10 %	8.00 % 2.84 % 1.16 %
Specification 3	1973(2) 1990(3)	1972(2) – 1974(2) 1979(2) – 2001(4)	1 % 10 %	7.99 % 2.88 % 1.19 %
Specification 4	1973(2) 1990(3)	1972(2) – 1974(2) 1979(2) – 2001(4)	1 % 10 %	8.01 % 2.82 % 1.14 %

Table 8a : West Germany (1960-1998), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1973(4)	1973(2) – 1974(1)	1 %	4.10 % 1.94 %
Specification 2	1973(4)	1973(2) – 1974(1)	1 %	4.15 % 1.93 %
Specification 3	1969(4)	1966(1) – 1973(4)	5 %	4.25 % 2.19 %
Specification 4	1973(1)	1967(4) – 1978(2)	5 %	4.19 % 2.01 %

Table 8b : Reunified Germany (1991-2002), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1997(3)	1996(3) – 1998(3)	5 %	1.93 % 0.80 %
Specification 2	1997(3)	1996(3) – 1998(3)	5 %	1.95 % 0.83 %
Specification 3	1997(3)	1992(3) – 2002(3)	5 %	2.18 % 0.80 %
Specification 4	1997(3)	1992(3) – 2002(3)	5 %	2.07 % 0.82 %

Table 9 : Spain (1970-2003), short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1985(4) 1996(1)	1982(4)– 1988(4) 1993(1) – 1999(1)	5 % 5 %	3.34 % 1.53 % -0.36 %
Specification 2	1985(4) 1996(1)	1982(4)– 1988(4) 1993(1) – 1999(1)	5 % 5 %	3.34 % 1.53 % -0.36 %
Specification 3	1994(1)	1992(1) – 1996(1)	1 %	2.93 % -0.09 %
Specification 4	1994(1)	1992(1) – 1996(1)	1 %	2.93 % -0.09 %

Table 10 : Netherlands (1960-2003), short sample (half-yearly data)

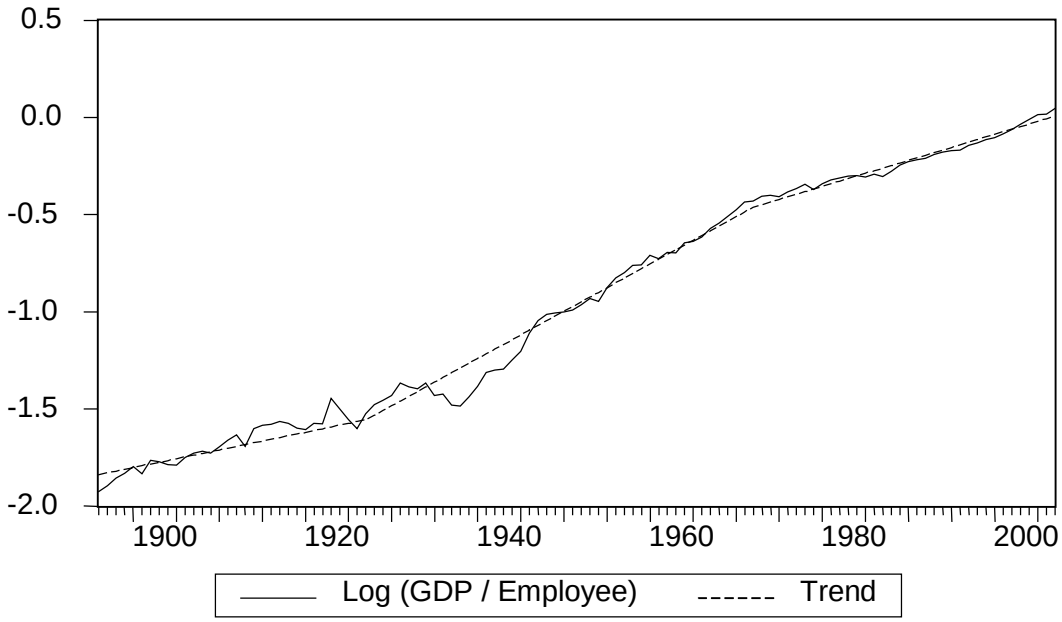
Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1976(1)	1972(2)– 1980(2)	1 %	4.09 % 1.38 %
Specification 2	1976(1)	1972(2)– 1980(2)	1 %	4.09 % 1.38 %
Specification 3	1976(2)	1971(2) – 1981(2)	5 %	3.67 % 1.29 %
Specification 4	1976(2)	1971(2) – 1981(2)	5 %	3.67 % 1.29 %

Table 11 : United states (1964-2002), hourly productivity, short sample (quarterly data)

Specification	Break date	Confidence interval	Significance	Growth rate
Specification 1	1967(4) 1995(3)	1967(3) – 1968(1) 1995(1) – 1996(1)	5 % 5 %	3.21 % 1.41 % 2.19 %
Specification 2	1967(4) 1995(3)	1967(3) – 1968(1) 1995(1) – 1996(1)	5 % 5 %	3.21 % 1.41 % 2.19 %
Specification 3	1968(1) 1995(3)	1967(1) – 1969(1) 1994(1) – 1997(1)	10 % 10 %	2.58 % 1.49 % 2.16 %
Specification 4	1968(1) 1995(3)	1967(1) – 1969(1) 1994(1) – 1997(1)	10 % 10 %	2.58 % 1.49 % 2.16 %

FIGURE 1 : UNITED STATES – LONG SAMPLE

Logarithm of productivity



Growth rate of productivity

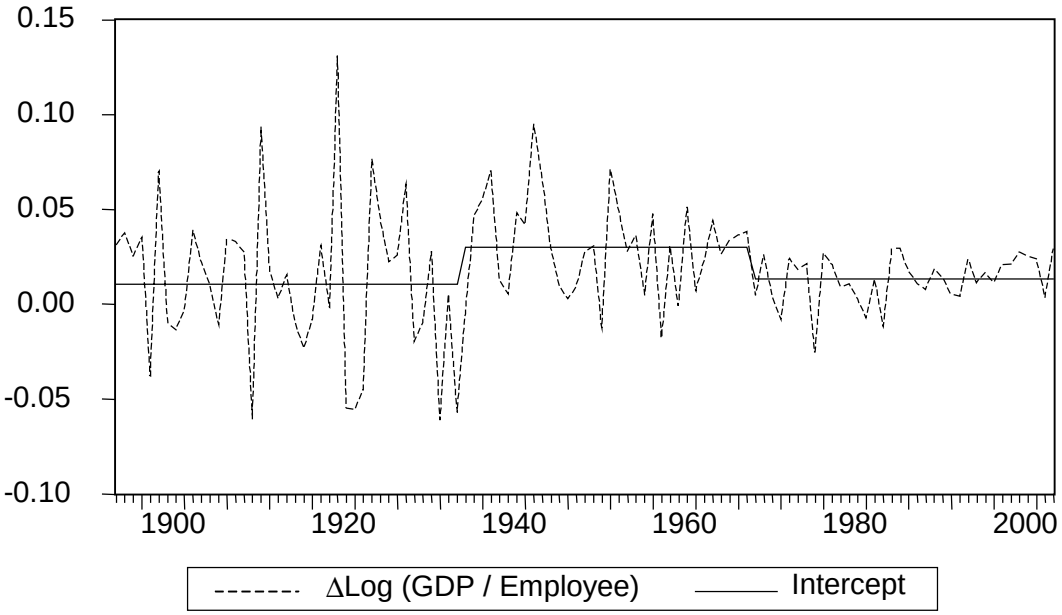


FIGURE 2 : FRANCE – LONG SAMPLE

Logarithm of productivity

Growth rate of productivity

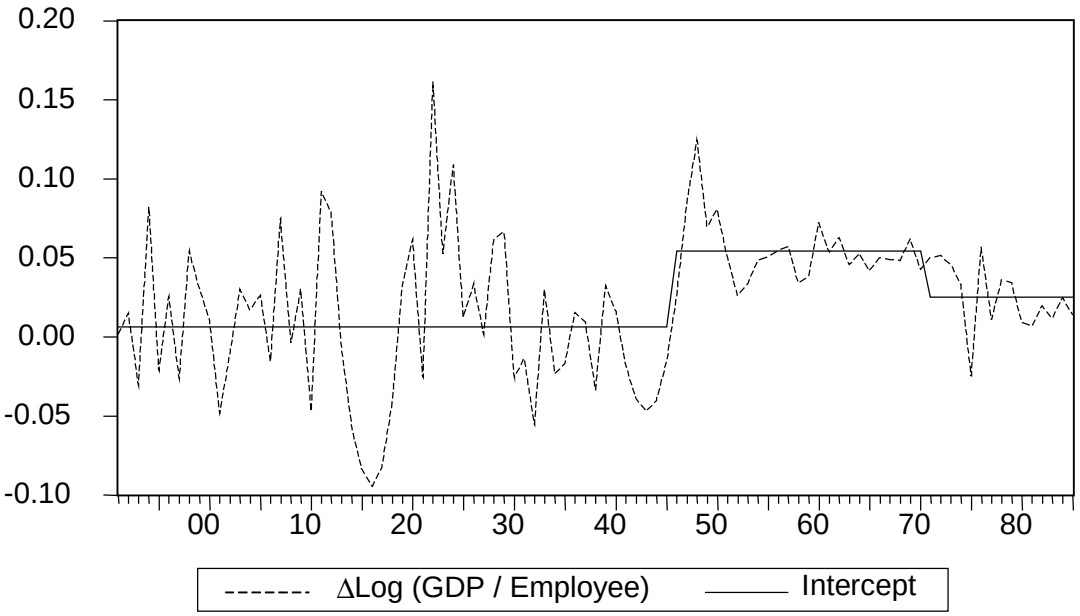
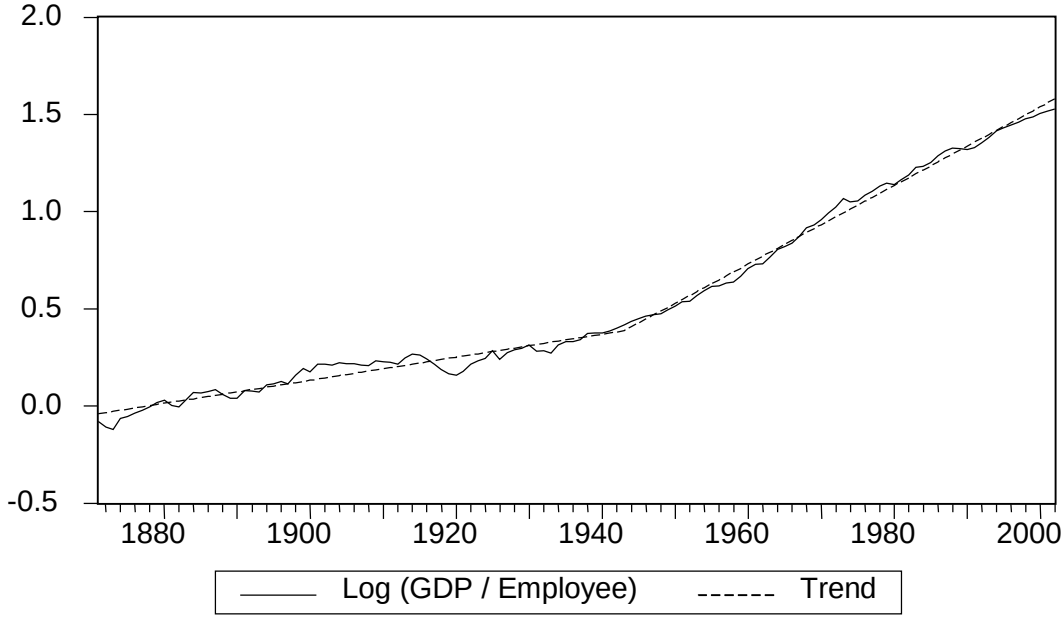


FIGURE 3 : UNITED KINGDOM – LONG SAMPLE

Logarithm of productivity



Growth rate of productivity

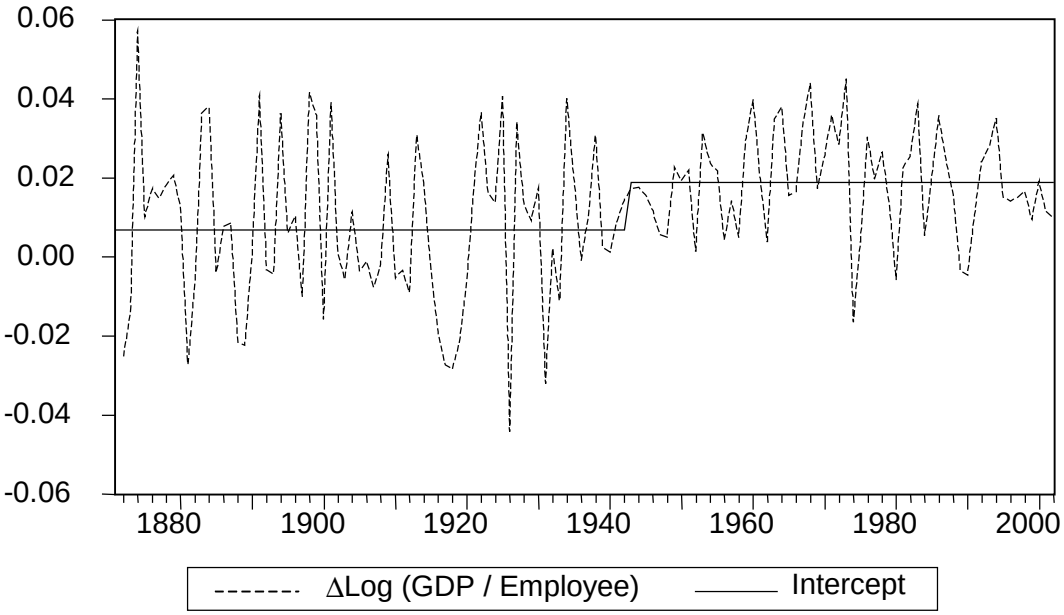


FIGURE 4 : UNITED STATES – SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

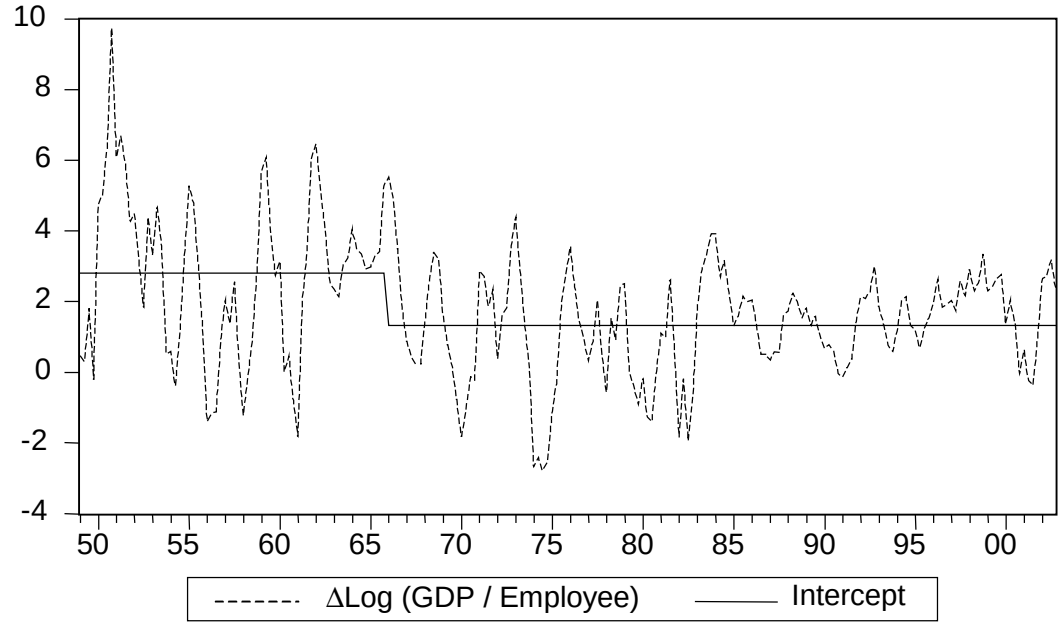


FIGURE 5 : FRANCE – SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

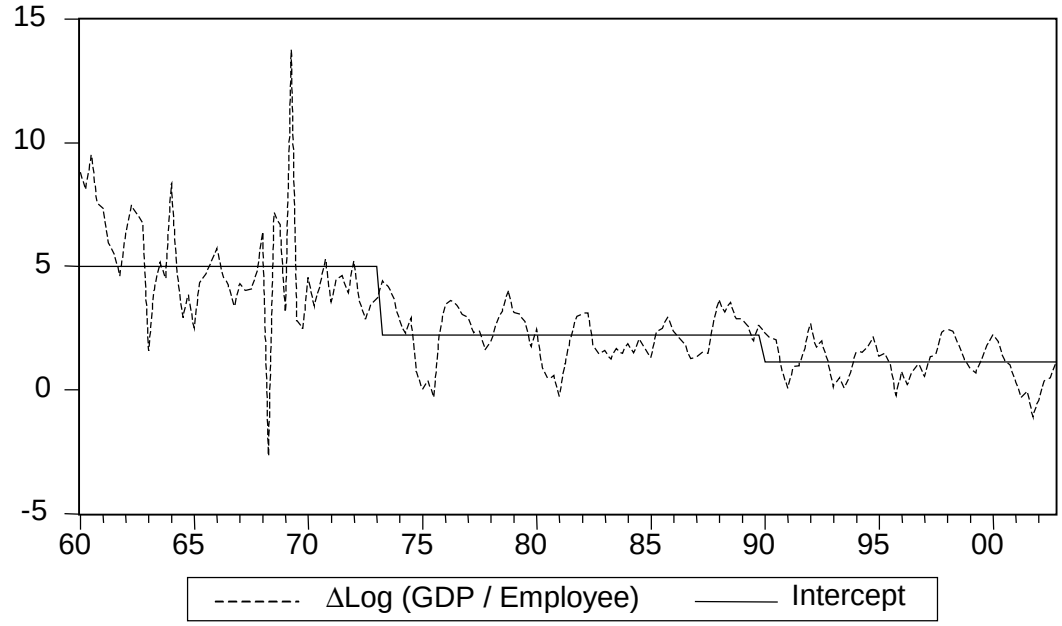
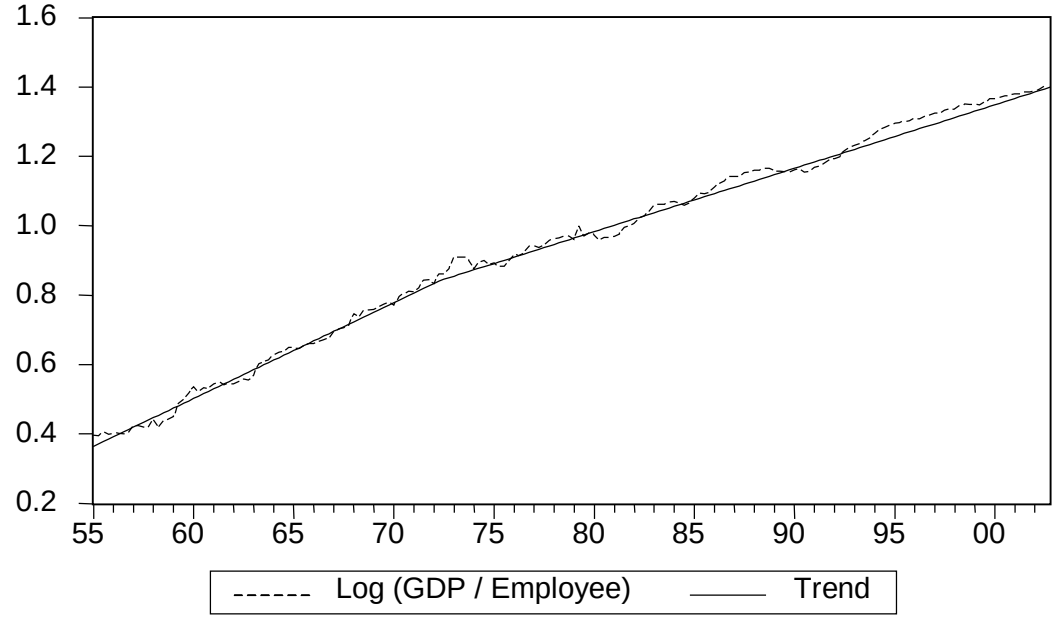


FIGURE 6 : UNITED KINGDOM – SHORT SAMPLE

Logarithm of productivity



Growth rate of productivity

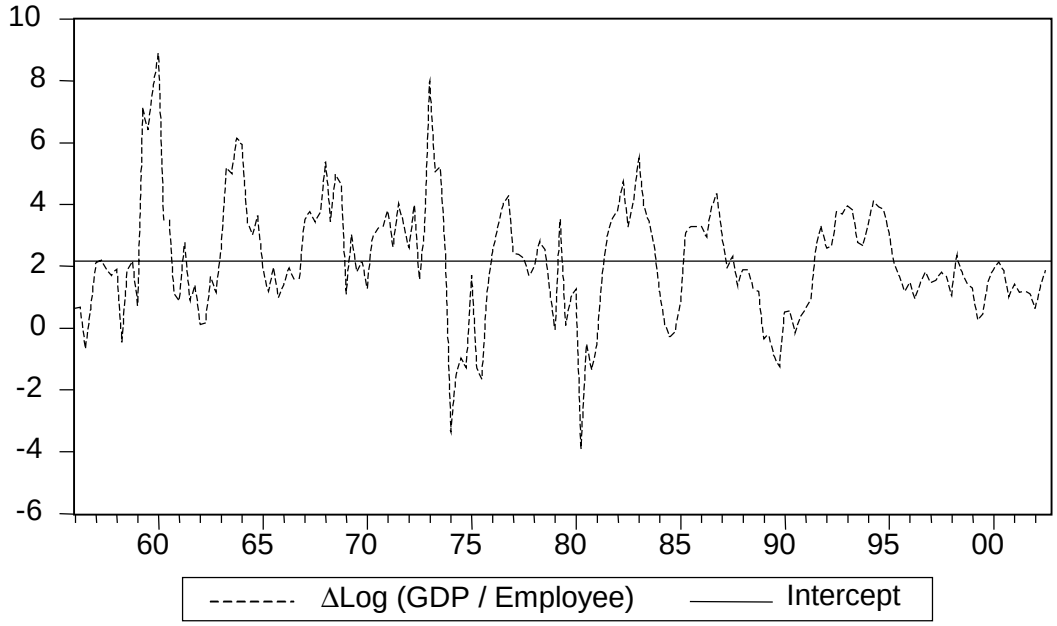


FIGURE 7 : JAPAN – SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

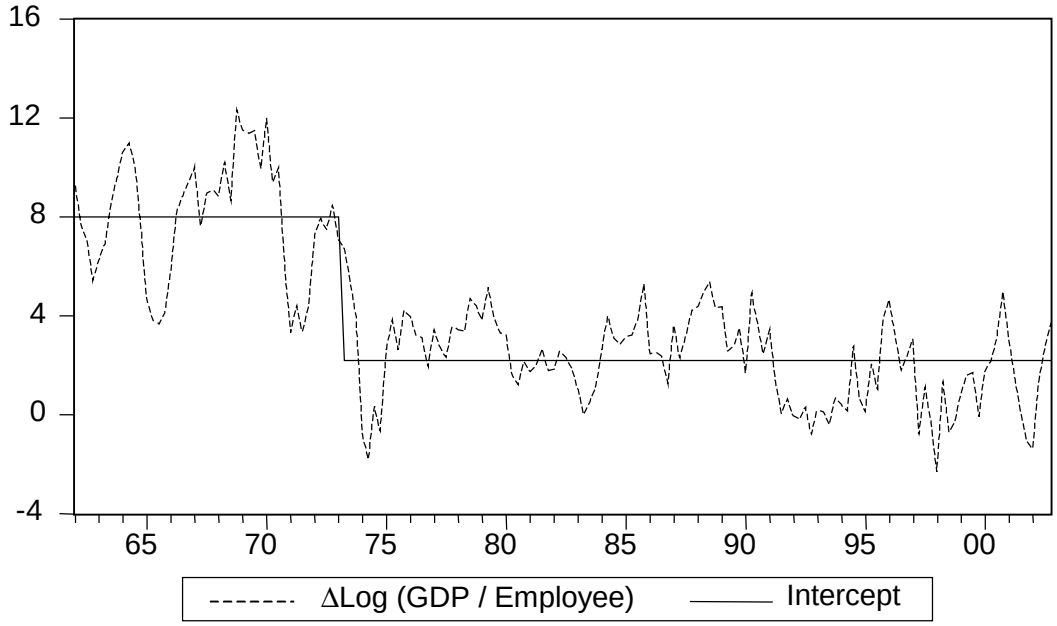


FIGURE 8a : WEST GERMANY -– SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

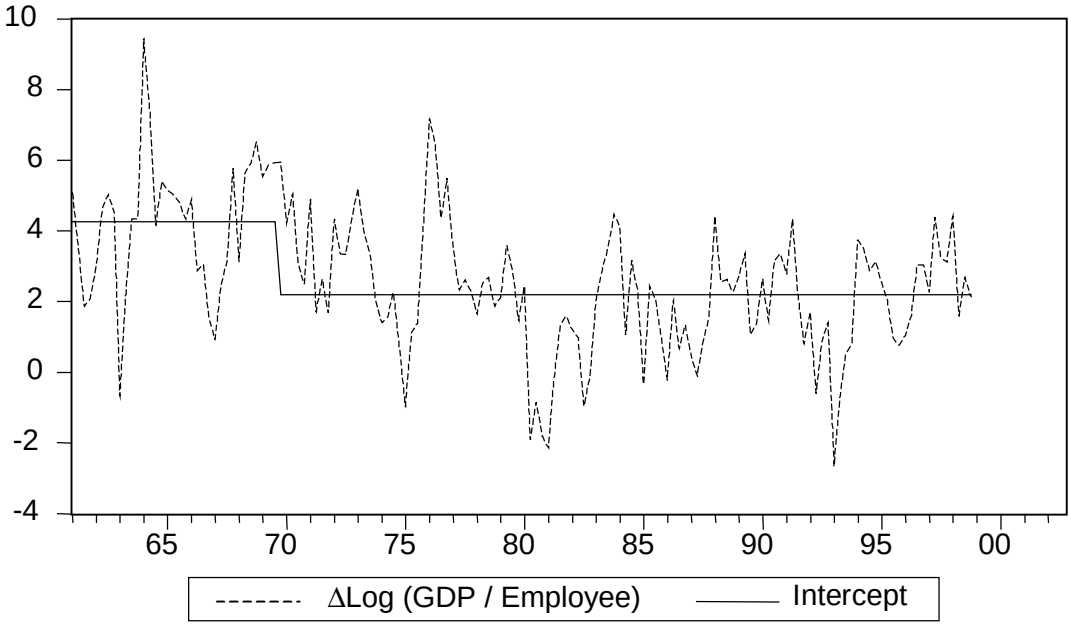
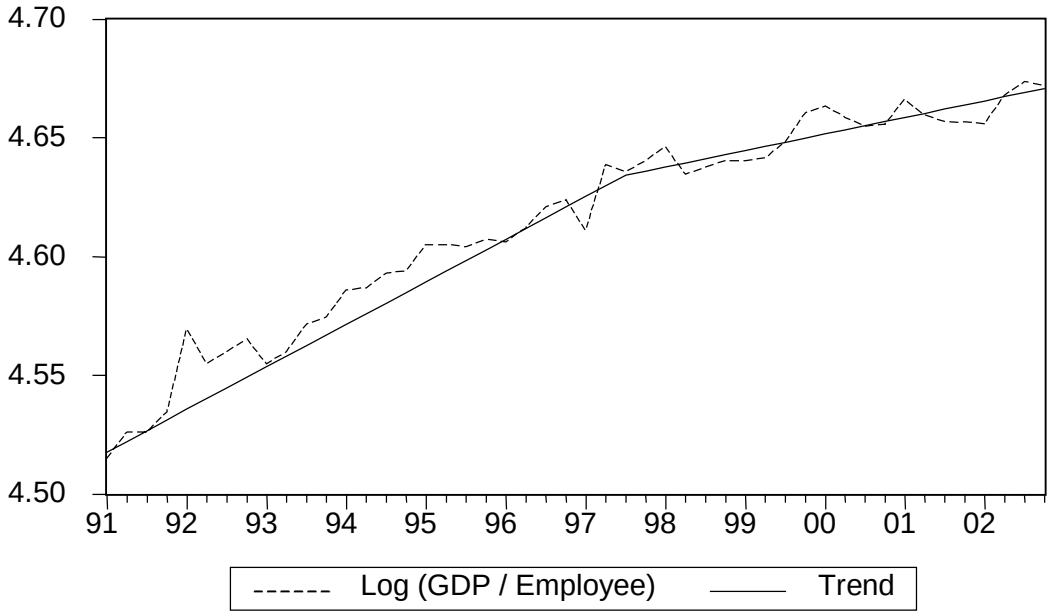


FIGURE 8b : REUNIFIED GERMANY– SHORT SAMPLE

Logarithm of productivity



Growth rate of productivity

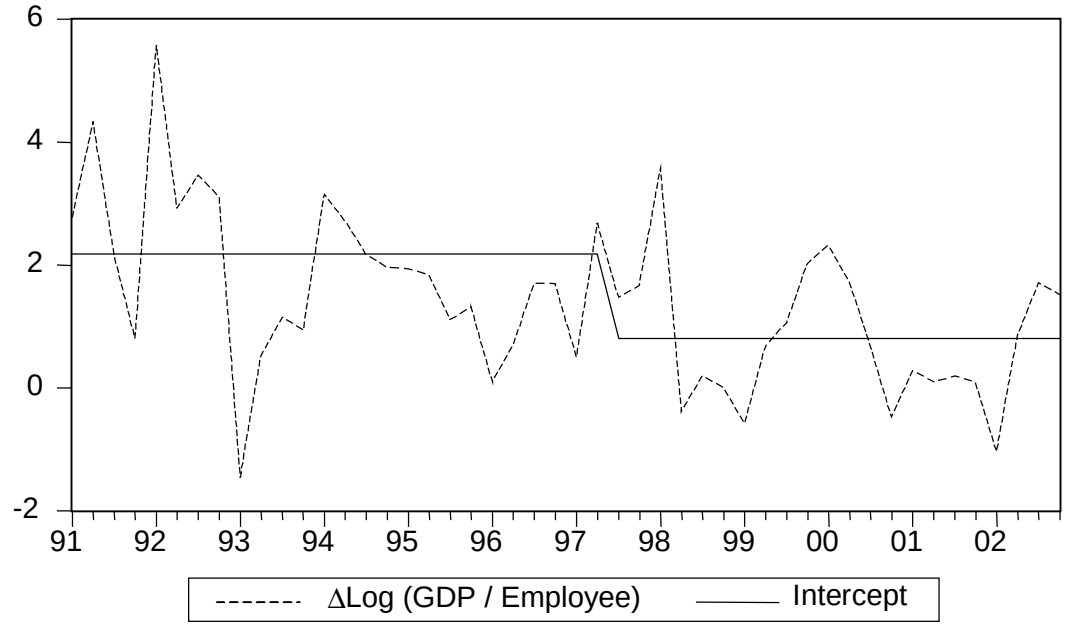


FIGURE 9 : SPAIN – SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

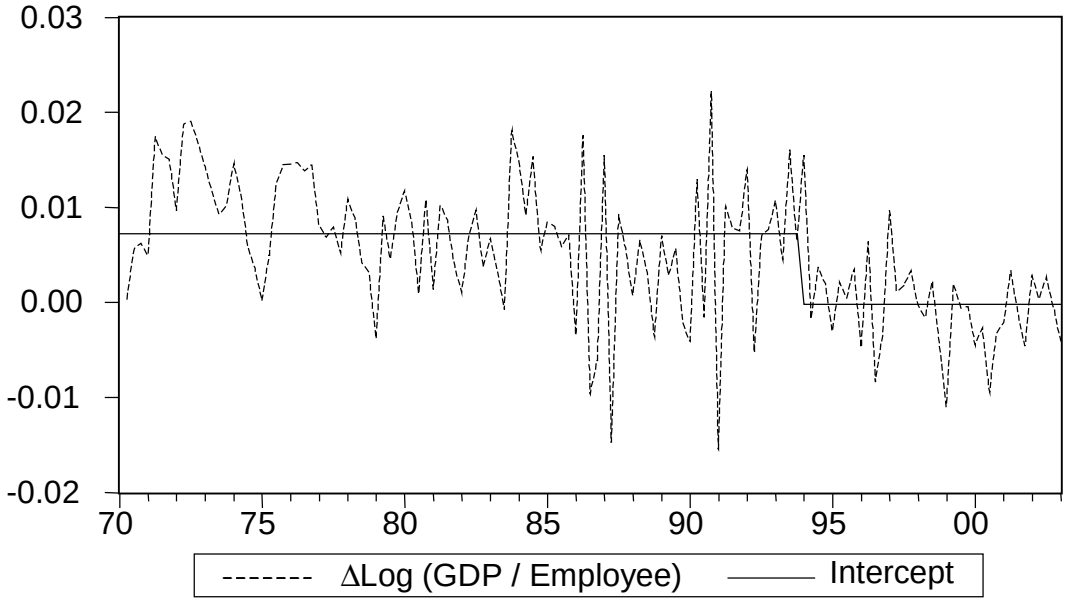


FIGURE 10 : NETHERLANDS – SHORT SAMPLE

Logarithm of productivity

Growth rate of productivity

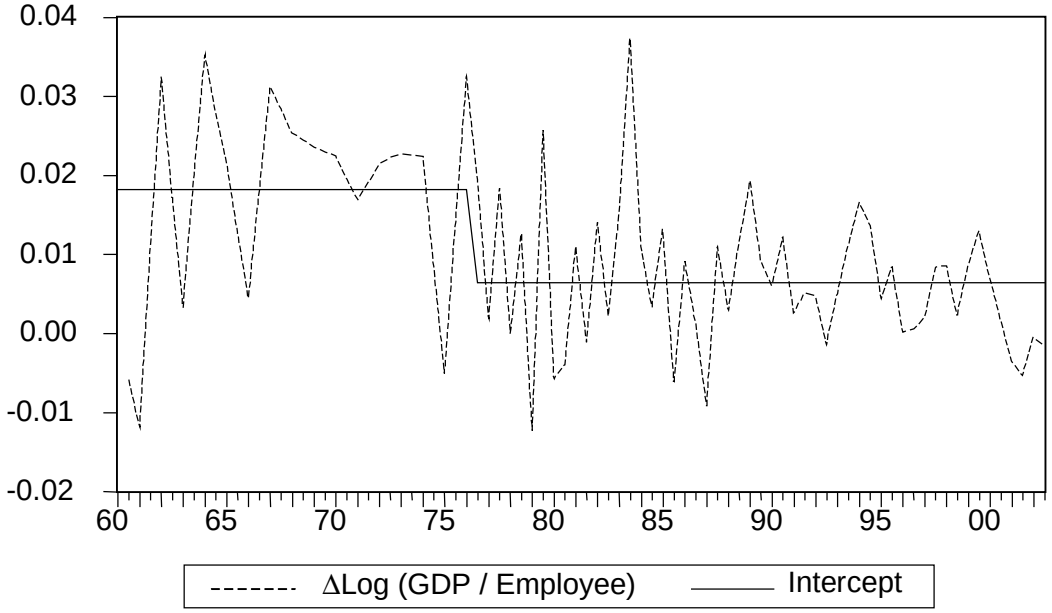
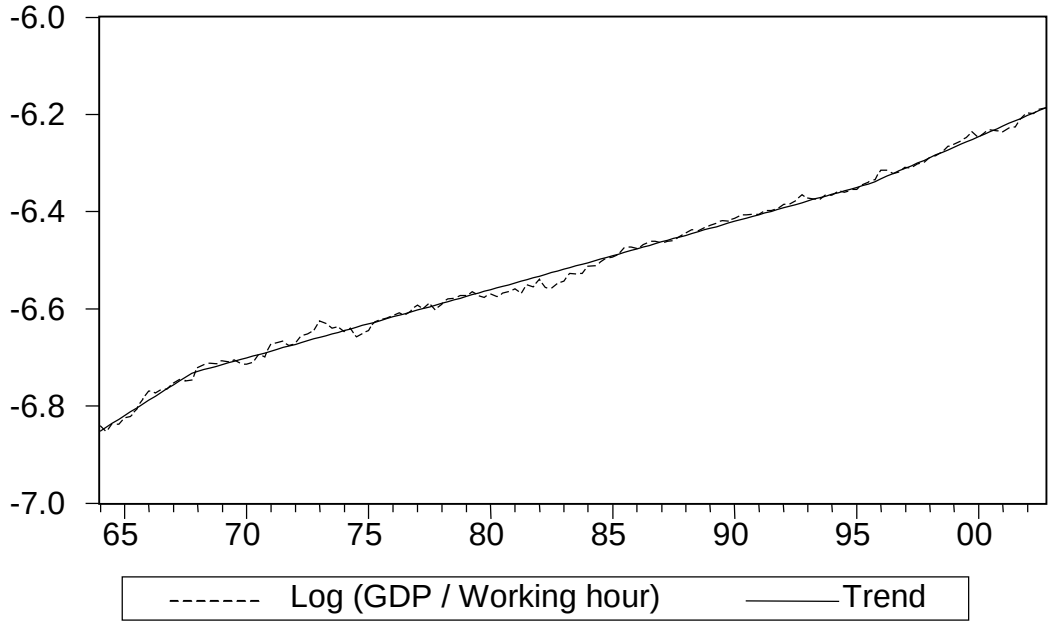
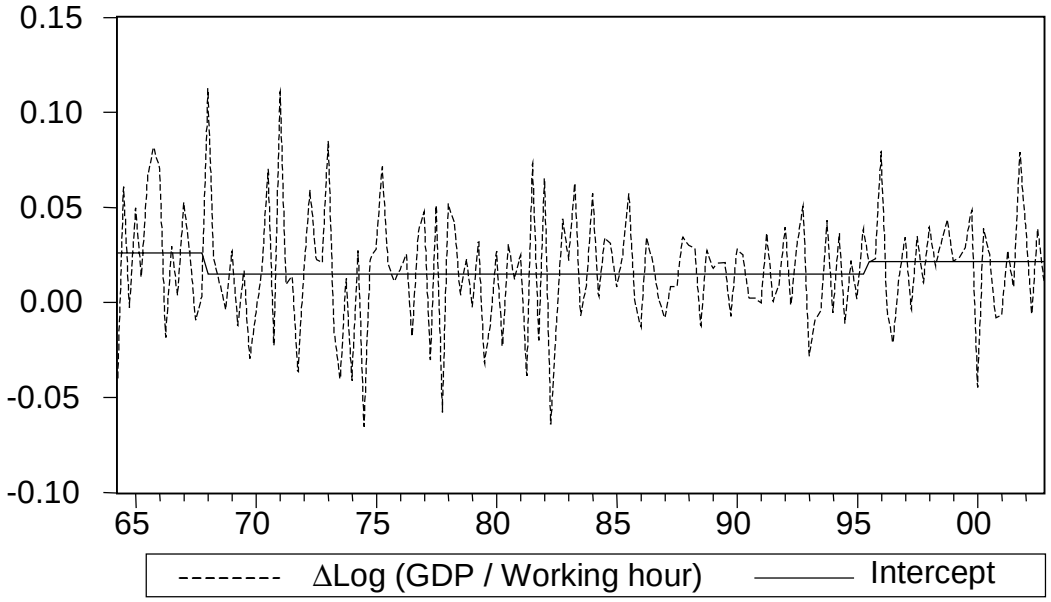


FIGURE 11 : UNITED STATES – SHORT SAMPLE (productivity per hour)

Logarithm of productivity



Growth rate of productivity



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