DOCUMENT

DE TRAVAIL

N° 475

**PRODUCTIVITY TRENDS FROM 1890 TO 2012
IN ADVANCED COUNTRIES**

Antonin Bergeaud, Gilbert Cette and Rémy Lecat

February 2014

DIRECTION GÉNÉRALE DES ÉTUDES ET DES RELATIONS INTERNATIONALES

DIRECTION GÉNÉRALE DES ÉTUDES ET DES RELATIONS INTERNATIONALES

PRODUCTIVITY TRENDS FROM 1890 TO 2012
IN ADVANCED COUNTRIES

Antonin Bergeaud, Gilbert Cette and Rémy Lecat

February 2014

Productivity trends from 1890 to 2012
in advanced countries

February, 5, 2014

Abstract: In order to examine innovation diffusion and convergence processes, we study productivity trends, trend breaks and levels for 13 advanced countries over 1890-2012. We highlight two productivity waves, a big one following the second industrial revolution and a small one following the ICT revolution. The first big wave was staggered across countries, hitting the US first in the Interwar years and the rest of the world after World War II. It came long after the actual innovation could be implemented, emphasizing a long diffusion process. The productivity leader changed during the period under study, the Australian and UK leadership becoming a US one during the first part of the XXth century and, for very particular reasons, also a Norwegian, Dutch and French one at least for some years at the end of the XXth century. The convergence process has been erratic, halted by inappropriate institutions, technology shocks, financial crises but above all by wars, which led to major productivity level leaps, downwards for countries experiencing war on their soil, upwards for other countries. Productivity trend breaks are detected following wars, global financial crises, global supply shocks (such as the oil price shocks) and major policy changes (such as structural reforms in Canada or Sweden). The upward trend break for the US in the mid-1990s is confirmed, as well as the downward trend break for the Euro Area in the same period. The downward trend break observed as early as the mid-2000s for the US leads one to question the future contribution of the ICT revolution to productivity enhancement.

JEL classifications: E22, N10, O47
Keywords: Productivity, convergence, technological change, global history

Résumé: Pour étudier les processus de diffusion de l'innovation et de convergence, nous examinons les tendances de productivité, les ruptures de tendance et les niveaux de productivité pour 13 pays avancés sur la période 1890-2012. Nous faisons apparaître deux vagues de productivité, une grande à la suite de la deuxième révolution industrielle et une petite à la suite de la révolution des TIC. La première grande vague a été échelonnée entre les pays, touchant d'abord les États-Unis dans l'entre-deux guerres et le reste du monde après la deuxième guerre mondiale. Elle est donc arrivée longtemps après que les innovations puissent être mises en œuvre, mettant en évidence un long processus de diffusion technologique. Les pays le plus avancés en termes de productivité ont changé pendant la période étudiée, l'Australie et le Royaume-Uni étant remplacés par les États-Unis pendant la première partie du XXème siècle et, pour des raisons très particulières, la Norvège, les Pays-Bas et la France pendant quelques années à la fin du XXème siècle. Le processus de convergence a été erratique, arrêté par des institutions peu adaptées, des chocs technologiques, des crises financières mais surtout par des guerres, qui ont conduit à des sauts de productivité, à la baisse pour les pays qui ont connu la guerre sur leur territoire, à la hausse pour les autres pays. Les ruptures de tendance de productivité ont été détectées à la suite des guerres, des crises financières mondiales, des chocs d'offre mondiaux (comme sur les prix du pétrole) et des changements de politiques économiques (comme les réformes structurelles au Canada ou en Suède). La rupture de tendance à la hausse aux États-Unis dans le milieu des années 1990 est confirmée, comme la rupture à la baisse pour la zone euro à la même période. La rupture à la baisse observée dès le milieu des années 2000 pour les États-Unis amène à s'interroger sur la contribution future de la révolution TIC à la croissance de la productivité.

Mots-clés: Productivité, convergence, progrès technologique, histoire mondiale

The views expressed herein are those of the authors and do not necessarily reflect the views of the institutions they belong to. We wish to thank, without implicating, Claude Diebolt, Eric Monnet and seminar participants at the Banque de France for their comments.

Non technical summary

Productivity trends from 1890 to 2012 in advanced countries

The aim of this study is to analyze empirically productivity level, evolution and trend breaks over a long period and for a large set of industrialized countries. Two productivity indicators are considered: labor productivity per hour worked (denoted *LP*) and total factor productivity (*TFP*). The computation of *TFP* is based on the usual assumptions of a Cobb-Douglas production function with constant returns to scale. We have also made the assumption of constant capital and labor service shares, each of these two shares being supposed to be the same for all countries. Waves of productivity growth are characterized by using Hodrick-Prescott filtering (denoted HP) and productivity trend breaks are detected by using the Bai and Perron (1998) statistical methodology.

The dataset is composed of 13 countries: the ones in the G7 (the United States, Japan, Germany, France, the United Kingdom, Italy and Canada), the other two biggest countries of the Euro Area (Spain and the Netherlands) and four other countries interesting for productivity analysis because of their specificities (a high productivity level at the beginning of the period for Australia, a specific European economic integration for Finland, a particular industry structure for Norway and the role of structural policies for Sweden). In addition, a Euro Area is reconstituted, which is here the aggregation of Germany, France, Italy, Spain, the Netherlands and Finland.

The analysis is carried out over the period 1890-2012 on annual data and also, from 1960, quarterly data. But to build capital stock series, using a permanent inventory model, information on investment over a longer period is used when available. The starting database was the one built by Cette, Kocoglu and Mairesse (2009) on the United States, Japan, France and the United Kingdom over the 1890-2006 period. We have updated and considerably enlarged this first database. For this, we have tried to make the best use of the estimates of long aggregate historical data series on GDP, employment, working time and investment (in two products, equipment and constructions). For the most recent decades of the analysis, we have relied as much as possible on national accounts data. For others, we have relied on data built by economists and historians on consistent assumptions. We have, then, made a large use of long term data from Maddison (1994, 2001, 2003) or Bolt *et al.* (2013) for several countries and from specific recent evaluations for others, as for example Baffigi (2011) for Italy or Prados (2003) for Spain. Many of these data are subject to uncertainty and inaccuracy, not only for the most distant periods but also for recent ones. The data are built at the country level under the hypothesis of constant borders, in their last state, but whatever the talents of economists and historians are, this needs some strong assumptions to reconstitute some countries. We may nevertheless consider that the orders of magnitude of our estimates and the ensuing large differentials in productivity levels and growth rates are fairly reliable and meaningful. Series for GDP and capital are given in constant national currencies of 2005 and converted to US dollars in purchasing power parity (ppp) with a conversion rate from the Penn World Tables.

The main originalities of the analysis are that it is proposed over a long period, on a large set of countries, with data reconstituted in purchasing power parity and on the basis of, as much as possible, consistent assumptions (and for example, for each of the two capital stock products, the same depreciation rate for all countries) which allow levels and growth comparisons among countries for each of the two productivity indicators.

This study leads to numerous results regarding productivity level, evolution and trend breaks. The main ones are the following:

(i) Over the whole 1890-2012 period, we observe two productivity growth waves, the first big one corresponding to the second technological revolution (use of electricity power, internal combustion engine, chemical production…) and the second, smaller and shorter, to the ICT technology revolution;

(ii) In the US, the first wave corresponds to a productivity acceleration during the 1920s and the 1930s and a deceleration during the two following decades and the second wave to a productivity acceleration during the 1980s and the 1990s and a deceleration afterwards. This latest deceleration leads one to question the future contribution of the ICT revolution to productivity enhancement;

(iii) Other countries benefited from these two productivity growth waves with a delay, and in a less explicit way for the second one, the length of this delay varying from one country to another;

(iv) The productivity leader changed during the period, the Australian and UK leadership becoming a US one during the first part of the XXth century and, for very particular reasons, also a Norwegian, Dutch and French leadership, at least for some years, at the end of the XXth century;

(v) There is no global and permanent convergence process regarding productivity level and divergence processes or stable gaps appear often during long sub-periods;

(vi) General productivity breaks appear in all countries at specific moments, such as world wars, global supply shocks (such as the petrol price one during the 1970s) or global financial crises (such as those which happened at the end of the 1920s or at the end of the first decade of the 2000s);

(vii) Country specific productivity breaks appear, which can be linked to idiosyncratic shocks such as policy ones (for example the implementation of structural reforms in Canada and Sweden in the 1990s) or technological ones (such as the early acceleration of the ICT technological shock in the US during the 1990s).

As far as comparisons are possible, these results are consistent with the ones of other analyses usually produced on one or on a limited number of countries and over shorter periods (see for example the survey of numerous analyses proposed by Crafts and O’Rourke, 2013).

1. Introduction

Productivity is one of the main living standard factors, and for this reason has always benefited from a large attention in economic literature. Two aspects have been mainly discussed in this literature: the factors of productivity growth and the country productivity convergence processes.

Technological progress appears to be the main engine of productivity growth. Nevertheless, the way this technological progress improves productivity depends on numerous aspects. For the country at the technological frontier, which means the productivity leader country, it depends on technological improvements and on institutions, these two dimensions being interdependent (see for a complete overview Aghion and Howitt, 1998, 2009, and Crafts and O'Rourke, 2013). Ferguson and Wascher (2004) showed in a detailed way how each productivity growth wave corresponded in the US over the last Century to an interaction between technological shocks and adapted institutions, among them education of the working age population as well as labor, product and financial market regulation. However, institutions also include the quality of the State (i.e. level of corruption, quality of justice…) and, as was stressed by Barro and Sala-I-Martin (1997), property right protection. Concerning the followers (i. e. countries behind the technological frontier), the productivity growth process seems easier as copying innovations is for them cheaper than innovating for the leading country. From this, one could conclude that a catch-up process, i.e. productivity convergence, should necessarily take place, but this is not what is observed. Indeed, copying innovation needs adapted institutions. As a consequence, from non-adapted institutions, the productivity convergence process of the followers to the leading productivity level country is often stopped, if not reversed. From these considerations, Crafts and O'Rourke (2013) show that the productivity leader can change over time, that productivity growth is characterized by waves and that productivity convergence is not guaranteed for the followers, all these aspects being explained by the interactions of institutions and innovations.

The legal Origin Theory approach tells us that institutional regulation changes, to become more adapted to innovation and growth, depend on whether the country is historically inscribed in a common law or a civil law culture, the former being better suited to useful evolutions (see for a survey La Porta *et al.*, 2008). Nevertheless, this approach fails to explain how some countries, usually considered as having a civil law culture, benefit from relatively high levels of productivity and standard of living, France being an example of such countries. For Algan and Cahuc (2010), among others, the institution impacts also largely depend on the trust and the confidence people have in them.

Numerous studies have proposed, on large country dataset, comparisons of productivity growth over a long period (see for example among others Islam, 2003, Madsen, 2010a and b and for a survey Crafts and O'Rourke, 2013). Their results are consistent with the analyses mentioned above. For the two last decades, the attention has focused mainly on the explanation of the productivity surge in the US and the productivity slowdown in Europe in the mid 1990s (among others see for example Jorgenson, 2001, van Ark *et al.*, 2008; Timmer *et al.*, 2011) and of the productivity slowdown in the US in the mid 2000s (see among others Gordon, 2012, 2013 and Byrne *et al.* 2013). The two 1990s contrasted breaks (upward in the US and downward in Europe) seem well explained by a dynamic interaction between innovation (carried by ICTs) and institutions, while the latest US productivity slowdown, preceding the current Great Recession, seems too recent to benefit from a large range of analyses.

The aim of the present study is to analyze empirically productivity level, evolution and trend breaks over a long period and for a large set of industrialized countries. Two productivity indicators are considered: labor productivity per hour worked (denoted *LP*) and total factor productivity (*TFP*). The computation of *TFP* is based on the usual assumptions of a Cobb-Douglas production function with constant returns to scale. We have also made the assumption of constant capital and labor service shares, each of these two shares being supposed to be the same for all countries. Waves of productivity growth are characterized by using Hodrick-Prescott filtering (denoted HP) and productivity trend breaks are detected by using the Bai and Perron (1998) statistical methodology.

The dataset is composed of 13 countries: the ones in the G7 (the United States, Japan, Germany, France, the United Kingdom, Italy and Canada), the other two biggest countries of the Euro Area (Spain and the Netherlands) and four other countries interesting for productivity analysis because of their specificities (a high productivity level at the beginning of the period for Australia, a specific European economic integration for Finland, a particular industry structure for Norway and the role of structural policies for Sweden). In addition, a Euro Area is reconstituted, which is here the aggregation of Germany, France, Italy, Spain, the Netherlands and Finland.

The analysis is carried out over the period 1890-2012 on annual data and also, from 1960, quarterly data[1]. But to build capital stock series, using a permanent inventory model, information on investment over a longer period is used when available. The starting database was the one built by Cette, Kocoglu and Mairesse (2009) on the United States, Japan, France and the United Kingdom over the 1890-2006 period. We have updated and considerably enlarged this first database. For this, we have tried to make the best use of the estimates of long aggregate historical data series on GDP, employment, working time and investment (in two products, equipment and constructions). For the most recent decades of the analysis, we have relied as much as possible on national accounts data. For others, we have relied on data built by economists and historians on consistent assumptions. We have, then, made a large use of long term data from Maddison (1994, 2001, 2003) or Bolt *et al.* (2013) for several countries and from specific recent evaluations for others, as for example Baffigi (2011) for Italy or Prados (2003) for Spain. Many of these data are subject to uncertainty and inaccuracy, not only for the most distant periods but also for recent ones. The data are built at the country level under the hypothesis of constant borders, in their last state, but whatever the talents of economists and historians are, this needs some strong assumptions to reconstitute some countries[2]. We may nevertheless consider that the orders of magnitude of our estimates and the ensuing large differentials in productivity levels and growth rates are fairly reliable and meaningful. Series for GDP and capital are given in constant national currencies of 2005 and converted to US dollars in purchasing power parity (ppp) with a conversion rate from the Penn World Tables.

The main originalities of the analysis are that it is proposed over a long period, on a large set of countries, with data reconstituted in purchasing power parity and on the basis of, as much as possible, consistent assumptions (and for example, for each of the two capital stock products, the same depreciation rate for all countries) which allow levels and growth comparisons among countries for each of the two productivity indicators.

This study leads to numerous results regarding productivity level, evolution and trend breaks. The main ones are the following: (i) Over the whole 1890-2012 period, we observe two productivity growth waves, the first big one corresponding to the second technological revolution (use of electricity power, internal combustion engine, chemical production…) and the second, smaller and shorter, to the ICT technology revolution; (ii) In the US, the first wave corresponds to a productivity acceleration during the 1920s and the 1930s and a deceleration during the two following decades and the second wave to a productivity acceleration during the 1980s and the 1990s and a deceleration after. This latest deceleration leads one to question the future contribution of the ICT revolution to productivity enhancement; (iii) Other countries benefited from these two productivity growth waves with a delay, and in a less explicit way for the second one, the length of this delay varying from one country to another; (iv) The productivity leader changed during the period, the Australian and UK leadership becoming a US one during the first part of the XXth century and, for very particular reasons, also a

1 1890 was selected as a starting date in order to allow for a break before WWI and in order to have long enough investment series to initialize the capital series (Cf. Appendix 1).

2 Think for example of the distance of these hypothetical constant border countries from the economic reality for Germany and even Italy and France over the period 1890-2012.

Norwegian, Dutch and French leadership, at least for some years, at the end of the XXth century;[3] (v) There is no global and permanent convergence process regarding productivity level and divergence processes or stable gaps appear often during long sub-periods; (vi) General productivity breaks appear in all countries at specific moments, such as world wars, global supply shocks (such as the petrol price one during the 1970s) or global financial crises (such as those which happened at the end of the 1920s or at the end of the first decade of the 2000s); (vii) Country specific productivity breaks appear, which can be linked to idiosyncratic shocks such as policy ones (for example the implementation of structural reforms in Canada and Sweden in the 1990s) or technological ones (such as the early acceleration of the ICT technological shock in the US during the 1990s).

As far as comparisons are possible, these results are consistent with the ones of other analyses usually produced on one or on a limited number of countries and over shorter periods (see for example the survey of numerous analyses proposed by Crafts and O'Rourke, 2013).

Section 2 presents the two productivity indexes and the data used in the analysis, and Section 3 summarizes the methodology used to characterize the productivity trend breaks. These aspects are detailed in the Appendixes 1, 2 and 3. The results are given and commented in Section 4 and some robustness checks are proposed in Section 5. Section 6 concludes.

2. Productivity indexes, data and country groups

The productivity analysis is realized through two indexes (2.1.), computed on 13 countries and the Euro Area over the period 1890-2012, which requires few series but on a long period, this aspect being the main challenge of the database construction (2.2.). Two groups of countries appear clearly when analyzing productivity co-movements (2.3.).

2.1. The two productivity indexes

We considered two productivity indexes: Labor Productivity (denoted *LP*) and Total Factor Productivity (denoted *TFP*).

The labor productivity indicator (*LP*) is easier to compute as it is the ratio of GDP (*Y*) over labor (*L*): $LP = Y / L$. Labor is considered as the number of hours worked, which means here that it is the product of the total employment (*N*) by the average working time by worker (*H*): $L = N * H$. Labor is considered as homogeneous.

The total factor productivity indicator (*TFP*) is the ratio of GDP (*Y*) over an aggregation of the two considered production factors, capital (*K*) and labor (*L*): $TFP = Y / F(K, L)$. Capital is here the sum of two components, equipment (*KE*) and buildings (*KB*): $K = KE + KB$. Assuming a Cobb-Douglas production function, *TFP* corresponds to the usual relation: $TFP = Y / (K^{\alpha} * L^{\beta})$, where α and β are the elasticities of output with respect to the inputs *K* and *L*. Assuming unitary returns to scale ($\alpha + \beta = 1$), the relation becomes: $TFP = Y / (K^{\alpha} * L^{1-\alpha})$. Note that we take as the measure of capital (*K*) used in the period *t* the volume of the stock of capital installed at the end of the period $t - 1$.

Solow (1956, 1957) was one of the first proponents, through the "*growth accounting approach*", to assess the contributions of the main factors of production to economic growth, with such an evaluation of total factor productivity. In this approach, GDP growth is the sum of two components, labor productivity (*LP*) growth and labor (*L*) growth. Labor productivity (*LP*) growth is itself decomposed in two sub-components: total factor productivity (*TFP*) growth and capital to labor ratio (K / L) growth

3 These particular reasons are an important industry specialization in high productivity activities (such as petrol, wood and fishing) concerning Norway and relatively short average working time and low employment rate with decreasing output returns of these two variables concerning Norway, The Netherlands and France.

multiplied by the elasticity of GDP to capital (α). This second sub-component is usually named the capital deepening effect. Taking logarithm first difference as an approximation of growth rate, this decomposition corresponds to the relationship (lower case corresponding to log): $\Delta y = \Delta tfp + \alpha * \Delta(k - l) + \Delta l$. The *TFP* term stands for the impact on growth of autonomous technical progress and of other unmeasured factors, and is usually evaluated as a residual, the other components of the equation being individually computed.

2.2. The data

The two productivity indexes (*LP* and *TFP*) are computed over the period 1890-2012 for 13 developed countries: Australia, Canada, Finland, France, Germany, Italy, Japan, The Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States. In addition, they are also computed for a reconstituted Euro Area which is here the aggregation of Germany, France, Italy, Spain, the Netherlands and Finland. This approximation seems acceptable as these six countries represent together, in 2012, 82% of the total current GDP of the Euro Area. The 13 countries of the dataset correspond to the ones in the G7 (the United States, Japan, Germany, France, the United Kingdom, Italy and Canada), to the other two biggest countries of the Euro Area (Spain and the Netherlands) and to four other countries interesting for productivity analysis for their specificities: a high productivity level at the beginning of the period for Australia, a specific European economic integration for Finland, a particular industry structure for Norway and the role of structural policies for Sweden. Data sources and construction are detailed in Appendix 1.

To compute the two productivity indexes over this long 1890-2012 period, three basic series are needed for each country: GDP (Y), labor (L) and capital (K). Regarding labor (L), we need data on total employment (N) and working time (H). The capital indicator is constructed by the permanent inventory method (PIM) applied for each of the two components (equipment KE and buildings KB) on each of the two the corresponding investment data (IE and IB). For this, as much as possible, very long term information on investment are used. When available data are not as long as necessary, the capital data are initialized by using usual assumptions at the starting point. As in Cette, Kocoglu and Mairesse (2009), the depreciation rates used to build the capital series by the PIM are 10.0% for equipment and 2.5% for buildings. It appears that the results of the study are robust to this choice and keep roughly stable for other realistic depreciation rates (see Section 5.). Finally, damages happening during WW1, WW2, earthquakes in Japan and the civil war for Spain are, as much as information is available for this, taken into account to build the capital series. The fact that the same assumptions are made for all countries of the database to build the capital series is of course important to compare *TFP* levels and evolutions.

In order to evaluate the *TFP* index, it is also necessary to measure the output elasticities with respect to the different inputs. In addition to the hypothesis of constant returns to scale ($\alpha + \beta = 1$), it is generally assumed that production factors are remunerated at their marginal productivity (at least over the medium to long term, which is the horizon of the study), which means that it is possible to estimate factor elasticities on the basis of the share of their remuneration (cost) in total income (or total cost). Given that labor costs (wages and related taxes and social security contributions) represent roughly two thirds of income, it is simply assumed here that $\alpha = 0.3$. It appears that the results of the study are also robust to this calibration of α and remain roughly stable for other realistic values (see Section 5.).

The data sources from which the productivity indexes are computed are historical and, as much as possible, national accounts series. Historical sources are numerous, and we use here the ones which allow the most international comparison (for example Maddison 2001, 2003). These data are annual and also, from 1960, quarterly, which gives more statistical strength to implement statistical tests to characterize the productivity breaks. Quarterly and annual data are totally consistent.

2.3. Two country groups

Table 1 gives, for the two productivity indexes, the correlations among countries of the productivity level relative to the US level (in log). Unsurprisingly, it appears that this correlation is high among Euro Area countries. A high correlation appears also among countries of the Commonwealth (United Kingdom, Australia and Canada) and among Scandinavian countries (Finland, Sweden and Norway). These high correlations can partly be explained by intense economic relations, in particular in terms of trade. More unexpectedly, a high correlation appears also between European countries and Japan. It will be commented forward (Section 4.) that, in all these countries who experienced WW2 on their own soil, the productivity decreased hugely during that war period, which is not the case for the other countries. This specific productivity behavior during WW2 contributes to this large correlation level. These rather high correlations among advanced countries are also consistent with international synchronization of long cycle fluctuations as evidenced by A'Hearn and Woitek (2001) in the late XIXth century or the existence of common world factor in business cycle as evidenced by Kose, Otrok and Whiteman (2003) in 1960-1990.

From these observations, two groups of countries will be considered in the following comments: Euro Area countries and the others.

Table 1
Correlation matrix for:
- Labor productivity (LP) over the US level, at the bottom part of the Table
- Total factor productivity (TFP) over the US level, at the upper part of the Table

		TFP											
		GE	**FR**	**IT**	**SP**	**NL**	**FI**	**JP**	**UK**	**CA**	**AU**	**SW**	**NO**
	GE	-	0.68	0.72	0.58	0.69	0.72	0.77	0.11	-0.22	0.02	0.61	0.72
	FR	**0.94**	-	0.89	0.58	0.70	0.49	0.55	-0.23	-0.32	-0.29	0.51	**0.93**
	IT	**0.92**	**0.97**	-	0.80	0.81	0.61	0.79	0.14	0.02	0.08	0.52	0.84
	SP	0.89	0.89	0.85	-	0.81	0.78	0.86	0.59	0.34	0.51	0.34	0.62
	NL	0.88	0.89	0.83	**0.92**	-	0.79	0.80	0.39	0.09	0.30	0.68	0.71
	FI	**0.93**	**0.96**	**0.93**	0.86	0.83	-	0.80	0.59	0.20	0.47	0.57	0.63
LP	**JP**	**0.91**	**0.93**	**0.95**	0.82	0.78	**0.96**	-	0.50	0.15	0.41	0.50	0.65
	UK	0.13	0.02	-0.08	0.39	0.38	0.02	-0.12	-	0.79	**0.94**	0.06	-0.12
	CA	-0.21	-0.18	-0.20	0.03	0.06	-0.26	-0.31	0.48	-	0.84	-0.23	-0.33
	AU	-0.17	-0.28	-0.37	0.08	0.09	-0.31	-0.43	**0.90**	0.58	-	-0.03	-0.23
	SW	0.78	0.85	0.89	0.61	0.67	0.84	0.88	-0.35	-0.26	-0.59	-	0.57
	NO	**0.90**	**0.96**	**0.96**	0.81	0.79	**0.97**	0.98	-0.14	-0.30	-0.45	**0.90**	-

Each cell contains the correlation coefficient for the two associated countries, calculated over the 1890-2012 period.
In bold: Correlation higher than 0.90.

3. Testing trend breaks

In order to establish a chronology of productivity trends, we have tested econometrically breaks in the series. Our methodology is based on Bai and Perron (1998), adjusted for the specific case of historical data disturbed by two world wars and a change in frequency from annual to quarterly series.

3.1. General methodology for detecting trend breaks

We define productivity trends as linear time trends of log productivity between two break dates: $y_t = \alpha + \sum_{k=0}^{m} \beta_k (t - T_k)\mathbb{I}(t \geq T_k) + u_t$ (eq. 1) where y is log productivity, m is the number of breaks, $\{T_1, T_2, \dots, T_m\}$ are the break dates, $\mathbb{I}$ is the indicator function, $\beta = \{\beta_1, \dots, \beta_m\}$ represents the difference in trend growth rate between two consecutive periods and u is the cyclical part of the time series.

First, we test the hypothesis of stationarity (i.e. $m = 0$), which would mean that productivity has a constant trend over the whole period. If stationarity is rejected, the values of m and the break dates $\{T_1, T_2, \dots, T_m\}$ have to be determined. Finally, the value of $\{\beta_0, \dots, \beta_m\}$ can be computed with a standard OLS regression.

Bai and Perron (1998) have developed a methodology to compute simultaneously the number of breaks, their dates and the trends. The main idea is to estimate $\{\beta_0, \dots, \beta_m\}$ for each ordered partition $\tau = \{T_1, T_2, \dots, T_m\}$ by minimizing the sum of squared residuals. Then, the appropriate value of τ is chosen by solving the following equation: $\tau^* = \arg\min_{\tau \in P_{m,T}} S(\tau, \beta(\tau))$ where $P_{m,T}$ is the set of ordered m-partition $\{T_1, T_2, \dots, T_m\}$ and $S(\tau, \beta(\tau))$ the sum of squared residuals for our model with the corresponding values of τ and β.

In addition, an essential rule to follow is to set a minimum number of observations between two breaks, therefore: $min_{i \in \{0,\dots,m\}}(T_{i+1} - T_i) > hT$ with h a trimming coefficient ($hm < T$ with $T_0 = 1$ and $T_{m+1} = T$).

We chose to set this parameter for annual data to 6% of the total number of observations, which accounts for approximately 7 years. In order to limit border effects and improve the performance of the test through a larger number of observations, we used quarterly data from 1960 onwards and set the parameter to 10% (5 years), with a maximum number of 4 breaks.

To merge the break dates from annual and quarterly series, we ran the test separately on annual data for the whole period and on quarterly data. Then, after the first break in quarterly series, we kept the break dates identified in quarterly series only. We removed the remaining last break date of annual series if it was located less than five years before the first break year of quarterly data (Cf. Appendix 3).

This way of testing for structural breaks assumes that a parameter β_k can only change at a punctual time T_k. In other words, we test at every date *t* the value of some boolean variable B_t whose value is 1 if a break happens and 0 otherwise. A more complex and general non linear approach known as Smooth Transition Regressions and presented for example in Terasvirta (1996) has been developed to deal with the fact that some transitions in macroeconomic time series are not punctual but spread over many years. In this case, B_t is no longer a boolean but a continuous function from (0,1) onto (0,1) and a break is detected if this function is higher than a given threshold. However, we preferred to use the Bai and Perron approach, keeping in mind that a detected break comes with a confident interval for the date and must be interpreted with caution.

3.2. Dealing with wars

WWI, WWII and the Spanish Civil War have led to disruptions of the production process and of statistical sources, with a variable intensity across countries. Data may hence be unreliable and volatile during the war periods, but also for some years afterwards as normalization may take several years. Countries not directly involved may be also affected through trade disruption or anticipated conversion to war economy. Therefore, although it is not relevant to apply the general trend break methodology, a consistent statistical procedure is necessary for assessing the length of the war disruption period for each country beyond the official war period.

Hence, we added dummy variables for war periods, allowing for breaks in productivity trend and level. The number of dummy variables used, *i.e.* the length of each war-related disruption period, is determined by an algorithm described in Appendix 2 and is specific to each country. Finally, a break date at the end of each war period has been added.

This method has a major shortcoming, by separating our data in three subsamples (respectively before WWI, between WWI and WWII and after WWII) we run the risk of missing obvious breaks if they are located too close to wars as they would be estimated on too small a number of observations. This is evidenced by clearly misestimated breaks, especially around 1928. After analyzing the first results, we decided to automatically move breaks located in 1927 and 1926 to 1928. This change concerned two countries: Canada and the US. We validated this process by calculating the new sum of square residuals which happens to be lower after this modification.

4. Results

Before characterizing the significant productivity trend breaks through a statistical approach, it seems appropriate to analyze the main productivity growth waves. These waves give a useful and easy representation of the diffusion of the most important technological shocks and of the convergence or divergence processes in terms of productivity levels. From this productivity growth wave analysis (4.1.), it gets easier to comment the productivity trend breaks, successively from 1890 to World War II (4.2.), and after World War II until 2012 which is the end of our dataset (4.3.).

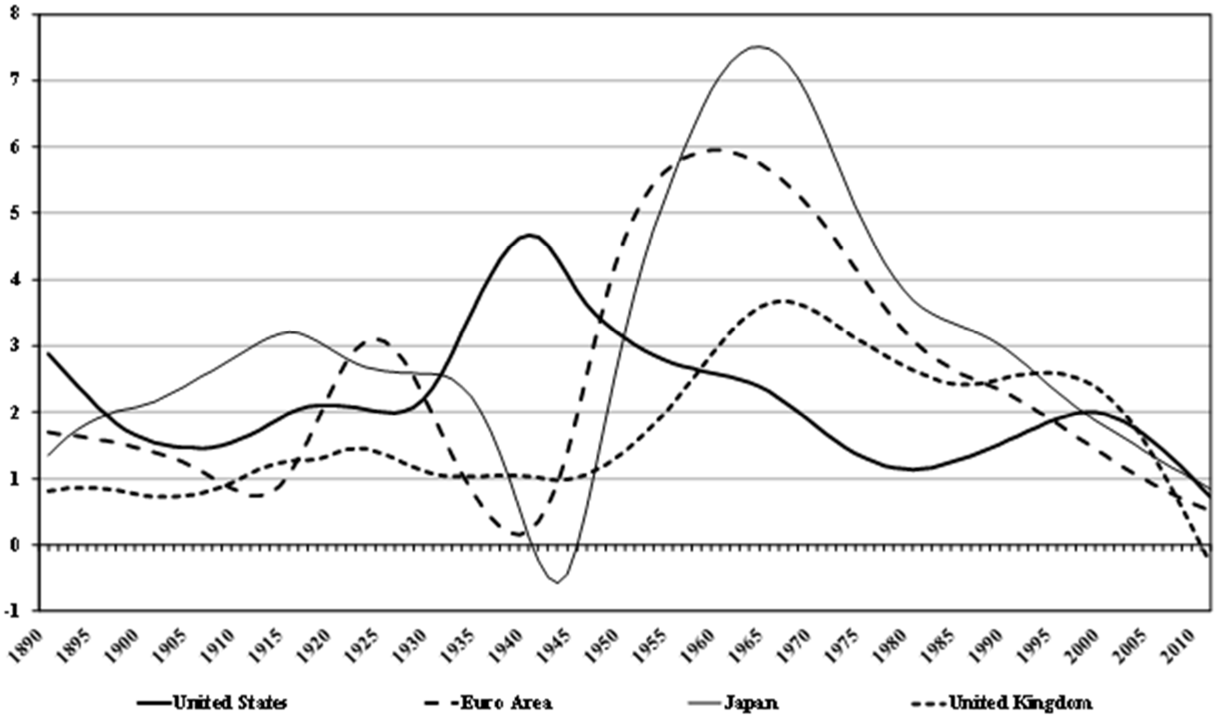
4.1. Productivity waves: innovation and convergence over the XXth century

In order to establish the stylized facts of productivity growth, we smooth productivity annual growth rate over the period using the Hodrick-Prescott filtration (HP). Considering the very high volatility of our data, the choice of the lambda coefficient, which set the length of the cycle we will capture, is of paramount importance. Setting a too high value for lambda would tend to absorb smaller cycles, while setting a too low value would consider major cyclical effects as trends, especially around WWII. We decided to focus on cycles of 30-year length, which implies a value of 500 for lambda, according to the HP filter transfer function.

Graphs 1 and 2 represent the smoothed productivity growth, respectively for labor productivity (*LP*) and for total factor productivity (*TFP*) from 1890 to 2012 for the United States, the Euro Area, Japan and the United Kingdom. Graphs 3 to 6 represent the level of labor productivity per hour (*LP*) and of total factor productivity (*TFP*) relative to the current US level for each country of the dataset. And finally, Graph 7 represents the distance with the US productivity (*LP* and *TFP*) level and breaks in this distance for Japan, United Kingdom and the Euro Area.

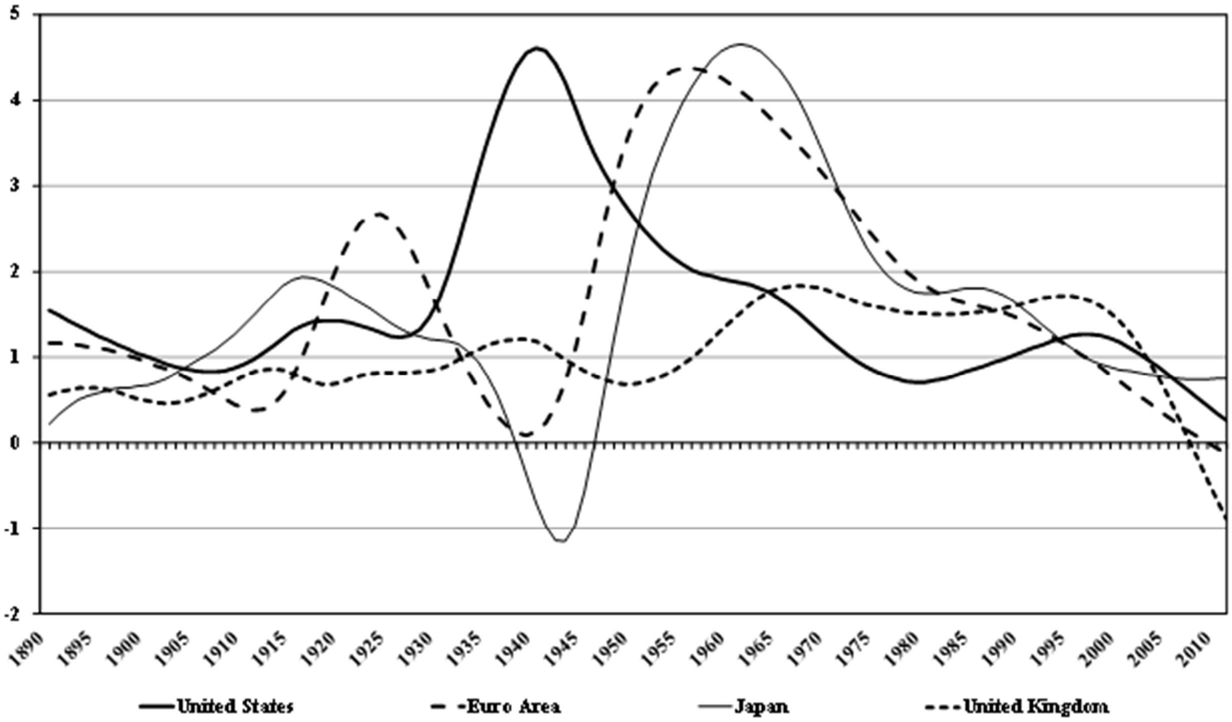
Graph 1

Smoothed (through Hodrick-Prescott filtering*) of the average annual growth of labor productivity per hour (*LP*) in the United States, the Euro Area, Japan and the United Kingdom
1891 to 2012 – In%



Graph 2

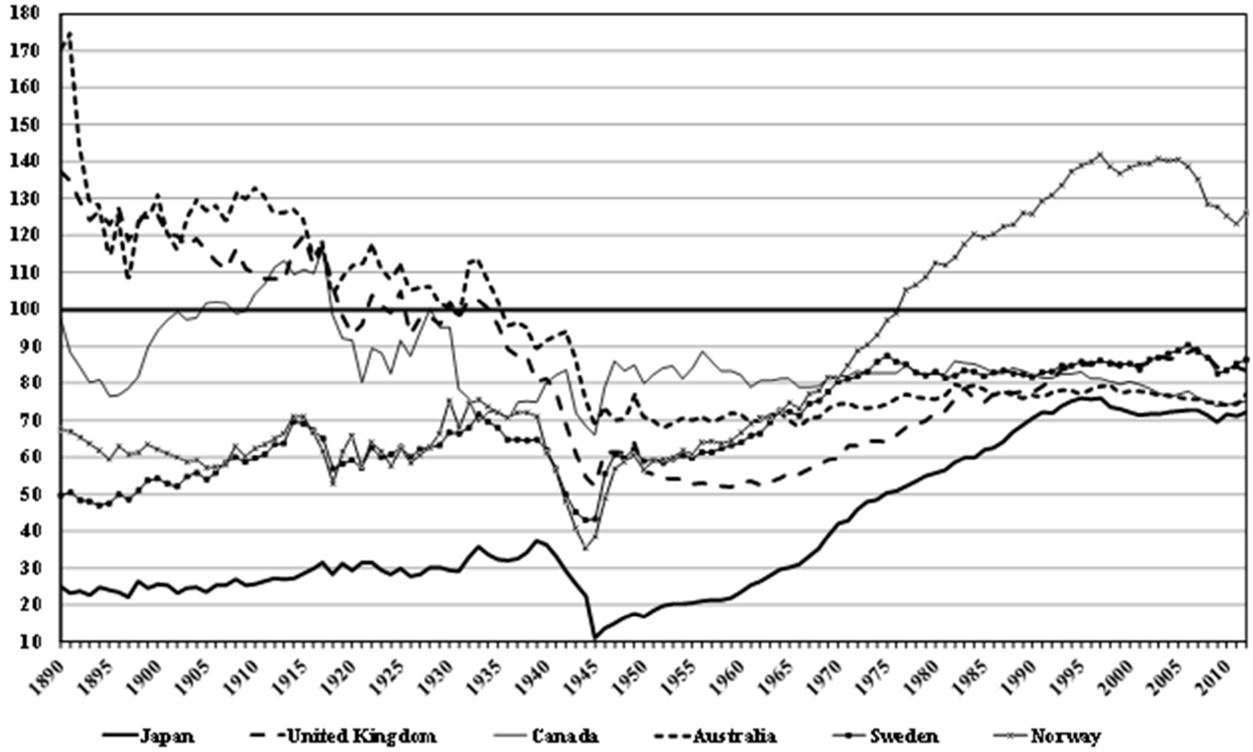
Smoothed (through Hodrick-Prescott filtering*) of the average annual growth of total factor productivity (*TFP*) in the United States, the Euro Area, Japan and the United Kingdom
1891 to 2012 – In%



*: $\lambda = 500$.

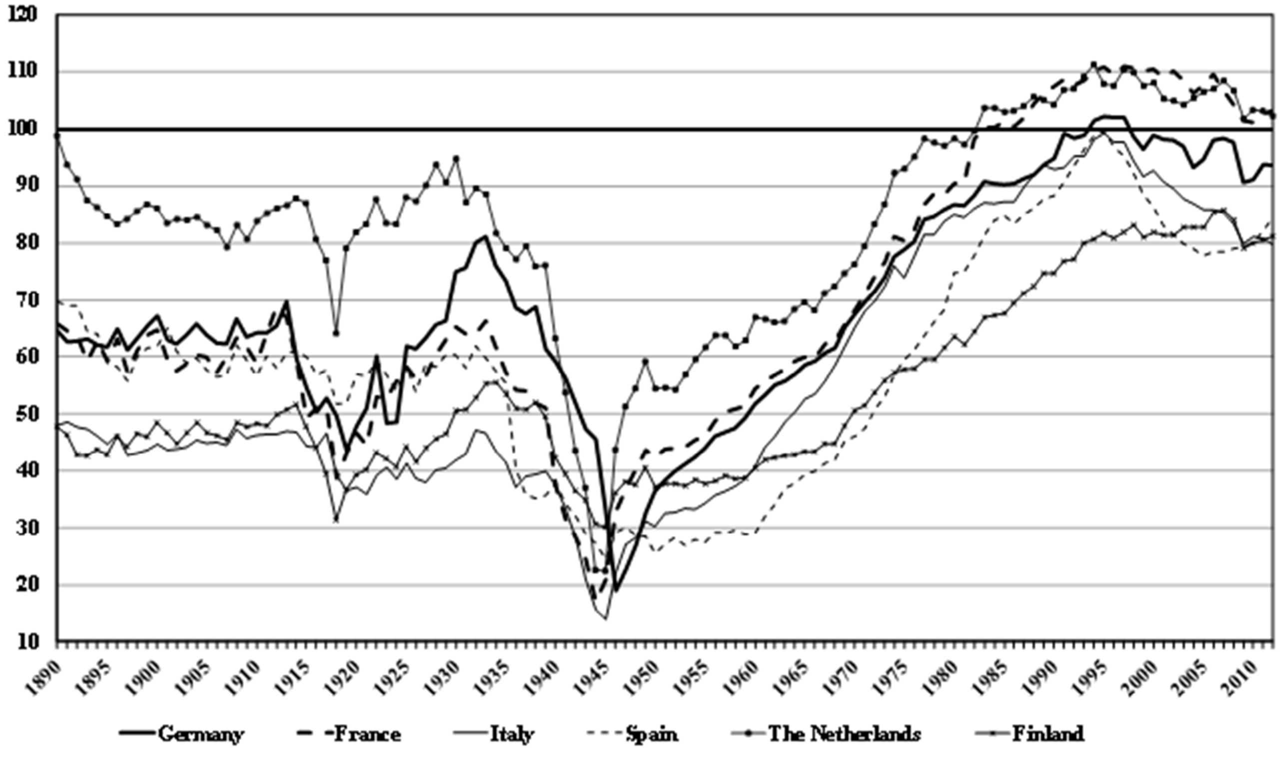
Graph 3

Level of labor productivity per hour (*LP*) relative to the current US level in non-Euro Area countries 1890 to 2012 - $ 2005 ppp – US level = 100



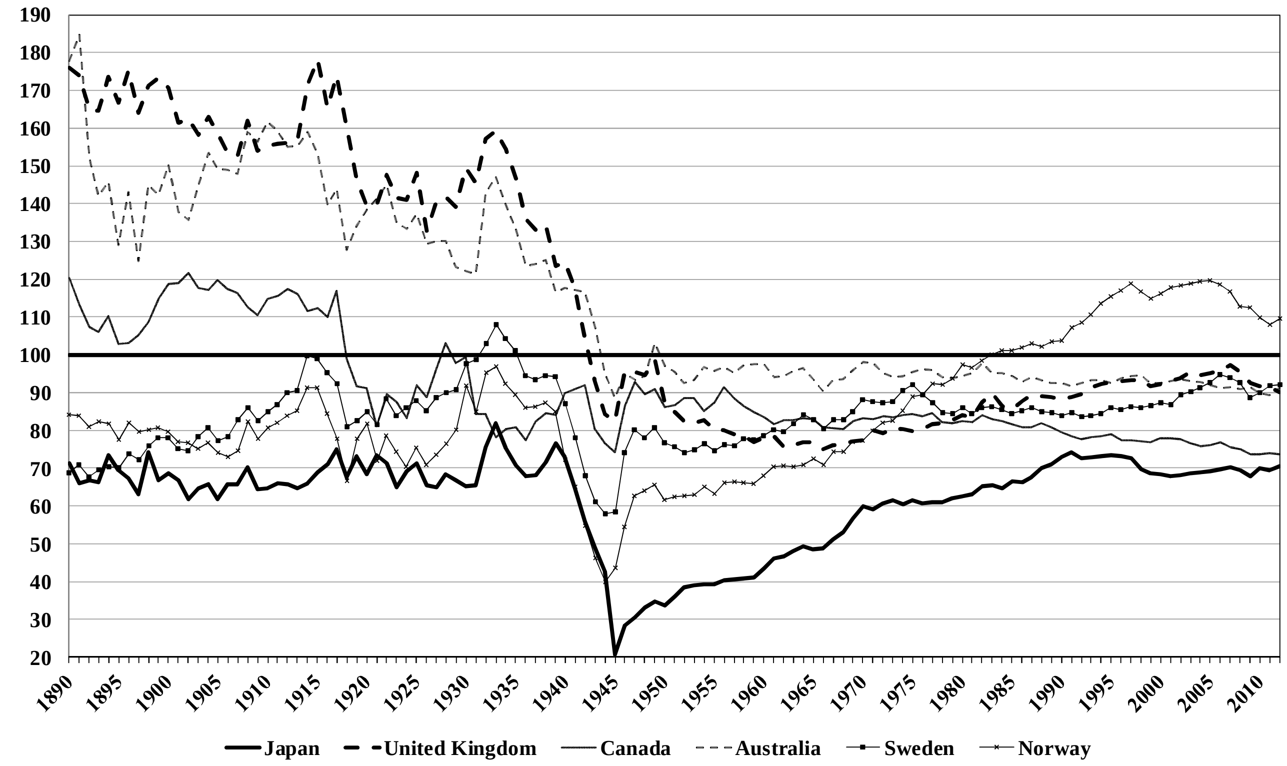
Graph 4

Level of labor productivity per hour (*LP*) relative to the current US level in Euro Area countries 1890 to 2012 - $ 2005 ppp – US level = 100



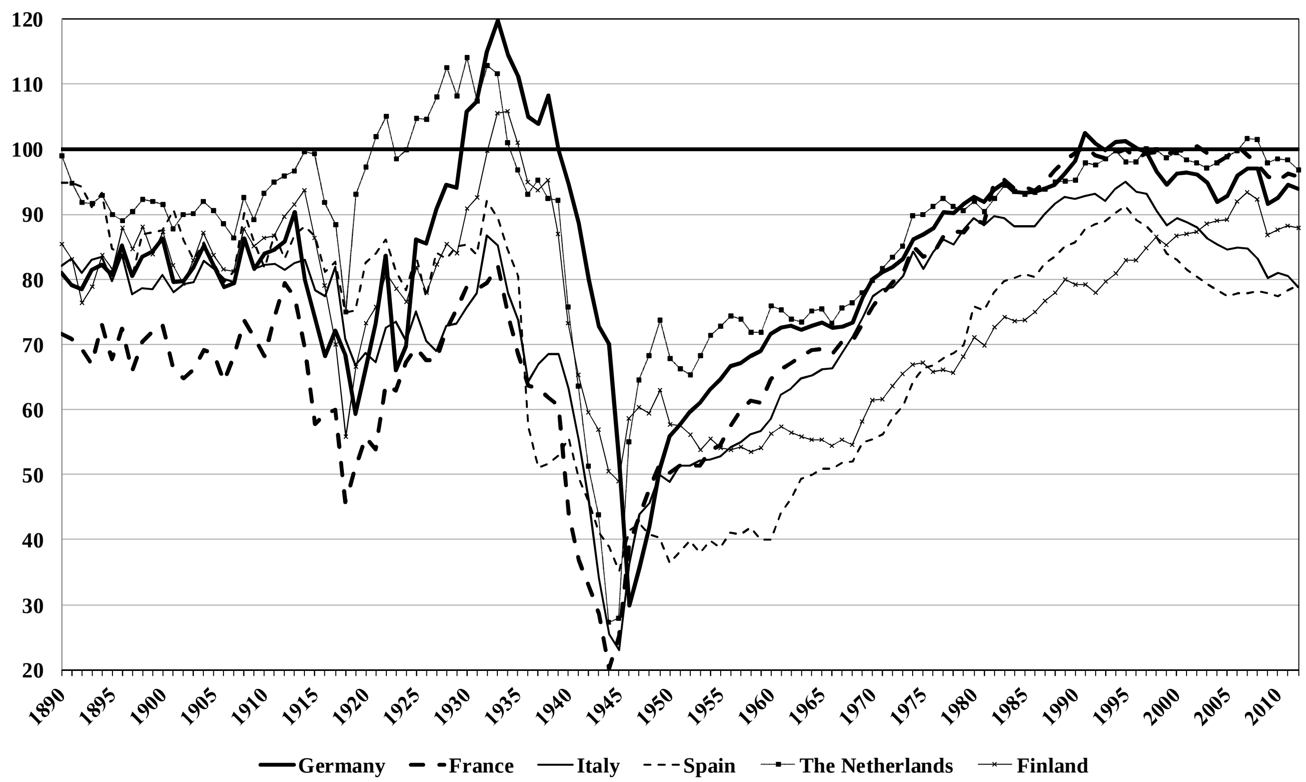
Graph 5

Level of total factor productivity (*TFP*) relative to the current US level in non-Euro Area countries 1890 to 2012 - \$ 2005 ppp – US level = 100



Graph 6

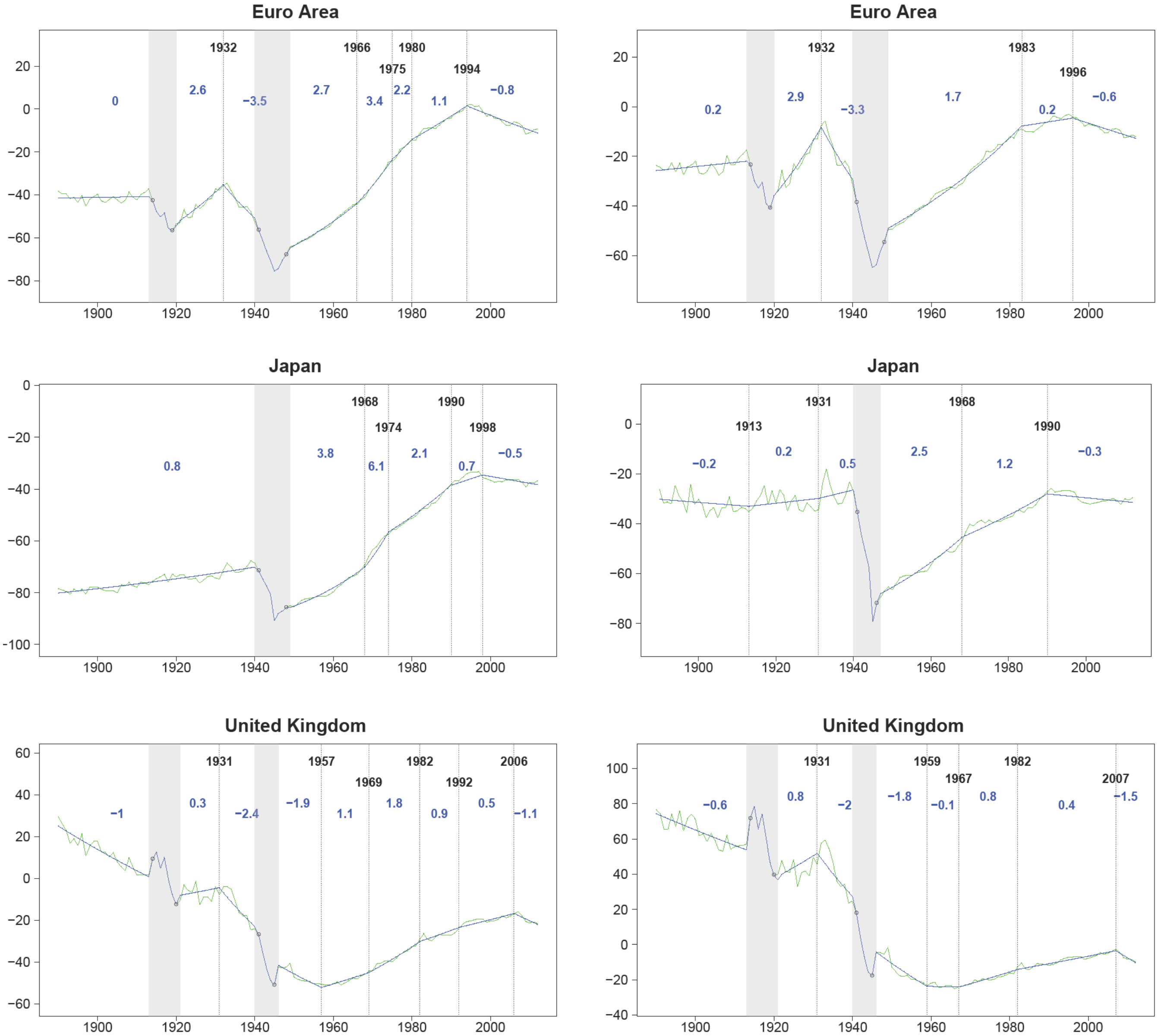
Level of total factor productivity (*TFP*) relative to the current US level in Euro Area countries 1890 to 2012 - \$ 2005 ppp – US level = 100



Graph 7

Distance with the US in productivity level and breaks of this distance for Japan, United Kingdom and the Euro Area -% over the US level

Left column corresponds to labor productivity, right column corresponds to TFP



4.1.1. *"One big wave" of productivity acceleration*

We can mainly distinguish four periods from 1890 to 2012 (cf. Graphs 1 to 6):

1. From 1890 to WWI, productivity was growing moderately and was characterized by a UK leadership and a catch-up by the other countries.
2. After the WWI slump, the Interwar and WWII years were characterized by a heightening of the US leadership, as it experienced an impressive big wave of productivity acceleration in the 1930s and 1940s (identified by Gordon, 1999, 2003), while other countries struggled with the Great Depression legacy and WWII.
3. After WWII, European countries and Japan benefited from the big wave experienced earlier in the United States.
4. Since 1995, the post-war convergence process has come to an end as US productivity growth overtook Japan and other countries', although it is not up to its 1930s or 1940s pace. Shorter and smaller than the first one, a second big wave appeared in the US and, in a less explicit way, in the other areas.

Hence, all countries experienced that one big wave of productivity acceleration, but in a staggered manner: first the United States in the 1930s and 1940s, next the European countries and Japan after WWII. This wave was the strongest in the Euro Area and Japan, but starting from a much lower starting level than the United States (and even the United Kingdom for TFP). After several leaps forward of the US relative productivity level during each World War and its own big wave, this gave rise to a convergence process after WWII which appeared completed in the 1990s for the Euro Area - but not yet for Japan or the United Kingdom- when this process came to an end.

4.1.2. *Innovation clusters and their diffusion in the XXth century*

Overall, this period saw major technological breakthroughs as the 2nd industrial revolution spread across countries and sectors. The 2nd industrial revolution was first technological, with the emergence of several General Purpose Technologies, *i.e.* technologies spreading to most sectors, improving over time and spawning innovation (Bresnahan and Trajtenberg, 1995). Gordon (2000) distinguishes four major clusters of fields for that technological revolution:

- Electricity, in the form of light bulb reducing the cost of light (Nordhaus, 1997) and electric motors, providing a decentralized and flexible source of power.
- The internal combustion engine, which changed totally the individual, collective and commercial transportation.
- Chemistry with petrochemistry and pharmaceuticals.
- Communication and information innovations with the telephone, radio, movies...

However, the 2nd industrial revolution was also a revolution in production organization and financial markets (Ferguson and Washer, 2004). Production was reorganized according to Taylor (1911) scientific management principles and through assembly lines in manufacturing (implemented for example for the Ford Model T in the Ford Motor Company in 1913). This reorganization led to larger average firm size as assembly lines increased economies of scale, while advances in communication technologies allowed for more vertical integration of industries into distribution or retailing. Finally, nonfinancial business investment, which used to be financed mainly through retained earnings or relatives' capital, could rely on debt or preferred stock before WWI and afterwards on equity markets.

Despite the impressive wave of technological innovations of the end-19th century, productivity accelerated significantly only in the Interwar period in the United States and after WWII in the Euro Area. Before WWI, labor productivity growth was around 1.½% per year in the United States and the Euro Area, and TFP growth around 1%. It was much weaker in the productivity leader of that period, the United Kingdom, at ¾% for labor productivity and ½% for *TFP*, and much higher for the productivity laggard, Japan, at 2.½% for labor productivity and 1% for *TFP*. After WWI, productivity growth impressively took off in the United States, with a short parenthesis for the Great depression, reaching around 5% for both labor productivity and TFP after 1933. The surge was not as clear for other areas: the productivity trend was almost unchanged for the United Kingdom or Japan; the Euro Area experienced a productivity rebound right after WWI but did not recover from the Great Depression. The full diffusion of the productivity gains of the second industrial revolution appears to have spread outside the United States only after WWII.

This slow diffusion hinges both on the classic S-shape time path of new innovations (described in Jerome, 1934, for electricity) and on the organizational changes needed to fully reap the benefits of these products. David (1990) analyses the factors behind the diffusion lag of innovation through the example of the dynamo. Although the first practical design of a dynamo was presented in 1867, the conversion of industrial processes to electricity only took off after 1914-1917 in the United States. First, electrification would prove unprofitable until still serviceable steam- or water-powered equipments would depreciate. Second, the overlaying of older power generation equipments with electric motors did not allow to reap the full productivity benefits of electricity, which required a radical redesign of factory structures (including buildings). Finally, these investments required experienced factory architects and electrical engineers, who could turn up only after a long process of learning by doing. David (1990) also emphasizes that the benefits of electrification could be understated by conventional productivity measures as quality improvements and new products are badly accounted for.

The ICT technology shock has a sizeable impact on productivity growth in the US from the 1980s, this impact becoming large from the 1990s, as was stressed by Jorgenson (2001) and after, among numerous others, by Jorgenson, Ho and Stiroh (2006, 2008). The ICTs have a favorable impact on productivity via two main channels (for a survey, see Oulton, 2012): (i) TFP gains largely driven by rapid technological progress in the different ICT-producing industries; (ii) Substitution effects linked to the accumulation of ICT capital (capital deepening), which itself results from the continuous and rapid improvements in the productive performance of ICT investments, leading to a sharp fall in the price of ICT relative to other capital goods and to labor.

A large body of literature (for example, among others, Shreyer, 2000; Colecchia and Shreyer, 2001; Pilat and Lee, 2001; van Ark *et al.*, , 2008, Timmer *et al.*, 2011) has shown that the level of the diffusion of ICT differs greatly across the main industrialized countries, the US and the UK being the countries where the diffusion appears to be the highest. Inklaar *et al.* (2005) showed that this gap in the ICT diffusion was mainly located in services industries. Numerous studies provide alternative explanations for the ICT diffusion lag observed everywhere but in the UK and in the US (see for example studies quoted above). Cette and Lopez (2012) present a survey of this literature and show, through an econometric approach on country panel data, that this lag can be explained by differences in the average education level of the working age population and by higher labor and product market regulations.

An impressive slowdown in the ICT productivity impact seems to happen from the mid 2000s in the US. Gordon (2012, 2013) interprets it as a huge deceleration of the Moore’s law. He stresses that the wave of the productivity growth corresponding to the ICT main diffusion period is shorter and lower than the one corresponding to the previous technological shock. For him, in terms of productivity gains, this technological shock is not as important as the previous ones, and the US productivity growth should be low after the temporary revival started in the 1990s. Other studies as Aizcorbe, Oliner and Sichel (2008) or Byrne, Oliner and Sichel (2013) present the slowdown in the ICT productivity impact as, at least partly, the result of an increase of price-cost markups in chip industry, or as a mismeasurement (see below). Even more, they do not exclude a second wave of productivity growth from ICT new improvements. Other explanations of this slowdown are also plausible (for a survey, see Cette, 2013).

4.1.3. Convergence dynamics over the XXth century

Another engine of productivity growth has been convergence to the productivity leader, first the United Kingdom and then the United States (see Graphs 3 to 6). The productivity convergence process may be explained by the copying behavior of the follower countries to the leader's best practices. Abramovitz (1986) lists several reasons why convergence may not take place or could keep unachieved, or why some countries benefit more than others from technological shocks as for example the US for the ICT one at the end of the XXth century. The main reason appears, in the literature, to be institutional obstacles to the adoption of the leader best practices and to the diffusion of the most efficient technologies (see Crafts and O'Rourke, 2013, for a large survey).

It is remarkable that over the XXth century, the productivity convergence process has relied, on an accounting approach, for a large part on sectoral composition effects (mostly rural exodus) and productivity growth within services and agriculture, while productivity gaps in manufacturing were persistent, at least until WWII (Broadberry, 1993).

The United States overtook the United Kingdom labor productivity level at the turn of the century, just after WWI in our database and in the 1890s in Broadberry and Irwin (2006), the divergence hinging mainly on purchasing power parity year reference and on productivity per employee *vs* productivity per hour. The United States had a large productivity lead in manufacturing as early as the mid-19th century but a less favorable sectoral composition (a greater share of labor in agriculture) and was lagging in services and agricultural productivity level (Broadberry, 1997; Broadberry and Irwin, 2006). The origin of the US productivity lead was traced back to a sizeable internal market (in particular Romer, 1996). However, when balancing the impact of long internal distances in the United States against the impact of borders in Europe, market potential can explain only partly the US leadership (Liu and Meissner, 2013). A greater emphasis is now put on the more efficient exploitation of natural resources endowment in the United States, as cheap resources and resource-using machinery were substituted for scarce skilled labor (Ames and Rosenberg, 1968; Nelson and Wright, 1992). A similar explanation can be given for Australia's very high initial productivity level, which eroded as the economy expanded beyond the mining sector (McLean, 2007 and Broadberry and Irwin, 2007).

Before WWI, the United States, the Euro Area and Japan were converging to the United Kingdom level of productivity. WWI allowed the United States to make a major leap forward as production in countries experiencing war on their soil were profoundly disorganized by human or physical capital destructions and the changeover to a war economy. France, Germany and the Euro Area as a whole experienced a downward break in their productivity levels, while the United States experienced an upward break. Compared to the prewar path, Japan and the United Kingdom did not experience a break in productivity level. The United States benefitted from a positive demand shock due to war expenses in European countries, which led to an acceleration of the diffusion of innovation, in particular of electrification, as demand required new investments. The decrease in electricity prices, which occurred from 1914-1917 onwards as regulated regional prices were lowered substantially, also boosted industrial electrification (David, 1989).

During the Interwar years, after a rebound in European countries as production went back to normal, the United States made a second leap forward after the great depression as a wave of radically new products was introduced in the 1930s (Kleinknecht, 1987). As a result, the Euro Area converged to the US productivity level in the immediate afterwar and during the Great depression, which hit harder the United States initially, but the United States widened the gap after 1933, as it experienced an upward break in 1933 in productivity trend while European countries never recovered from the 1929 downward break. In Germany, labor productivity and total factor productivity were relatively dynamic during this Interwar sub-period, with a convergence to the US level not completely achieved for labor productivity but over-achieved for TFP during the Nazi period, this performance being due to the adoption of very high performance productive technologies (see Ristuccia and Tooze, 2013). The productivity gap remained largely constant with Japan during the Interwar years, while it increased with the United Kingdom as barriers to competition allowed high cost producers to remain in business

(Broadberry and Crafts, 1990). During WWII, the impulse given by 1930s new products in the United States was reinforced by the positive demand shock from European countries and later by military R&D expenditures, while European countries and Japan were disorganized by war destructions. As a result, the United States experienced an upward break in productivity level, European countries and Japan a downward break.

Hence, the convergence process was not continuous, as it was disrupted by wars and innovation clusters. Moreover, contrary to what could be expected, convergence during that period did not apply to the manufacturing sector, which displays a much greater degree of stationarity than the whole economy measures of productivity (Broadberry, 1993). Labor productivity in the US manufacturing sector was twice as large as in the United Kingdom and Germany throughout most of the period and twice and a half as large after WWII.[4] Convergence during that period proceeded from sectoral reallocation and in particular rural exodus[5] as well as productivity growth in agriculture and services.

At the end of WWII, the productivity level relatively to the US level was lower than just before WWII, both for labor productivity and for *TFP*, in all the countries except Canada where it was slightly superior (see Graphs 3 to 6). In 1950, the relative (to the US level) productivity level was particularly low (below 75%) in Japan and all European countries, mainly for those which have experienced the conflict (for Spain, the civil war) on their soil (France, Germany, Italy, Spain, The Netherlands, Finland).

After WWII, we observe during a first sub-period an impressive catch-up process to the US productivity level in all countries except the United Kingdom, Canada and, for *TFP*, Australia (see Graphs 3 to 6). This catch-up process can be due to different factors which are not independent from one another: a catch-up of the US higher average education level of the working age population, the diffusion of technologies already in large use in the US, changes in the economic structure and, for example, a decline of the share of agriculture which became more in line with that in the United Kingdom and the United States.[6] It ended most frequently during the 1990s, and earlier during the 1970s in Sweden and the beginning of the 2000s for TFP in Finland and Norway. After this catch-up process, we observe, relatively to the US level, stabilization or even more frequently a decline. The end of the catch up process appears statistically significant and happened in the 1990s for the Euro Area[7] and Japan, and the 2000s for the UK (see Graph 7).

In some cases, the productivity level observed at the end of the catch-up process was equivalent or even superior to the US one: in France, Germany, The Netherlands, Norway and, for labor productivity, Italy and Sweden. It could be wrong to conclude from this that these countries were, at that moment, as efficient as the US in terms of productivity. In these countries, the working time and/or the employment rate were lower than in the US. Several empirical studies find diminishing returns to hours worked and to the employment rate (see Bourlès and Cette, 2005, 2007, for a survey and estimates) which means that at least part of the productivity performance of these countries were obtained from relatively low levels of hours worked or employment rate compared to the US one. In Norway, part of the performance came (and still comes) also, for

4 This is however not the case in Japan, which manufacturing productivity relative to the US increased over the period (Pilat, 1993); France relative manufacturing productivity, on the contrary decreased over the period (Dormois, 2006).

5 The United Kingdom had a very small share of employment in agriculture in 1870 (22%) compared to other countries (50% in the United States and Germany), allowing this share to diminish more rapidly on other countries during the period (Broadberry, 1997).

6 Card and Freeman (2002) estimated that between 1960 and 1979, the impact on labor productivity of a change in the weight of employment in the agricultural sector amounted in average to roughly 0.5% each year in France, against 0.1% in the United Kingdom and the United States.

7 Boulhol and Turner (2008) found also such a statistically significant break in the productivity catch up process of Europe in the 1990s.

labor productivity, from a high level of the capital intensity, linked to the particular industry structure of this country (important share of capital intensive industry as petrol, fishing and wood).

On the contrary, the catch-up process stopped in Japan at a large distance from the US productivity level. Recent analyses, for example Aghion and Howitt (2006) and Aghion *et al.* (2009), stress that the education level and rigidities in labor and product markets have a large negative impact on productivity growth, the size of the impact depending on whether a country is far from or close to the technological frontier. We know that in the 1990s and even in the current period, market rigidities at an aggregate level are, among the countries of our dataset, the highest in Japan and the lowest in the United Kingdom and the United States, with the other countries in an intermediate situation. This could contribute to explain the unfinished Japanese catch-up.

In the United Kingdom, the catch-up process started from the 1960s, after a decline, and ended in the 2000s. In Canada, we observe a permanent decline for TFP, and for labor productivity a stability until the 1980s and a decline after. In Australia, we observe for TFP a permanent decline, nevertheless from a high starting level. Boulhol and de Serres (2010) emphasize the role of remoteness from markets, which could cost as much as 10% of GDP for Australia or New Zealand. Moreover, inappropriate institutions (protective trade barriers, centralized industrial relations) could have weighed on economic convergence (Parham, 2002).

4.2. Productivity breaks from 1890 to World War II

Graphs 8 represent the productivity trends and breaks over the whole period 1890-2012 for the main countries and areas (A), the Euro Area countries (B) and for the other countries (C). Productivity growth rates are given in these Graphs and for this reason not in the following comment.

The period from the end of the XIXth century to World War II was a period of major innovations as the 2nd industrial revolution spread, of very large shocks to productivity with the two world wars or the Great Depression, and a period of leadership change as the United States took over the United Kingdom in its productivity lead.

We may distinguish four sub-periods during this period: from 1890 to WWI, the WWI itself, the interwar years and the WWII itself.

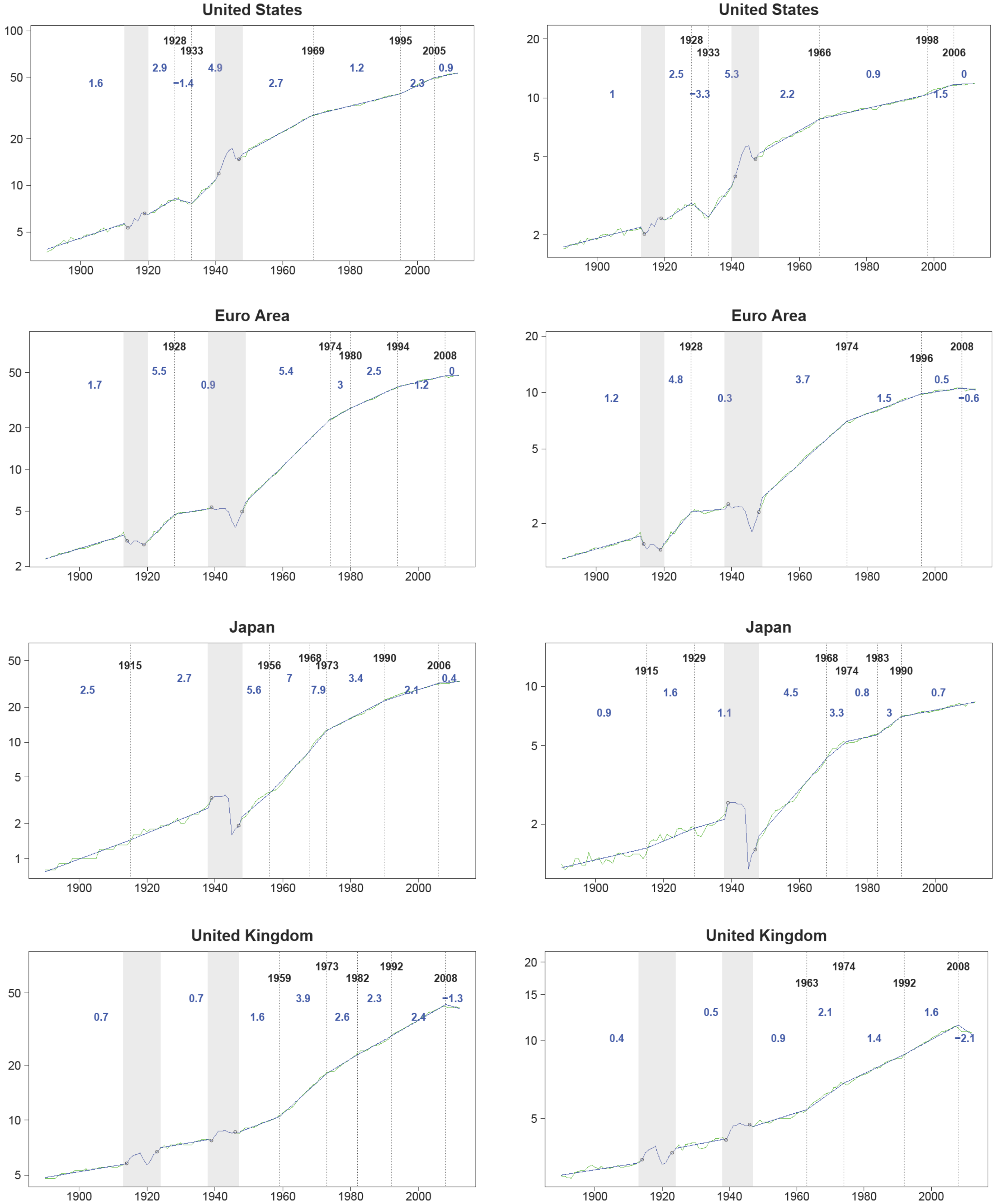
Graph 8

Productivity with breaks

A- For Main Countries and Areas

US$ PPP of 2005 (log scale)– left column is Labor Productivity per hours, right column is TFP

Areas in grey represent war periods as calculated by minimizing the AIC (see Section 3. above).

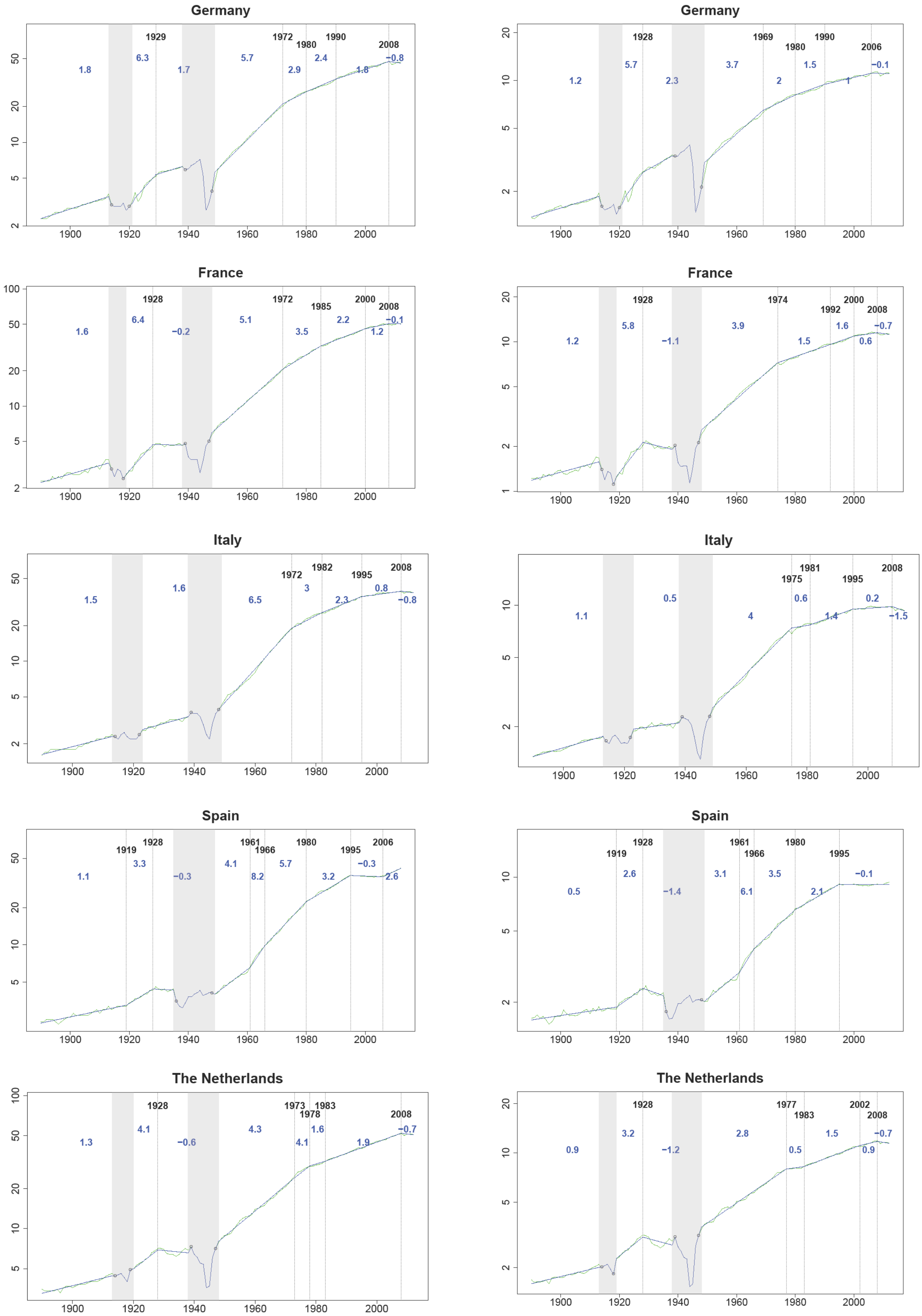


Graph 8

Productivity with breaks

B - For Euro Area Countries

US$ PPP of 2005 (log scale)– left column is Labor Productivity per hours, right column is TFP
Areas in grey represent war periods as calculated by minimizing the AIC (see Section 3. above).



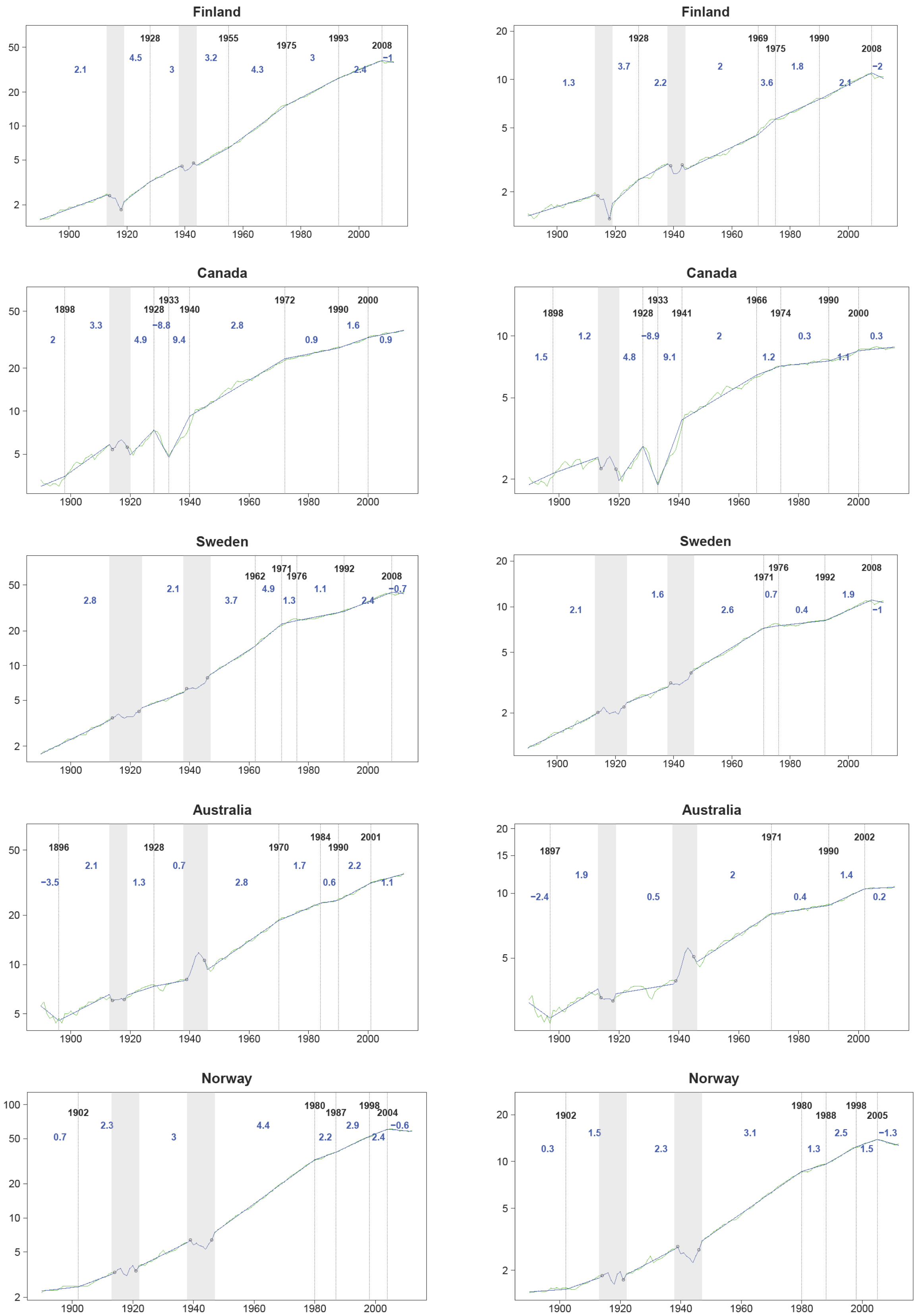
Graph 8

Productivity with breaks

C - For Other Countries

US$ PPP of 2005 (log scale)– left column is Labor Productivity per hours, right column is TFP

Areas in grey represent war periods as calculated by minimizing the AIC (see Section 3. above).



4.2.1. Moderate and continuous growth from 1890 to WWI

Despite major innovations, productivity growth during this period has been slower than in the Interwar years or the period after WWII and most countries did not experience breaks. Among the main areas, the United Kingdom, the productivity leader at that time, experienced the slowest growth (0.7% for labor productivity and 0.4% for *TFP*), while Japan, the productivity laggard, experienced the fastest growth, mostly through capital accumulation (2.5% for labor productivity but 0.9% for *TFP*). Productivity growth was similar in the United States and the Euro Area around 1.6% for labor productivity and 1% for *TFP*.

In the Euro Area, the fastest labor productivity growth was experienced by Germany, in particular through the development of heavy industries and the slowest in Spain, which industrialization was delayed by political disruption and protectionism (1906 tariff law). *TFP* growth was around 1.2% in most countries, apart from a dismal 0.5% in Spain.

4.2.2. WWI: general break in trend and level of productivity

The First World War led to major production disorganization in countries experiencing war on their soil (France and Italy) and a drop in their productivity level. Germany was only slightly affected on its soil, but lost several highly productive regions (Lorraine and High Silesia), experienced uprisings at the end of the war and its capital stock was worn out from intensive war use. On the contrary, the positive demand shock from allied countries at war accelerated innovation diffusion and led to a leap forward in US productivity. This is reflected by a negative break in productivity level in the Euro Area and a positive one in the United States. Countries only slightly involved in the conflict such as Japan[8] and Spain were left unaffected in productivity level. The United Kingdom is a particular case: although it did not experience war on its soil, it was strongly involved in the conflict, which took its toll on British youth and on its fleet and turned the economy to war needs. Productivity growth was very volatile during that period but eventually went back to the level it would have reached with its pre-war trend.

Most countries experienced an upward break in productivity trend after the war as diffusion of innovation boosted productivity in the United States, while productivity was boosted by reconstruction in European countries. The United Kingdom did not experience such an upward break as barriers to entry protected high-cost producers which stayed in business and sterilized resources for innovation (Broadberry and Crafts, 1990).

4.2.3. The Interwar years: high volatility due to innovation diffusion, catching-up and the Great Depression

Productivity accelerated almost everywhere after the war as innovation from the 2nd industrial revolution spread, as European countries recovered from war destruction and as the catching-up process fuelled growth. Productivity accelerated in the United States, in the Euro Area, with an impressive yearly growth rate around 5% in labor productivity and *TFP*, and a slight acceleration in Japan. In the Euro Area, France and Germany, which were the most affected by the war, experienced the strongest rebound, around 6% both for labor productivity and *TFP*. The UK productivity trend was barely affected by the war.

The Great Depression hit unevenly in intensity and duration: many countries experienced a downward break in productivity growth, but only some experienced a subsequent upward break, while others faced a protracted slump. US and Canadian productivity growth were strongly hit by the Great

8 Japan was involved in the conflict through its navy.

Depression and turned negative for 5 years, but strongly recovered afterwards as part of a cyclical rebound but also through an impressive innovation cluster (Kleinknecht, 1987), a surge in privately-funded R&D and well-chosen public infrastructure spending in particular in the road system (Field, 2012). In the Euro Area, France, Germany, the Netherlands and Spain experienced a downward break in productivity growth, which remained anemic or even negative for France, the Netherlands and Spain throughout the 1930s[9]. As explained before, this downward break was smaller and productivity more dynamic after it in Germany than in other Euro Area countries and also than in the US. In some countries (Japan, the United Kingdom, Italy, Sweden, Norway), productivity trend was unaffected by the Great Depression as it hit less severely or durably there than elsewhere.

4.2.4. *WWII: new general break on productivity trend and level, with a new leap forward of the United States*

The Second World War had a similar but more widespread impact than the First World War as it centered on Europe but spread more strongly to Asia. It led to an upward break in level for the United States and Australia, which benefitted from a positive demand shock from countries at war and massive public spending, which led to the closure of the large output gap created by the Great Depression (Field, 2012). On the contrary, in countries experiencing war on their soil (the Euro Area, in particular Germany, Japan), there was a downward break productivity level. The impact on UK productivity level was limited as its war damages were much smaller than in Germany or Japan.

4.3. Productivity breaks after World War II

We comment now productivity behavior over four sub-periods: from WWII to the first oil shock during the 1970s, from the first oil shock to the early 1990s which corresponds to the end of the catch-up process for most of the countries, from the early 1990s to the start of the current Great Recession during the 2000 and from the start of the Great Recession to 2012, the end of the period analyzed.

4.3.1. *From WWII to the first oil shock: productivity slowdown in the leading country and generalized productivity convergence*

During these 25 to 30 years, US productivity growth was lower than during the years preceding WWII, and during the years preceding the Great Depression. This corresponds to the second part of the "Big Wave" of productivity described by Gordon (1999, 2003). This productivity slowdown, which is observed both for labor productivity and for *TFP*, has became so acute at the end of the 1960s that a large and highly statistically significant breakdown[10] is detected. This slowdown has been often commented in the literature. For example, Gordon (1999, 2003) interprets it as a gradual decline in the impact of the technological shock mainly linked to the electricity and internal combustion engine diffusion and to the use of chemical products. Nevertheless, Bourlès and Cette (2007) have made the case that two thirds of this slowdown in US productivity can be accounted for by a rise in the employment rate and a smaller decline in working hours, with strong diminishing returns in both variables. It could also be linked to the increase of the Vietnam War US engagement. The productivity slowdown in the US was favorable to the productivity catch-up process which started in all the other countries of the dataset but, as commented before, in Canada and Australia.

[9] For France, on this sub-period and the following one, our diagnosis is totally consistent with the one of Carre, Dubois and Malinvaud (1972).

[10] Such a statistically significant US productivity breakdown at the end of the 1960s was previously found in other studies as for example Maury and Pluyaud (2004).

Five countries experienced productivity breaks before the 1970s: Canada, the United Kingdom, Spain, Finland and Japan. In Canada, a downward break is detected only for *TFP*, in 1966. This break, which occurred at the same moment as the US one, can be explained by the intense commercial and technological relations between the two countries. The fact that labor productivity growth remained stable at the same moment is explained by an acceleration in capital intensity and, consequently, in capital deepening effects. In the UK, a large upward productivity break occurred in 1959 for labor productivity and 1963 for *TFP*. From this upward break and the US downward one, the relative (to the US) United Kingdom long productivity decline stopped and the catch-up process started. In the three other countries, a catch-up of the US productivity level is observed during the whole sub-period. In Spain, both for labor productivity and TFP, a short but huge productivity acceleration happened in 1961 followed by a large downward break in 1966, the productivity growth from this second break being nevertheless above the one observed just after WWII. In Finland, an upward productivity break occurred in 1955 for labor productivity, when final international institutional decisions concerning this country were made, and 15 years later for *TFP*, which can be explained by an acceleration in the capital intensity and consequently in the capital deepening impact during these 15 years. In Japan, we observe two accelerations of labor productivity, the first one in 1956 and the second one in 1968. In the same time, *TFP* growth decreased in 1968. This contrast between the upward breaks for labor productivity and the downward one for TFP means a huge acceleration in the capital intensity and in the capital deepening effects.

During the 1970s, a productivity breakdown occurred in most of the countries of the dataset: France, Germany, Italy, The Netherlands, Australia, Canada, Finland and Sweden. As a result, such breakdown appeared also in the Euro Area considered as a whole. This downward break occurred at the beginning (even in 1969 for *TFP* in Germany), the middle or the end of the decade but considering the unavoidable relative statistical uncertainty of most of break dates, these breaks can be attributed to the first oil shock. Except for Australia, Canada and Sweden , the catching-up process to the US productivity level was not interrupted by this breakdown, but became often slower. In Sweden, it was definitively interrupted at around 85% of the US level, both for labor productivity and for TFP. No catching-up process was taking place in Australia and Canada before this breakdown (see above).

Three countries of our dataset did not experience productivity breakdown: The US, Spain and Norway. But such a breakdown occurred before in the second half of the 1960s in the US and in Spain. And, in the US, this breakdown could have been offset by a positive productivity shock from a large deregulation process in particular industries such as energy, communications, transportation (see Duernecker and Mand, 2013). Concerning Norway, the petrol price increase has made profitable for this country to extract at a large scale petrol from its continental shelf and the development of this high productivity level activity has probably made quite uncertain the global productivity impact of the first oil shock.

4.3.2. *From the first oil shock to the early 1990s: downward or upward productivity growth breaks and productivity convergence still ongoing*

During this sub-period, productivity growth in the US stayed quite stable at the low level started in the 1960s, and the productivity catch-up process continued at least for some years in all other countries except, as commented before, Canada and Australia.

Most of the countries in the dataset experienced a downward or upward productivity break during the 1980s and the early 1990s.

A productivity slowdown occurred in France, Germany, Spain and Japan. As a result, such breakdown appeared also in the Euro Area considered as a whole, but only for labor productivity. In France, it occurred in 1985 and concerned only labor productivity. This slowdown can be linked to the implementation of different large policies trying explicitly to reduce productivity growth, as for example social tax cuts targeted on low skilled employees. In Germany, it occurred in 1980 and 1990 and concerned both labor productivity and *TFP*. The slowdown in 1990 must of course be linked to the reunification, the East side of Germany being less efficient than the West side. Nevertheless, a part of the estimated *TFP* slowdown could come from a capital over-evaluation, part of the capital installed in the East side of Germany being in fact rapidly scrapped after the reunification, which is not the case in our capital evaluation which assumes invariant scrapping behavior. In Spain, the productivity slowdown is huge and occurred in 1980 both for labor productivity and *TFP*. In Japan, we observe from 1983 a very brief acceleration of the *TFP* which came back from 1990 to its previous low growth rate (0.7%) and at the same moment a slowdown of labor productivity. In these four countries, the productivity catch-up to the US level was interrupted by these slowdowns. In the Euro Area considered as a whole, such breakdown appeared in 1980, but only for labor productivity which means that capital intensity decreased.

We observe productivity upward breaks in the United Kingdom, The Netherlands, Canada, Australia and Sweden. In the United Kingdom, it occurred in 1992.[11] It is a very slight one which can probably be linked to the development of the share of the highly productive financial industry. In The Netherlands, it occurred in 1983, one year after the Wassenaar agreement between social partners, which gave a new surge to the Dutch economy (see on these aspects Visser and Hemerijck, 1998). It concerned both labor productivity and *TFP*. The upward break occurred in 1990 in Canada and Australia, and 1992 in Sweden, and it concerned also both labor productivity and *TFP*. In these three countries, it can be linked to the very large implementation of ambitious structural reforms, mainly concerning the State but also the product and labor markets (for Sweden, see Edquist, 2011).

In Finland, Italy and Norway, the productivity behavior during this sub-period seems more complex. In Italy, we observe a labor productivity breakdown in 1982 and, quite at the same moment in 1981, an upward break in *TFP* trend growth. This contrast means that the capital intensity and the capital deepening effect slowed down sharply at that moment. In Finland, we observe a similar contrast at the early 1990s: a labor productivity breakdown in 1993 and a *TFP* upward one in 1990 which corresponds also to a slowdown in capital intensity. In Norway, we observe successively, both for labor productivity and for *TFP*, a downward and an upward break. The downward one occurred in 1980 and the upward one occurred in 1987 for labor productivity and 1988 for the *TFP*. The growth rate of the two indicators is lower after these two breaks than before, which means that these breaks correspond globally to a slowdown, possibly linked to a slowdown of the oil extraction industry.

4.3.3. From the early 1990s to the start of the Great Recession: upward productivity growth break in the US, some downward ones elsewhere, and the end of the convergence process

During this sub-period, we observe a sharp contrast in the productivity behavior among countries: an upward break in the US and a downward one in several other countries. Hence, the productivity catch-up to the US productivity level was interrupted in all countries where it was not already the case (except Finland for the *TFP*) and even become a relative decline in some of them. Previous studies have already found these statistically significant US upward productivity break (see for example Maury and Pluyaud, 2004, Bosquet and Fouquin, 2008) and interruption in the European productivity catch-up process (see for example Boulhol and Turner, 2008). An abundant literature has been devoted to the US productivity upward break and to the contrast between this break and the productivity behavior in other countries.

11 Such statistically significant productivity upward breaks in the early 1990 in Sweden and the UK were already shown in the literature, for example by Bosquet and Fouquin (2008).

In the US, this upward break was large and bore both on labor productivity and on *TFP*, but it was insufficient to recover the rate of productivity growth observed before the breakdown of the 1960s. Jorgenson (2001) was probably the first to stress the role of the ICTs to explain the upward productivity break and to point the role of ICT production and use. This productivity surge was the result of the ICT price decrease acceleration, from an acceleration of the Moore’s law itself.

The other countries did not benefit from the same positive impact of ICT on productivity growth because, except in the United Kingdom, ICT diffusion is not as much widespread as in the US. This delay in the diffusion of the ICT technological shock reminds the several decades delay for the diffusion of the previous technological shock (see above). It has been stressed in numerous studies (see for example Van Ark *et al.*, 2008, Timmer *et al.*, 2011). One important question is of course the reason of the ICT diffusion delay in the non-US countries. As evoked before, several studies (for example Van Ark *et al.*, 2008, Aghion *et al.*, 2009, Cette and Lopez, 2012) stressed this point and showed that this ICT diffusion delay was due to a lower education level of the working age population and to product and labor markets higher rigidities. This situation, which is still in place, leaves room for policies and consequently for productivity improvement in numerous advanced countries.

A productivity breakdown occurred in this sub-period in France, Italy, The Netherlands, Spain, Australia and Canada, and as a result in the Euro Area considered as a whole. It concerned both labor productivity and *TFP* and occurred in the mid 1990s in Italy, Spain, and the Euro Area considered as a whole, and at the start of the 2000s in France, Australia and Canada. In The Netherlands, it occurred in 1995 and concerned the sole *TFP*. These productivity breakdowns have different origins. In several countries such as the European ones, they can be explained for a large part by the implementation and the development of employment policies as for example subsidized jobs and social tax cuts. In other countries, as for example Spain, they came also from the rapid development of the construction industry which is characterized by a relatively low productivity level and productivity growth. It means that the productivity losses from these breakdowns are not necessarily definitive and could be compensated in the future by productivity acceleration if the anti-productivity policies stop and if housing bubbles disappear.

4.3.4. From the start of the Great Recession to 2012: productivity slowdown and no resumption of productivity convergence

In most countries, a downward break occurred at the start of the Great Recession. As explained above, the dating of the productivity breaks cannot pretend to be very precise and we assume breaks happening from the second part of the 2000s to be linked to the Great Recession. At least part of these productivity downward breaks could be due to the cyclical impact of the huge growth decrease during the crisis, production factor adjustments being not instantaneous. In this case, we should observe a productivity acceleration during the recovery, even over the path of the previous sub-period. As productivity growth appears negative in average during this sub-period in several countries, this points to a structural explanation, although a long-term *negative* productivity growth is not credible in innovation-prone or innovation-using economies. However, an acute decomposition between cyclical and structural components of the productivity behavior from the Great Recession needs longer data and could be realized only in some years. We have also to stress that a part of the TFP growth decrease during the Great Recession could be due to a capital mismeasurement. Our indicator assumes invariant capital mortality laws and we know that in fact, the capital scrapping behavior is related to the economic global cycle (see Bonleu, Cette and Horny, 2013, for an analysis of this behavior on French firms). It means that *TFP* could, in fact, be more dynamic during the Great Recession than what appears from our data.

In the US, a large productivity break occurred, in 2005 for labor productivity and in 2006 for TFP. After this break, productivity growth became even lower to the one observed from the mid-1960s to the mid-1990s. Several analyzes have commented this productivity slowdown. As mentioned before, Gordon (2012, 2013) presents it as the result of the decreasing impact of the ICT technological shock, and his point of view is that the US productivity growth could be low in the future, after the temporary revival started in the 1990s. This decreasing impact is for example characterized by an impressive slowdown of the ICT price decrease from the beginning of the 2000s, which would mean a huge deceleration of the Moore's law itself and which seems consistent with the analysis from Pillai (2011). Aizcorbe, Oliner and Sichel (2008) and more recently Byrne, Oliner and Sichel (2013) present this ICT price behavior as, at least partly, the result of an increase of price-cost markups in the chip industry, or as a mismeasurement: BLS matched-model methodology could over-evaluate chip price evolution from 2001 (for a survey, see Cette, 2014).

A productivity breakdown occurred also during the second part of the 2000s in Japan, the United Kingdom, France, Germany, Italy, The Netherlands, Finland, Sweden and Norway, and in the Euro Area considered as a whole. In Japan, it bore only on labor productivity, which means a strong acceleration of the capital intensity. In the other countries, it concerned both labor productivity and *TFP*.

No productivity break occurred in Australia and Canada, but these two countries are characterized by a previous productivity breakdown in the early 2000s.

Spain is a particular and interesting country case: we observe there a huge upward productivity break in 2006. This can be explained by the implosion of the over-developed construction industry, which is characterized by a low relative productivity level. The fact that we do not observe any break for *TFP* could come from capital stock mismeasurement, as our indicator assumes invariant capital mortality laws and as we know that the capital scrapping behavior is cyclical related (see Bonleu, Cette and Horny, 2013). We cannot exclude a TFP upward break in fact during this sub-period.

5. Robustness

Three robustness tests are presented: the first one concerns the significance of the break dates (5.1.), the second one the sensitivity of the *TFP* break computation to the capital share (α) calibration (5.2.) and the third one the sensibility of the *TFP* break computation to the depreciation rates (δ) calibration (5.3.).

5.1. The significance of the break dates

As a first robustness test, we examine the significance of break dates and sensitivity to changes of significance thresholds. Break dates are reported according to Bai and Perron (1998) methodology which jointly determines break dates and their number by minimizing the sum of squared residuals of equation 1 (see section 3.1). Some break dates which are not significant at the 10% threshold are reported as the number of break dates is optimal for the whole equation.

The significance of break dates is reported in the Table 2. It appears that, except few cases, the significance of the break dates is high.

Table 2
Break dates significance: Student test for the break coefficient (coefficient β_k in equation 1, section 3.1)
*: less than 10%; **: less than 5%; ***: less than 1% significance

Country	Total factor productivity (TFP)	Labor productivity (LP)
United States	1928***, 1933***, 1966***, 1998***, 2006***	1928***, 1933***, 1966***, 1998***, 2006***
Japan	1915***, 1929, 1968**, 1974***, 1983***, 1990***	1915, 1956**, 1968, 1973***, 1990***, 2006**
United Kingdom	1963***, 1974***, 1992*, 2008***	1959***, 1973***, 1982, 1992, 2008***
Euro Area	1928***, 1974***, 1995***, 2008***	1928***, 1974***, 1996***, 2008***
Germany	1928***, 1969***, 1980, 1990*, 2006*	1929***, 1972***, 1980, 1990*, 2008***
France	1928***, 1974***, 1992, 2000*, 2008	1928***, 1972***, 1985***, 2000***, 2008
Italy	1975***, 1981*, 1995***, 2008***	1972***, 1982***, 1995***, 2008**
Spain	1919***, 1928***, 1961***, 1966***, 1980***, 1995***	1919***, 1928***, 1961***, 1966***, 1980***, 1995***
The Netherlands	1928***, 1977***, 1983***, 2002, 2008*	1928***, 1973, 1978***, 1983, 2008***
Finland	1928***, 1969***, 1975***, 1990, 2008***	1928***, 1955***, 1975***, 1993***, 2008***
Canada	1898, 1928***, 1933***, 1941***, 1966***, 1974**, 1990**, 2000*	1898**, 1928***, 1933***, 1940***, 1972***, 1990**, 2000
Australia	1897***, 1971***, 1990***, 2002***	1896***, 1928, 1970***, 1984***, 1990***, 2001***
Sweden	1971***, 1976, 1992***, 2008***	1962***, 1971***, 1976, 1992***, 2008***
Norway	1902***, 1980***, 1988***, 1998***, 2005***	1902***, 1980***, 1987**, 1998, 2004***

Some breaks are significant neither for labor productivity nor for *TFP*. In these cases, the change in trend rate is limited in size. For some of them, historical events may still vindicate their reporting: the Great Depression for Japan in 1929 or Australia in 1928, although these countries have been less affected by this crisis than others; the oil shocks for the Netherlands in 1973 or Germany in 1980; major reforms after the banking crisis in Finland in 1990; the Great Recession for France in 2008. In other cases, there is no such justification: Sweden in 1976, the UK in 1982, France in 1992, The Netherlands in 2002.

Some breaks are significant for *TFP* and not for labor productivity, which points to a break in the capital stock trend. This is the case for Japan in 1915, as the country may have been affected by WWI, and in 1968, for the Netherlands in 1983, which corresponds to a major economic policy change (the Wassenaar agreement in 1982), for the UK in 1992, for Norway in 1998 and for Canada in 2000.

All breaks are significant for the US, the Euro Area, Italy and Spain.

With a lower significance threshold of 5%, other breaks would be rejected. Some would be neither significant for labor productivity and *TFP*, which point to their lack of robustness: Germany in 1990, the UK in 1992, Canada in 2000. Others would still be significant for the other productivity indicator: Italy in 1981, France in 2000, Germany in 2006, The Netherlands in 2008.

5.2. The sensitivity of the *TFP* break computation to the capital share (α) calibration

The second robustness test bears on the computation of TFP breaks. It may be sensitive to the way its conventional parameter α, the capital share, is set. In place of the benchmark value ($\alpha = 0.3$), we set a high ($\alpha = 0.35$) and a low ($\alpha = 0.25$) value.

The results of this test are reported in the Table 3. It appears that TFP break computation is globally robust to the capital share calibration.

Table 3

***TFP* robustness test with respect to α, the capital share – Break dates**

----$^+$ (resp ----$^-$) stands for appearing (resp disappearing) break date when changing coefficient to a higher or lower value

Country	Benchmark value $\alpha = 0.3$	High value $\alpha = 0.35$	Low value $\alpha = 0.25$
United States	1928, 1933, 1966, 1998, 2006	-	1905$^+$
Japan	1915, 1929, 1968, 1974, 1983, 1990	-	-
United Kingdom	1963, 1974, 1992, 2008	-	-
Euro Area	1928, 1974, 1995, 2008	-	-
Germany	1928, 1969, 1980, 1990, 2006	-	-
France	1928, 1974, 1992, 2000, 2008	1992$^-$	-
Italy	1975, 1981, 1995, 2008	-	-
Spain	1919, 1928, 1961, 1966, 1980, 1995	1972$^+$, 1980$^-$, 1988$^+$	-
The Netherlands	1928, 1977, 1983, 2002, 2008	-	1983$^-$
Finland	1928, 1969, 1975, 1990, 2008	-	-
Canada	1898, 1928, 1933, 1941, 1966, 1974, 1990, 2000	-	1933$^-$
Australia	1897, 1971, 1990, 2002	1928$^+$	1928$^+$
Sweden	1971, 1976, 1992, 2008	-	-
Norway	1902, 1980, 1988, 1998, 2005	-	-

Changing the capital share calibration makes no change for Japan, the UK, the Euro area, Germany, Italy, Finland, Sweden and Norway. It comforts the 1928 break in Australia which appeared in labor productivity (LP) but not in total factor productivity (TFP). On the contrary, it weakens the 1992 break in France and the 1983 break in The Netherlands, which are not significant for labor productivity. It changes the profile of Spanish breaks in the 1970s and 1980s with a new break in 1972 and 1988 but no break in 1980. A break appears in 1905 in the US, with no labor productivity counterpart, and disappears in 1933 in Canada, although it is highly significant for labor productivity.

5.3. The sensitivity of the *TFP* break computation to the capital depreciation (δ) calibration

The third robustness test bears also on the computation of *TFP*. It may be sensitive to the way its conventional parameters δ, the capital depreciation rate (divided into δ^E for materials and equipments and δ^B for buildings), are set. Instead of the benchmark values ($\delta^E = 0.1$ and $\delta^B = 0.025$), we set high ($\delta^E = 0.15$ and $\delta^B = 0.05$) and low ($\delta^E = 0.05$ and $\delta^B = 0.015$) values.

The results of this test are reported in the Table 4. It appears that *TFP* break computation is globally robust to the capital depreciation parameters.

The robustness test affects breaks only after 1970. Japan, Germany, France, Finland and Norway are unaffected. The Euro Area profile is strongly affected by a high depreciation rate: breaks would appear in 1989 and 2000 and disappear in 1995 and 2008, which would be at odds with labor productivity breaks and historical evidence. TFP breaks would also be affected in Italy, Spain and The Netherlands by a high depreciation rate: breaks would appear around the oil shock (1968 for Italy, 1972 for Spain and 1973 for The Netherlands) and disappear in 1980 for Spain, in 1995 and 2008 for Italy, 2002 for The Netherlands. A new break appears in 1966 for Australia, 1980 for the US, 1984 for Canada and Sweden, 1987 for the UK. Apart for Spain, which 1970s and 1980s profile seems very sensitive to the tests, and the 1983 break in the Netherlands, the changes are not supported by other robustness tests.

Table 4

TFP robustness test with respect to δ, the depreciation rate of the capital – Break dates

----$^{+}$ (resp ----$^{-}$) stands for appearing (resp disappearing) break date when changing coefficient to a higher or lower value

Country	Benchmark value $\delta^E = 0.1$ and $\delta^B = 0.025$	High value $\delta^E = 0.15$ and $\delta^B = 0.05$	Low value $\delta^E = 0.05$ and $\delta^B = 0.015$
United States	1928, 1933, 1966, 1998, 2006	-	1980^{+}
Japan	1915, 1929, 1968, 1974, 1983, 1990	-	-
United Kingdom	1963, 1974, 1992, 2008	1987^{+}	-
Euro Area	1928, 1974, 1995, 2008	1989^{+}, 1995^{-}, 2000^{+}, 2008^{-}	-
Germany	1928, 1969, 1980, 1990, 2006	-	-
France	1928, 1974, 1992, 2000, 2008	-	-
Italy	1975, 1981, 1995, 2008	1968^{+}, 1995^{-}, 2000^{+}, 2008^{-}	-
Spain	1919, 1928, 1961, 1966, 1980, 1995	1972^{+}, 1980^{-}, 1985^{+}	-
The Netherlands	1928, 1977, 1983, 2002, 2008	1973^{+}, 2002^{-}	1983^{-}
Finland	1928, 1969, 1975, 1990, 2008	-	-
Canada	1898, 1928, 1933, 1941, 1966, 1974, 1990, 2000	-	1966^{-}, 1984^{+}
Australia	1897, 1971, 1990, 2002	-	1966^{+}
Sweden	1971, 1976, 1992, 2008	-	1971^{-}, 1984^{+}
Norway	1902, 1980, 1988, 1998, 2005	-	-

6. Conclusions

Adopting a long-term view on productivity developments is crucial when studying decade-long phenomena such as innovation diffusion or convergence processes. It provides a precious diagnosis on the way innovation spread to productivity within and across countries, highlighting the current ICT revolution diffusion and its prospects.

We built a productivity database over 1890-2012 for thirteen countries, representing major advanced countries (G7), major euro area countries (G7 euro area countries along with Finland, Spain and The Netherlands) and some specific countries particularly relevant for productivity analysis (Australia, Norway and Sweden). Productivity indicators are labor productivity per hour worked and *TFP*, computed through a growth accounting approach distinguishing between equipment and building capital. We provide a dating of productivity trend breaks through the Bai-Perron method and an assessment of productivity trends through a Hodrick-Prescott filter. We present relative productivity levels, although the results are highly sensitive to the reference year of the Purchasing Power Parity used to convert productivity indicators.

Over the 20th century, we observe "one big wave" of productivity growth linked to the second industrial revolution and one small, ongoing one linked to the ICT revolution. The first big wave of productivity growth occurred long after the actual innovation that triggered it (internal combustion engine, electricity, chemistry, telephone, assembly lines…) and spread across countries in a staggered way, first in the US during the Interwar years, then in the rest of the world after WWII. The productivity leader changed during the period, the Australian and UK leadership becoming a US one during the first part of the XXth century and, for very particular reasons, also a Norwegian, Dutch and French one at least for some years at the end of the XXth century. The convergence process has been erratic, disrupted by inappropriate institutions, technology shocks (2nd industrial revolution, ICT revolution), financial crises but also largely by wars, which led to major productivity level leaps, downwards for countries affected on their soil and upwards for other countries. Productivity trend breaks were detected following wars, financial crises (the Great Depression and the Great Recession), supply shocks (the two oil shocks), but also major policy changes such as the implementation of structural reforms (Canada or Sweden in the 1990s). The upward break in the US in the mid-1990s is confirmed, as well as the downward break in the euro area in the same period. A global downward break following the subprime crisis and as soon as the mid-2000s in the US is observed, casting doubt on the prospects of the ICT revolution, although the long lag in the diffusion of the second industrial revolution shows that technology clusters may not yield all their benefits within a decade. As far as comparisons are possible, these results are consistent with the ones of other analyses usually produced on one or on a limited number of countries and over shorter periods (see for example the survey of numerous analyses proposed by Crafts and O'Rourke, 2013).

This study could be further developed through examining standards of living developments along the same lines, as GDP per capita is linked to labor productivity through employment rates. Indeed, it appears difficult to interpret productivity growth developments and levels alone, as decreasing returns to employment rates have been highlighted (Bourlès and Cette, 2007).

References

Abramovitz, Moses (1986): “Catching up, forging ahead and falling behind”, Journal of Economic History, n° 46, pp. 385-406.

Aghion, Philippe and Peter Howitt (1998): “Endogeneous growth theory”, Cambridge, MA: MIT Press.

Aghion, Philippe and Peter Howitt (2006): “Joseph Schumpeter Lecture Appropriate Growth Policy: A Unifying Framework”, Journal of the European Economic Association, MIT Press, vol. 4(2-3), 04-05, pp. 269-314.

Aghion, Philippe and Peter Howitt (2009): “The economics of growth”, Cambridge, MA: MIT Press.

Aghion, Philippe, Philippe Askenazy, Renaud Bourlès, Gilbert Cette and Nicolas Dromel (2009): « Education, Market Rigidities and Growth”, Economics Letters, n° 102, Iss. 1, January, pp. 62-65.

A'Hearn, Brian and Ulrich Woitek (2001): “More international evidence on the historical properties of business cycles”, Journal of Monetary Economics, Volume 47, Issue 2, April 2001, pp. 321-346.

Aizcorbe, Ana, Stephen Oliner and Daniel Sichel (2008): “Shifting Trends in Semiconductor Prices and the Pace of Technological Progress”, Business Economics, Vol. 43, N°3, pp. 23-29.

Algan, Yann and Pierre Cahuc (2010): “Inherited Trust and Growth”, American Economic Review, Vol 100, n° 5, December, pp. 2060-2092.

Altman, Morris (1999): “New estimates of hours of work and real income in Canada from the 1880s to 1930s: Long Run trends and workers’ preferences”, Review of Income and Wealth, International Association for research in Income and Wealth, vol. 45(3), September, pp. 353-372.

Ames, Edward and Rosenberg, Nathan (1968): “The Enfield Arsenal in Theory and History”, Economic Journal, Vol. 78, n° 312, Dec., 1968, 78. pp. 827-842.

Andrews, Donald, Lee Inpyo and Werner Ploberger (1996): “Optimal changepoint tests for normal linear regression”, Journal of Econometrics, Elsevier, vol. 70(1), January, pp. 9-38.

Baffigi, Alberto (2011): “Italian National Accounts, 1861-2011”, Bank of Italy, Economic Research and International Relations Area, Quaderni di storia economica (Economic History Working Papers) 18.

Bai, Jushan (1997): “Estimation Of A Change Point In Multiple Regression Models”, The Review of Economics and Statistics, MIT Press, vol. 79(4), November, pp. 551-563.

Bai, Jushan and Pierre Perron (1998): “Computation and Analysis of Multiple Structural-Change Models”, Université de Montréal, Département de sciences économiques, Cahiers de recherche 9807, 59 p**.**

Bai, Jushan and Pierre Perron (2003):“Computation and analysis of multiple structural change models”, Journal of Applied Econometrics, John Wiley & Sons, Ltd., vol. 18(1), pp. 1-22.

Baily, Martin, James Manyika and Shalabh Gupta (2013): “US Productivity Growth: An Optimistic Perspective”, International Productivity Monitor, Centre for the Study of Living Standards, vol. 25, Spring, pp. 1-12.

Barro, Robert and Xavier Sala-I-Martin (1997): "Technological diffusion, convergence and growth", Journal of Economic Growth, 2, pp. 1-27.

Bolt, Jutta and Jan Luiten van Zanden (2013): "The First Update of the Maddison Project; Re-estimating Growth Before 1820", Maddison Project Working Paper 4.

Bonleu, Antoine, Gilbert Cette and Guillaume Horny (2013): "Capital Utilisation and retirement", Applied Economics, 45, pp. 3483-3494.

Bosquet, Clément and Michel Fouquin (2008): "Productivité du travail : la fin du processus de convergence ?", Economie et Statistique, N°419-420, pp. 125-142.

Boulhol, Hervé and Alain de Serres (2010): "Have developed countries escaped the curse of distance?", Journal of Economic Geography, Oxford University Press, vol. 10(1), January, pp. 113-139.

Boulhol, Hervé and Laure Turner (2008): "Recent Trends and Structural Breaks in US and EU15 Labor Productivity Growth", OECD Economics Department, OECD Publishing, Working Papers 628.

Bourlès, Renaud and Gilbert Cette (2005): "A comparison of structural productivity levels in the major industrialised countries", OECD Economic Studies, OECD Publishing, vol. 2005(2), pp. 75-108.

Bourlès, Renaud and Gilbert Cette (2007): "Trends in 'Structural' Productivity Levels in the Major Industrialized Countries", Economics Letters, vol. 95(1), Avril, pp. 151-156.

Bresnahan, Timothy F and Manuel Trajtenberg (1995): "General Purpose Technologies "Engines of Growth"?", National Bureau of Economic Research, Inc, NBER Working Papers 4148.

Broadberry, Stephen (1993): "Manufacturing and the Convergence Hypothesis: What the Long-Run Data Show", The Journal of Economic History, Cambridge University Press, vol. 53(04), December, pp. 772-795.

Broadberry, Stephen (1997): "The Long Run Growth and Productivity Performance of the United Kingdom", Scottish Journal of Political Economy, Scottish Economic Society, vol. 44(4), September, pp. 403-424.

Broadberry, Stephen and Nicholas Crafts (1990): "Explaining Anglo-American Productivity Differences in the Mid-Twentieth Century", Oxford Bulletin of Economics and Statistics, Department of Economics, University of Oxford, vol. 52(4), Special I, pp. 375-402.

Broadberry, Stephen, Claire Giordano, and Francesco Zollino (2011): "A sectoral Analysis of Italy's Development: 1861-2010", Competitive Advantage in the Global Economy (CAGE), Online Working paper Series 6.

Broadberry, Stephen and Douglas Irwin (2006): "Labor productivity in the United States and the United Kingdom during the nineteenth century", Explorations in Economic History, Elsevier, vol. 43(2), April, pp. 257-279.

Broadberry, Stephen and Douglas Irwin (2007): "Lost Exceptionalism? Comparative Income and Productivity in Australia and the UK, 1861–1948", The Economic Record, Vol. 83, No. 262, September, 2007, pp. 262–274.

Butlin, Matthew (1977): "A preliminary annual database 1900/01 to 1973/74", Reserve Bank of Australia: Sidney, Research Discussion Paper 7701.

Byrne, David, Stephen Oliner and Daniel Sichel (2013): "Is the Information Technology Revolution Over?", International Productivity Monitor, n° 25, Spring, pp. 20-36.

Card, David and Richard Freeman (2002): "What Have Two Decades of British Economic Reform Delivered in Terms of Productivity Growth?", International Productivity Monitor, Centre for the Study of Living Standards, vol. 5, Fall, pp. 41-52.

Carré, Jean-Jacques, Paul Dubois and Edmond Malinvaud (1972): "La croissance française. Un essai d'analyse économique causale de l'après guerre", Seuil, Paris.

Cette, Gilbert (2013): "Does ICT remain a powerful engine of growth ?", AFSE Presidential Adress, forthcoming in the Revue d'Economie Politique.

Cette, Gilbert, Yusuf Kocoglu and Jacques Mairesse (2009): "Productivity growth and levels in France, Japan, the United Kingdom and the United States in the Twenthieth Century.", NBER Working Paper: 15577.

Cette, Gilbert and Jimmy Lopez (2012): "ICT demand behaviour: an international comparison", Economics of Innovation and New Technology, Taylor and Francis Journals, vol. 21(4), June, pp. 397-410.

Chow, Gregory (1960): "Tests of Equality Between Sets of Coefficients in Two Linear Regressions", Econometrica, vol. 28(3), pp. 591–605.

Colecchia, Alessandra and Paul Schreyer (2001): "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case?", OECD, October, DSTI/DOC(2001)7.

Crafts, Nicholas and Kevin O'Rourke (2013): "Twentieth Century Growth", Discussion Paper Series, CEPR, n° 9633, September.

David, Paul (1989): "Computer And Dynamo: The Modern Productivity Paradox In A Not-Too Distant Mirror", University of Warwick, Department of Economics, The Warwick Economics Research Paper Series (TWERPS) 339.

David, Paul (1990): "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", American Economic Review, American Economic Association, vol. 80(2), May, pp. 355-61.

Demotes-Mainard, Magali (1989): "L'économie de la RFA", Collection Repères.

Dormois, Jean-Pierre (2006): "Tracking the elusive French productivity gap in industry 1840-1973", Hitotsubashi University, March, Institute of Economic Research Working Paper No. 152.

Duernecker Georg and Matthias Mand (2013): "Macroeconomic effects of US product market deregulation", mimeo, University of Mannheim, Department of Economics, November, 14.

Edquist, Harald (2011): "Can investment in intangibles explain the Swedish productivity boom in the 1990s?", the Review of Income and Wealth, series 57, number 4, December, pp. 658-682.

Edquist, Charles (2011): "Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures)", Industrial and Corporate Change, Oxford University Press, vol. 20(6), December, pp. 1725-1753.

Feinstein, Charles and Sidney Pollard (1988): “Studies in Capital Formation in the United Kingdom 1750-1920”, Clarendon Press, Oxford University, number 9780198284086, 477 p.

Ferguson, Roger and William Wascher (2004): “Distinguished lecture on economics in Government: lessons from past productivity booms”, The Journal of Economic Perspectives, vol. 18, n° 2, Spring, pp. 3-28.

Field, Alexander (2012): “A Great Leap Forward: 1930s Depression and U.S. Economic Growth”, Yale University Press, April 26, 2012, 400 p.

Gordon, Robert (1999): “US Economic Growth since 1970: One Big Wave?”, American Economic Review, Vol. 89, No. 2, pp.123-128.

Gordon, Robert (2000): “Does the "New Economy” Measure Up to the Great Inventions of the Past?”, Journal of Economic Perspectives, American Economic Association, vol. 14(4), Fall, pp. 49-74.

Gordon, Robert (2003): “Deux siècles de croissance économique: l'Europe à la poursuite des États-Unis”, Revue de l'OFCE, Janvier, n° 84.

Gordon, Robert (2012): “Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds”, National Bureau of Economic Research, Inc, NBER Working Papers 18315.

Gordon, Robert (2013): “US productivity Growth: The Slowdown has returned after a temporary revival”, International Productivity Monitor, Centre for the Study of Living Standards, vol. 25, Spring, pp. 13-19.

Groote, Peter, Ronald Albers and Herman de Jong (1996): “A standardised time series of the stock of fixed capital in the Netherlands, 1900-1995”, Groningen Growth and Development Centre, University of Groningen, GGDC Research Memorandum 199625.

Grytten, Ola (2004): “The Gross Domestic Product for Norway 1830-2003”, Historical Monetary Statistics for Norway 1819-2003, Norges Bank Occasional Papers No 35., Oslo, pp. 241-288.

Hjerppe, Riitta (1996): “The Finnish Economy 1860-1985. Growth and Structural Changes”, Bank of Finland, Government printing center.

Hoffmann, Walter (1965): “Das Wachstum der Deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts. ”, Berlin: Heidelberg.

Humble, Richard (1975): “War in the Air 1939-1945”, Purnell 1975.

Inklaar, Robert, Mary O’Mahony and Marcel Timmer (2005): “ICT and Europe’s productivity performances: industry level growth comparisons with the United States”, The Review of Income and Wealth, series 51, n° 4, December, pp. 505-536.

Islam, Nazrul (2003): “Productivity dynamics in a large sample pf countries: a panel study”, The Review of Income and Wealth, Series 49, n° 2, June, pp. 247-272.

Jerome, Harry (1934): “Mechanization in Industry”, National Bureau of Economic Research, Inc, March, number jero34-1.

Jorgenson, Dale (2001): “Information technology and the US economy”, The American Economic Review, Vol. 91, March, N°1, pp. 1-32.

Jorgenson, Dale, Mun Ho and Kevin Stiroh (2006): "Potential Growth of the US Economy: Will the Productivity Resurgence Continue?", Business Economy, January 2006, Volume 41, Issue 1, pp 7-16.

Jorgenson, Dale, Mun Ho and Kevin Stiroh (2008): "A Retrospective Look at the U.S. Productivity Growth Resurgence", Journal of Economic Perspectives, Vol. 22, N°1, Winter 2008, pp. 3-24.

Kirner, Wolfgang (1968): "Zeitreihen für das Anlagevermögen der Wirtschaftsbereiche in der Bundesrepublik Deutschland", Berlin: Dunkcer & Humblot.

Kleinknecht, Alfred (1987): "Innovation patterns in crisis and prosperity: Schumpeter's long cycle reconsidered", London: Macmillan.

Kose, M. Ayhan, Christopher Otrok, and Charles H. Whiteman (2003): "International Business Cycles: World, Region, And Country-Specific Factors" American Economic Review 93.4 (2003), pp. 1216-1239.

La Porta, Rafael, Florencio Lopez-De-Silanes and Andrei Shleifer (2008): "The Economic Consequences of Legal Origins", Journal of Economic Literature, vol. 46, June, n°2, pp. 285-332.

Lévy-Leboyer, Maurice (1978): "Capital Investment and Economic Growth un France (1820-1913)", Cambridge History of Europe, Chapter V, pp. 231-295.

Liesner, Thelma (1989): "One hundred years of Economics Statistics", The Economist Publications.

Liu, Dan and Christopher M. Meissner (2013): "Market Potential and the Rise of US Productivity Leadership", National Bureau of Economic Research, Inc, NBER Working Papers 18819.

McLean, Ian W (2007): "Why was Australia so rich?", Explorations in Economic History, Elsevier, vol. 44(4), October, pp. 635-656.

Maddison, Angus (1994): "Standardised Estimates of Fixed Capital Stock: A Six Country Comparison", Groningen Growth and Development Centre, University of Groningen, GGDC Research Memorandum 199409.

Maddison, Angus (2001): "The World Economy, a Millennial Perspective", OECD publishing.

Maddison, Angus (2003): "L'économie mondiale, statistiques historiques", OECD publishing.

Madsen, Jakob (2010a): "Growth and capital deepening since 1870: is it all technological progress?", Journal of Macroeconomics, 32, pp. 641-656.

Madsen, Jakob (2010a): "The **anatomy** of growth in the OECD since 1870", Journal of Monetary Economics, 57, pp. 753-767.

Madsen, Jakob and Timol Isfaaq (2010): "Long-Run Convergence in Manufacturing and Innovation-Based Models", The Review of Economics and Statistics, November 2011, 93(4), pp. 1155-1171.

Maury, Tristan-Pierre and Bertrand Pluyaud (2004): "Les ruptures de tendance de la productivité par employé de quelques grands pays industrialisés", Banque de France, Janvier, bulletin N°121.

Mitchell, Brian (1998a): "The Americas, 1750-1993", International Historical Statistics, 4th Edition. Stockton Press.

Mitchell, Brian (1998b): “Europe, 1750-1993”, International Historical Statistics, 4th Edition. Stockton Press.

Mitchell, Brian (1998c): “Africa, Asia and Oceania, 1750-1993”, International Historical Statistics, 4th Edition. Stockton Press.

Nordhaus, William (1997): "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not," in Bresnahan-Gordon, “The Economics of New Goods”, University of Chicago Press for NBER, 1997), pp. 29-66.

Nelson, Richard and Gavin Wright (1992): “The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective”, Journal of Economic Literature, American Economic Association, vol. 30(4), December, pp. 1931-64.

Oulton, Nicholas (2012): “Long-term implication of the ICT revolution: applying the lessons of growth theory and growth accounting”, Economic Modelling, 29, pp. 1722-1736.

Parham, Dean (2002): “Microeconomic reforms and the revival in Australia’s growth in productivity and living standards”, Paper presented to the Conference of Economists, Adelaide, 1 October 2002.

Pilat, Dirk (1993): “The Sectoral Productivity Performance of Japan and the U.S., 1885-1990”, Review of Income and Wealth, International Association for Research in Income and Wealth, vol. 39(4), December, pp. 357-75.

Pilat, Dirk and Frank Lee (2001): “Productivity growth in ICT-producing and ICT-using industries: a source of growth differentials in the OECD?”, mimeo, DSTI/DOC(2001)4, June.

Pillai, Unni (2011): “Research Spotlight: Technological Progress in the Microprocessor Industry”, Survey of Current Business, February, pp. 13-16.

Prados de la Escosura, Leandro (2003): “El progreso economico de España (1850-2000)”, Fundacion BBVA edition 1, number 201136.

Prados de la Escosura, Leandro and Juan Roses (2008): “Long-run estimates of Physical Capital in Spain, 1850-2000”, Universidad Carlos III, Departemento de Historia Economica e Institucioes, Working Papers in Economic History wp08-07.

Prados de la Escosura, Leandro and Juan Roses (2009): “Human Capital and Economic Growth in Spain, 1850-2000”, Universidad Carlos III, Departamento de Historia Económica e Instituciones, Working Papers in Economic History wp09-06.

Prados de la Escosura, Leandro, Juan Roses and Isabel Sanz Villarroya (2011): “Economic Reforms and Growth in Franco’s Spain”, Universidad Carlos III, Departamento de Historia Económica e Instituciones, Working Papers in Economic History wp11-07.

Ristuccia, Cristiano Andrea and Adam Tooze (2013): “Machine tools and mass production in the armaments booms: Germany and the United States, 1929-44”, The Economic History Review, Vol. 66, Issue 4, pp. 953-974.

Shreyer, Paul (2000): “The contribution of Information and Communication Technology to Output Growth: A Study on the G7 Countries”, OECD, March, STI Working Paper, 200/2.

Smits, Jan-Pieter, Edwin Horlings, and Jan Luiten van Zanden (2000): “Dutch GNP and its components, 1800-1913”, Groningen Growth and Development Centre, University of Groningen, GGDC Research Memorandum No.5.

Solow, Robert (1956): “A Contribution to the Theory of Growth”, Quarterly Journal of Economics, Vol. 70, pp. 65-94.

Solow, Robert (1957): “Technical Change and Aggregate Production Function”, Review of Economics and Statistics, Vol. 39, pp. 312-320.

Taylor, Frederick Winslow (1911): “Principles of Scientific Management”, New York and London, Harper & brothers.

Temin, Peter (2002): “The Golden Age of European growth reconsidered”, Cambridge University Press, European Review of Economic History 6, 3-22.

Teräsvirta, Timo (1996): “Modelling Economic Relationships with Smooth Transition Regressions”, Stockholm School of Economics, Working Paper Series in Economics and Finance 131.

Timmer, Marcel, Robert Inklaar, Mary O'Mahony and Bart Van Ark (2011): “Productivity and Economic Growth in Europe: A Comparative Industry Perspective”, International Productivity Monitor, Centre for the Study of Living Standards, vol. 21, Spring, pp. 3-23.

Van Ark, Bart, Mary O'Mahoney and Marcel Timmer (2008): “The Productivity Gap between Europe and the United States: Trends and Causes”, Journal of Economic Perspectives, American Economic Association, vol. 22(1), Winter, pp. 25-44.

Villa, Pierre (1994): “Un siècle de données macroéconomiques”, INSEE Résultats, Série Économie générale, N° 86-87.

Visser, Jelle and Anton Hemerijck (1998): “A Dutch Miracle: Job Growth, welfare Reform and corporatism in the Netherlands”, Amsterdam University Press.

Zeileis, Achim, Christian Kleiber, Walter Krämer and Kurt Hornik (2002): “Testing and dating of structural changes in practice”, Technical Reports 2002, 39, Technische Universität Dortmund, Sonderforschungsbereich 475: Komplexitätsreduktion in multivariaten Datenstrukturen.

Appendix 1: data

Data are computed for 13 developed countries: Australia, Canada, Finland, France, Germany, Italy, Japan, The Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States. In addition, they are also computed for a reconstituted Euro Area which is here the aggregation of Germany, France, Italy, Spain, the Netherlands and Finland. This approximation seems acceptable as these six countries represent together, in 2012, 82% of the total current GDP of the Euro Area. Each of the 13 countries is considered in its borders of 2012.

To calculate the two productivity indexes (Labor Productivity, *LP*, and Total Factor Productivity, *TFP*) we need to compute data concerning GDP (*Y*), total hours worked (*H*), employment (*N*) and capital (*K*). Capital calculation needs itself long information concerning investment (*I*). Series for GDP and capital are given in constant national currencies of 2005 and converted to US dollars in purchasing power parity (ppp) of 2005 with a conversion rate given by Penn World Table 7.1.

The starting database was the one built by Cette, Kocoglu and Mairesse (2009) on the United States, Japan, France and the United Kingdom over the 1890-2006 period. We have updated and considerably enlarged this first database. We present successively the computation of annual (1.) and quarterly data (2.), and the ppp conversion (3.).

1. Annual data

Annual data are directly computed over the whole 1890-1960 sub-period. Over the sub-period 1961-2012, they are built from the quarterly series.

1.1. GDP (*Y*)

Australia 1820-1960: Bolt *et al.* (2013) updating Maddison (2001).
Canada 1870-1960: Bolt *et al.* (2013) updating Maddison (2001).
Finland 1860-1960: Bolt *et al.* (2013) updating Maddison (2001).
France 1820-1949: Villa (1994); 1949-1960: National accounts from INSEE.
Germany 1850-1960: Bolt *et al.* (2013) updating Maddison (2001).
Italy 1861-1960: Baffigi (2011).
Japan 1870-1960: Bolt *et al.* (2013) updating Maddison (2001).
Netherlands 1815-1820: Smits *et al.* (2000); 1820-1960: Bolt *et al.* (2013) updating Maddison (2001).
Norway 1830-1960: Bolt *et al.* (2013) updating Maddison (2001).
Spain 1850-1960: Prados (2003).
Sweden 1800-1820: *Swedish Historical National Account 1800-2000*; 1820-1850: Maddison (2001); 1850-1960: Bolt *et al.* (2013) updating Maddison (2001).
United Kingdom 1812-1960: Bolt *et al.* (2013) updating Maddison (2001).
United States 1870-1929: Bolt *et al.* (2013) updating Maddison (2001); 1929-1960: BEA: *Summary National Income and Product series 1929-1993* (1994).

1.2. Total Hours Worked (*H*)

NB: data referred to as 'Maddison (2001)' are taken from Maddison (2001) who gives data on total hours worked for six benchmark years: 1870, 1913, 1950, 1973, 1990 and 1998. Data are linearly interpolated by us between these benchmark years to get annual data over the period 1870-1950.

Australia 1870-1901: Maddison (2001); 1901:1950: Butlin (1977); 1950-1960: *The Conference Board Total Economy Database* (hereafter referred to as CB-TED).
Canada 1870-1901: Maddison (2001); 1901-1926: Altman (1999) where data correspond to total weekly average hours worked; 1926-1950: Maddison (2001); 1950-1960: CB-TED.
Finland 1870-1950: Maddison (2001); 1950-1960: CB-TED.
France 1870-1950: Maddison (2001); 1950-1960: CB-TED.
Germany 1870-1950: Maddison (2001); 1950-1960: CB-TED.
Italy 1870-1950: Maddison (2001); 1950-1960: CB-TED.
Japan 1870-1950: Maddison (2001); 1950-1960: CB-TED.

Netherlands 1870-1950: Maddison (2001); 1950-1960: CB-TED.
Norway 1870-1950: Maddison (2001); 1950-1960: CB-TED.
Spain 1870-1950: Data for Spain are not available before 1950. We assumed therefore that figures follow Italian total hours worked trend; 1950-1960: CB-TED.
Sweden 1870-1950: Maddison (2001); 1950-1960: CB-TED.
United Kingdom 1856-1950: Mitchell (1988b); 1950-1960: CB-TED.
United States 1870-1950: Maddison (2001); 1950-1960: CB-TED.

1.3. Total Employment (*N*)

Australia 1890-1901: We used the growth rate of population from Bolt *et al.* (2013) updating Maddison (2001); 1901-1956: Butlin (1977); 1956-1960: CB-TED.
Canada 1871-1960: Historical Statistics of Canada (Section D), which gives values every 10 years for data before 1921, these values being linearly interpolated.
Finland 1860-1960: Hjerppe (1996).
France 1890-1960: Villa (1994).
Germany 1849-1939 (except 1913-1924): Hoffman (1965); 1913 to 1924: we used figures of unemployment over total population, computed by Mitchell (1998b); 1939-1950: we have computed these data through a sixth-degree polynomial interpolation; 1950-1960: CB-TED.
Italy 1861-1960: Broadberry *et al.* (2011).
Japan 1870-1955: Maddison (2001, 2003), who gives six points (1870, 1913, 1950, 1973, 1990 and 1998) linearly interpolated; 1956-1960: CB-TED.
Netherlands 1800-1880: Smits *et al.* (2000); 1880-1960: *Tweehonderd jaar statistiek in tijdreeksen 1800-1999*, who gives 11 values (1807, 1848, 1859, 1889, 1899, 1909, 19920, 1930, 1947, 1960, and 1971) linearly interpolated.
Norway 1865-1900: Mitchell (1998b) who gives seven points (1875, 1891, 1900, 1910, 1930, 1946 and 1950) linearly interpolated; 1956-1960: CB-TED.
Spain 1850-1960: Prados (2003).
Sweden 1850-1960: *Swedish Historical National Account 1800-2000.*
United Kingdom 1855-1920: Feinstein *et al.* (1988); 1920-1960: Office for National Statistics.
United States 1890-1950: Mitchell (1998a); 1950-1960: CB-TED.

1.4. Investment (*I*)

We divided total gross fixed capital formation between two types of assets. First we considered buildings investment, including dwellings, then we considered investment in machineries and equipments. The purpose of this separation is to apply different depreciation rates. Unless otherwise stated, building (denoted *IB*) and equipment (*IE*) investment series cover the same period.

Australia 1880-1902: Mitchell (1998c) gives values for total investment, we assumed the two types of investments follow the growth of total investment; 1902-1960: Butlin (1977).
Canada (we proceed as Madsen *et al.*, 2010) 1871-1900: Historical Canadian Macroeconomic Dataset (1871-1994), from which we use total non-residential investment in value, deflated using Implicit Price Deflator; 1900-1926: Historical Statistics of Canada (Section F), where data are only given every five years. We spread these data following the growth of total non residential investment; 1926-1960: Historical Statistics of Canada (Section F).
Finland 1860-1960: Hjerppe (1996) deflated by cost of living.
France (we proceed as Cette *et al.*, 2009) 1820-1935: Levy-Leboyer (1978), who gives total GFCF that was split between equipment and buildings using Villa (1994); 1935-1960: Maddison (1994).
Germany concerning IB, 1850-1880: Kirner (1968) ; 1880-1960: Maddison 1994 ; Concerning IE, 1850-1900: we supposed that equipment investment trend was the same as the one of building investment; 1900-1920: Kirner (1968), we assumed that total equipment trend follows investment in equipment in the sector "*Schifffahrt*" (Navigation and Shipping); 1920-1960: Maddison (1994).
Italy 1861-1960: Baffigi (2011).
Japan 1870-1960: Maddison (1994).
Netherlands 1800-1880: Smits *et al.* (2000); 1880-1960: Groote *et al.* (1996).
Norway 1865-1900: Statistisk Sentralbyra (SSB) Historical National Accounts. After 1900, eight points are given (1910, 1920, 1930, 1939, 1946, 1950, 1955 and 1960). We used those data to calculate the weight of

equipment over total investment and interpolated this ratio; 1900-1949: Grytten (2004) data of total investment separated with SSB ratio; 1949-1960: SSB Historical Statistics. For all those data, we chose to consider ships and oil platforms as buildings.
Spain 1850-1960: Prados (2003).
Sweden 1800-1960: Swedish Historical National Account 1800-2000.
United Kingdom 1800-1960: Maddison (1994).
United States 1870-1960: Maddison (1994).

1.5. Capital (*K*)

1.5.1. Calculation

The permanent inventory method (PIM) is used to construct the capital series from data on investment. Equipment and building investment (*IE* and *IB*) and capital (*KE* and *KB*) are distinguished with different life expectancy. The annual depreciation rates, noted δ, have been chosen according to Cette *et al.* (2009) as 10% for equipment and 2.5% for buildings. In addition, for each year, we updated the given capital stock with a war and natural disasters damage coefficient (d_t) (with $0 \leq d_t \leq 1$) in order to take into consideration the capital destruction.

The PIM corresponds to the relation $K_{t+1} = \left(K_t * (1-\delta) + I_{t+1} * \sqrt{1-\delta}\,\right) * \, (1 - d_{t+1})$. This relation assumes that the whole investment is done in one flow and in the middle of the year which explains that a part of it is slightly depreciated with a coefficient $\sqrt{1-\delta}$ at the end of the year.

1.5.2. Initialization

In order to calculate K_t for every year, we need to initialize the capital stock at t_0. To do so, we considered that the growth of capital follows the average growth of GDP. We calculated the average growth rate for the first ten available data of our study for each country. Let g be this growth (initial war and natural disasters damage coefficient is assumed to be null): $g = \frac{K_{t_0+1} - K_{t_0}}{K_{t_0}} = -\delta + \sqrt{(1-\delta)}\frac{I_{t_0+1}}{K_{t_0}}$ or equivalently: $K_{t_0} = \frac{\sqrt{(1-\delta)}}{\delta+g} I_{t_0+1}$.

The initialization date t_0 varies among countries and depends of the shortest time series between investment and GDP, see Table A1-1 below.

Table A1-1
Initialization date (t_0) of the capital series (*K*)

Australia	1880
Canada	1871
Finland	1861
France	1821
Germany	1850
Italy	1862
Japan	1885
Netherlands	1821
Norway	1865
Spain	1851
Sweden	1801
United Kingdom	1831
United States	1875

1.5.3. War and major natural disasters damage

Australia: None.
Canada: None.
Finland: None.

France: Villa (1994). Villa uses a different approach by changing the depreciation rate according to destruction laws. We had to convert them in order to fit with our model.
Germany: According to Demotes-Mainard (1989), West Germany underwent a loss of 15% in capital during WW2. Among them, 3% is a consequence of factory disassembling in 1945. In order to spread the remaining 12%, we used the information from Humble (1975) concerning bombs dropped by the Allies over the German territory (Table A1-2).

Table A1-2
Bombing over Germany by Royal Air Force and US Air Force
Source: Humble (1975)

Year	RAF bombing (in tons)	USAF bombing (in tons)	% of total	Among the 12% loss without disassembling
1939	31	0	0	0
1940	13,033	0	0.82	0.10
1941	31,504	0	1.98	0.24
1942	45,561	1,561	2.97	0.36
1943	157,457	44,165	12.70	1.52
1944	525,518	389,119	57.59	6.91
1945	191,540	188,573	23.94	2.87

Italy: Following Broadberry *et al.* (2011), we assumed 1% of war damage in both equipment and building capital in 1944 and another 1% in 1945.
Japan: For damages caused by major natural disasters, we used a study by the OECD *From tragedy to the revitalization of Japan, OECD Economic survey, Japan 2013*. For WW2, we used a document kindly provided by the Bank of Japan and entitled *Hundred Years Statistics of the Japanese Economy*.
Netherlands: Following Madsen *et al.* (2010), we assumed 3.5% war damage between 1943 and 1945.
Norway: None.
Spain: According to Prados (2008), total capital destruction in Spain during the civil war reached 7% of the 1935 capital stock. Besides, buildings and infrastructures were destroyed by 4% to 6%. We deduced the capital destruction in equipment and spread the damages between 1936 and 1938.
Sweden: None.
United Kingdom: Following Madsen et al. (2010), we added 3.3% war damage between 1943 and 1945.
United States: None.

2. Quarterly data

Quarterly data start in 1960q1 and end in 2012q4 with the exception of Spain (1960q4) and Canada (1961q1). GDP and GFCF are given in US$ 2005 PPP thanks to conversion rate from the World Bank.

Concerning Germany, in order to deal with the reunification issue in 1990, we decided to consider the evolution of data for West Germany before 1991 and to rescale them with 1991 values for the whole country.

2.1. GDP (*Y*)

Australia 1960q1-2012q4: National Accounts of Australia.
Canada 1960q1-2012q4: OECD quarterly national accounts (2012).
Finland 1960q1-1975q1: Tilastokeskus National Accounts; 1975q1-2012q4: Eurostat National Accounts (2012).
France 1960q1-1980q1: OECD Economic Outlook Database (2012); 1980q1-2012q4: Eurostat National Accounts (2012).
Germany 1960q1-1970q1: BIS Macroeconomics data for West Germany; 1970q1-1991q1: National Accounts from Bundesbank; 1991q1-2012q4: Eurostat National Accounts (2012).
Italy 1960q1-1991q1: Data provided by Baffigi and the Bank of Italia (updating Baffigi, 2011); 1991q1-2012q4: Eurostat National Accounts (2012).
Japan 1960q1-1980q1: OECD Economic Outlook Database (2012); 1980q1-2012q4: Eurostat National Accounts (2012).

Netherlands 1960q1-1988q1: OECD Economic Outlook Database (2012); 1988q1-2012q4: Eurostat National Accounts (2012).
Norway 1960q1-1978q1: OECD Economic Outlook Database (2012); 1978q1-2012q4: Eurostat National Accounts (2012).
Spain 1960q1-1991q1: Data provided by Prados and the Bank of Spain (updating Prados, 2008) ; 1991q1-2012q4: Eurostat National Accounts (2012).
Sweden 1960q1-1983q1: OECD Economic Outlook Database (2012); 1983q1-2012q4: Eurostat National Accounts (2012).
United Kingdom 1960q1-2012q4: Eurostat National Accounts (2012).
United States 1960q1-1970q1: OECD Economic Outlook Database (2012); 1970q1-2012q4: Eurostat National Accounts (2012).

2.2. Total Hours Worked (*H*)

Australia 1960q1-1970q1: Annual data from CB-TED (see section 1 of this Appendix) linearly interpolated; 1970q1-2012q4: OECD Economic Outlook Database (2012).
Canada 1961q1-2012q4: OECD Economic Outlook Database (2012).
Finland 1960q1-2012q4: OECD Economic Outlook Database (2012).
France 1960q1-1970q1: CB-TED ; 1970q1-2012q4: OECD Economic Outlook Database (2012).
Germany 1960q1-2012q4: OECD Economic Outlook Database (2012).
Italy 1960q1-2012q4: OECD Economic Outlook Database (2012).
Japan 1960q1-1970q1: CB-TED ; 1970q1-2012q4: OECD Economic Outlook Database (2012).
Netherlands 1960q1-1970q1: CB-TED; 1970q1-2012q4: OECD Economic Outlook Database (2012).
Norway 1960q1-1962q1: CB-TED; 1962q1-2012q4: OECD Economic Outlook Database (2012).
Spain 1960q4-1970q1: CB-TED; 1970q1-2012q4: OECD Economic Outlook Database (2012).
Sweden 1960q1-2012q4: OECD Economic Outlook Database (2012).
United Kingdom 1960q1-1970q1: CB-TED; 1970q1-2012q4: OECD Economic Outlook Database (2012).
United States 1960q1-2012q4: OECD Economic Outlook Database (2012).

2.3. Total Employment (*N*)

For every country but Australia, we used data from the OECD Economic Outlook Database (2012) (2012). For Australia, OECD data start in 1964q1, we completed them with CB-TED.

2.4. Investment (*I*)

Australia 1960q1-2012q4: OECD quarterly national accounts (2012) Database.
Canada 1960q1-1982q4: OECD Economic Outlook Database (2012). Total investment has been split by us in equipment and buildings using an annual separation rate calculated from Historical Statistics of Canada (Section F) (1960-1975) and National Accounts (1975-1982). For this period, we assumed that the growth rate of equipment and buildings investment is equal to the one of non residential investment; 1982q1-2012q4: OECD quarterly national accounts (2012) Database.
Finland 1960q1-1975q1: Tilastokeskus National Accounts; 1975q1-2012q4: Eurostat National Accounts (2012).
France 1960q1-1980q1: Maddison (1994), annual data interpolated to quarterly by Banque de France; 1980q1-2012q4: Eurostat National Accounts (2012).
Germany 1960q1-1991q1: Maddison (1994) annual data interpolated to quarterly by Banque de France; 1991q1-2012q4: Eurostat National Accounts (2012).
Italy 1960q1-1991q1: Data provided by Baffigi and the Bank of Italia (updating Baffigi, 2011); 1991q1-2012q4: Eurostat National Accounts (2012).
Japan 1960q1-1980q1: OECD Economic Outlook Database (2012). Total investment has been split by us between equipments and buildings using an annual separation rate calculated from Maddison (1994); 1980q1-2012q4: OECD quarterly national accounts (2012) Database.
Netherlands 1960q1-1988q1: OECD Economic Outlook Database (2012). Total investment has been split by us between equipments and buildings using an annual separation rate calculated from Groote *et al.* (1996) for the sub-period 1960-1969 and from Eurostat Annual National Accounts for the sub-period 1969-1988; 1988q1-2012q4: Eurostat National Accounts (2012).

Norway 1960q1-1978q1: OECD Economic Outlook Database (2012). Total investment has been split by us between equipments and buildings using an annual separation rate calculated from SSB historical statistics for the sub-period 1960-1970 and from Annual National Accounts from SSB for the sub-period1970-1978; 1978q1-2012q4: Quarterly National Accounts from SSB, rescaled with Eurostat National Accounts (2012).
Spain 1960q1-1995q1: Data provided by Prados and the Bank of Spain (updating Prados, 2008); 1995q1-2012q4: Eurostat National Accounts (2012).
Sweden 1960q1-1993q1: OECD Economic Outlook Database (2012). Total investment has been split by us between equipments and buildings using an annual separation rate calculated from Swedish Historical National Account 1800-2000; 1960q1-1993q1: Eurostat National Accounts (2012).
United Kingdom 1960q1-1980q1: OECD Economic Outlook Database (2012). Total investment has been split by us between equipments and buildings using an annual separation rate calculated from Maddison (1994) for the sub-period 1960-1965 and from Eurostat Annual National Accounts (2012) for the sub-period 1965-1980; 1980q1-2012q4: Eurostat National Accounts (2012).
United States 1960q1-1995q1: OECD Economic Outlook Database (2012). Total investment has been by us between equipments and buildings using an annual separation rate calculated from Maddison (1994); 1995q1-2012q4: OECD quarterly national accounts (2012) Database.

2.5. Capital (*K*)

We proceed as for annual data considering a depreciation rate δ_q, such that $(1 - \delta_q) = (1 - \delta)^{1/4}$. We didn't consider any war and natural disaster damage for quarterly data, except for Japan in 1995 and 2011. In order to initialize the series of capital, we use the value of capital at the end of 1959 given by annual data.

3. Purchasing Power Parity conversion index

In order to compare the productivity indexes among countries and to compute relative levels to US, we have converted national currencies into USD2005 PPP. It seems important to notice that this conversion only affects levels relative to US which means that breaks and growth are not affected.

The Table A1-3 compare conversion index from different sources. The differences appear very low and barely affect our results. As usual for productivity analysis, we use here the Penn World Table indexes.

Table A1-3
PPP conversions indexes to USD2005 and comparison to the Penn World Table ones
Conversion indexes for the Euro Area countries are not needed as we use data which have already been converted into USD2005 PPP by Eurostat, using itself the Penn World Table ones.

	Number of national 2005 currency for 1 USD2005			Comparison to the Penn World Table indexes, in%	
	Penn World Table	**World Bank**	**IMF**	**World Bank**	**IMF**
Australia	1.29	1.39	1.39	+7.7	+7.7
Canada	1.16	1.21	1.21	+4.9	+4.9
Finland	0.93	0.98	0.98	+4.7	+5.4
France	0.87	0.92	0.92	+5.6	+5.5
Germany	0.85	0.87	0.89	+1.7	+4.7
Italy	0.82	0.87	0.88	+5.3	+6.3
Japan	125.37	129.55	129.55	+3.3	+3.3
The Netherlands	0.86	0.90	0.90	+4.3	+4.5
Norway	8.65	8.90	8.84	+2.8	+2.2
Spain	0.73	0.76	0.77	+4.2	+4.6
Sweden	9.06	9.38	9.24	+3.5	+2.0
United Kingdom	0.61	0.64	0.65	+4.3	+6.3

Appendix 2: war periods treatment

For each country, with a few exceptions (see below), maximum periods covered by dummy variables are: 1914-1923 and 1939-1950. We tested the following model:

$$z_t(a,b) = \alpha + \sum_{k=0}^{p} \beta_k (t - T_k)\mathbb{I}(t \geq T_k) + \sum_{i=1914}^{a} \gamma_i \mathbb{I}(t = i)t + \sum_{i=1939}^{b} \delta_i \mathbb{I}(t = i)t + \theta_1 \mathbb{I}(t \geq a) + \theta_2 \mathbb{I}(t \geq b)$$

Where z is the productivity indicator (in log), $\mathbb{I}$ is the indicator function, p the number of breaks computed by the Bai and Perron algorithm, β_k productivity growth rate as a difference to the previous period. θ_1 and θ_2 enable discontinuities in productivity level during the wars.

We calculated $y(a,b)$ for each $a \in \{1914\,;1923\}$ and $b \in \{1939\,;1950\}$ and the corresponding Akaike Information Criteria (AIC). Then we looked for the minimum value of the criteria which provides optimal parameters (a^*, b^*).

This procedure has been first implemented for total factor productivity (*TFP*) and after for labor productivity (*LP*) with the same *a* and *b*.

Some exceptions have to be noticed:

- Spain: WWI is not statistically significant (consistent with historical evidence) and WWII corresponds to the Civil War and starts in 1936;
- US: WWII starts in 1941, consistently with statistical and historical evidence;
- Japan: WWI is not statistically significant, which is consistent with historical evidence (limited involvement of Japan through its Navy).

The results concerning the end of the world wars year fixed effect periods are given in the Table A2-1.

Table A2-1
End dates of the two world wars year fixed effect periods (*a* and *b*)

Country	WWI end-date (*a*)	WWII end-date (*b*)
Australia	1918	1945
Canada	1919	1939
Finland	1918	1943
France	1918	1947
Germany	1920	1948
Italy	1922	1948
Japan	1914	1947
The Netherlands	1918	1947
Norway	1921	1946
Spain	1914	1948
Sweden	1923	1946
United Kingdom	1923	1946
United States	1919	1947
Euro Area	1919	1948

WWI end-date=1914 and WWII end-date=1939 means that no special treatment is made for the wars.

Appendix 3: merging annual and quarterly series

This merge is realized by four successive steps.

Step 1: Computing breaks with Bai and Perron algorithm.

Let $\{d_1, d_2, \dots, d_{p+2}\}$ and $\{l_1, l_2, \dots, l_q\}$ be the sets of the break dates for annual and quarterly productivity index (in log) respectively, as computed by the Bai and Perron algorithm and such that: $min_{i\in\{1,\dots,p+1\}}(d_{i+1} - d_i) > 0.06 * T$ *and* $min_{i\in\{1,\dots,q-1\}}(l_{i+1} - l_i) > 0.1 * T'$ where T and T' are the numbers of observations on annual and quarterly series respectively (here $T = 123$ and $T' = 208$), p and q are the number of breaks without the two world war breaks. *a* and *b*, the end dates of the two world wars year fixed effect periods (see Appendix 2), are included in the set of annual break dates. We assume $p \leq 6$ and $q \leq 4$.

Step 2: Removing annual breaks located after or too closely to the first quarterly break.

We do not consider any break computed on annual data which would be located less than five years before the first break computed on quarterly data.

Step 3: Filtering the smallest breaks.

In order to keep only the most relevant breaks in the quarterly series, we remove breaks if the resulting change in productivity growth does not exceed 0.2pp.

Step 4: Merging annual and quarterly series.

The final set of break dates is then computed by combining the two previous sets: $\{d_1, d_2, \dots, d_{p^*}, \lfloor l_1 \rfloor, \lfloor l_2 \rfloor, \dots, \lfloor l_q \rfloor\}$ where $\lfloor l_q \rfloor$ is the rounded value of l_q. and p^* is the last index of annual breaks.

Once this final set is built, we ran a standard OLS regression and find values for $\beta = \{\beta_0, \beta_1, \dots, \beta_m\}$, where m is the total number of breaks. It is then easy to convert these breaks into growth rates. Note that a growth rate calculated this way is not strictly equal to the average growth rate of the related sub sample: $g_k = \left(\frac{z_{d_{k+1}}}{z_{d_k}}\right)^{\frac{1}{(d_{k+1}-d_k+1)}}$ (for example) because we require continuity between our trends.

Documents de Travail

460. J. Carluccio and M. Bas, "The Impact of Worker Bargaining Power on the Organization of Global Firms," November 2013

461. F. Canova, F. Ferroni and C. Matthes, "Choosing the variables to estimate singular DSGE models," November 2013

462. S. Avouyi-Dovi, G. Horny and P. Sevestre, "The dynamics of bank loans short-term interest rates in the Euro area: what lessons can we draw from the current crisis?," November 2013

463. D. Fougère, C. Golfier, G. Horny et E. Kremp, "Quel a été l'impact de la crise de 2008 sur la défaillance des entreprises ?," Novembre 2013

464. T. Duprey, "Heterogeneous Banking Efficiency: Allocative Distortions and Lending Fluctuations," November 2013

465. L. Arrondel, M. Debbich and F. Savignac, "Financial Literacy and Financial Planning in France," December 2013

466. P. Antipa, "Fiscal Sustainability and the Value of Money: Lessons from the British Paper Pound, 1797-1821," December 2013

467. D. Bellas and Vincent Vicard, "French firms exports during downturns: evidence from past crises," December 2013

468. V. Chouard, D. Fuentes Castro, D. Irac and M. Lemoine, "Assessing the losses in euro area potential productivity due to the financial crisis," December 2013

469. G. Cléaud, M. Lemoine and P-A. Pionnier, "Which size and evolution of the government expenditure multiplier in France (1980-2010)?," December 2013

470. D. Irac and J. Lopez, "Euro area structural convergence? A multi-criterion cluster analysis," December 2013

471. L. De Benedictis, S. Nenci, G. Santoni, L. Tajoli and C. Vicarelli, "Network Analysis of World Trade using the BACI-CEPII dataset," December 2013

472. G. Gaulier, G. Santoni, D. Taglioni and S. Zignago, "Market Shares in the Wake of the Global Crisis: the Quarterly Export Competitiveness Database," December 2013

473. M. Mogliani, V. Brunhes-Lesage, O. Darné and B. Pluyaud, **"**New estimate of the MIBA forecasting model. Modeling first-release GDP using the Banque de France's Monthly Business Survey and the "blocking" approach," January 2014

474. F. Mayneris and L. Py, **"**The Efficiency of Enterprise Zone Programs: Some Conflicting Results?," January 2014

475. A. Bergeaud, G. Cette and R. Lecat, "Productivity trends from 1890 to 2012 in advanced countries," February 2014

BANQUE DE FRANCE
49- 1404 Labolog
75049 Paris Cedex 01
tél : 0033 (0)1 42 97 77 24 ou 01 42 92 63 40 ou 48 90 ou 69 81
email : 1404-ut@banque-france.fr