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A Comparison of Productivity Growth in France, Japan, the United Kingdom and the United States over the Past Century

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Abstract

The present study contributes to the numerous other analyses of economic growth and productivity by comparing France, Japan, the United Kingdom and the United States over the very long run (since 1890) and the medium run (since 1980). During the past century, the United States has overtaken the United Kingdom and become the leading world economy and. During the last 25 years, productivity growth has posted contrasted developments in the four countries, in particular as a result of an unequal growth of information and communication technology (ICT) investments.

The past 120 years have been characterised by : (i) rapid economic growth and large productivity gains in the four countries; (ii) a decline in productivity in the United Kingdom relative to the United States and to a lesser extent relative to France and Japan until the second world war (WW2), and its subsequent catching-up relative to the United States; (iii) the remarkable catching-up of the United States by France and Japan after WW2, which was however interrupted in the case of Japan during the 1990s. The contribution of capital deepening - as it can be measured- accounts for a large share of these different performances, with an increasing share of ICT capital in the last 25 years. This contribution varies considerably over time and across the four countries, and it is always less important, except in Japan, than that of the unmeasured factors underlying total factor productivity, such as, in particular, labour skills, technical and organisational changes and knowledge spillovers.

At present (in 2006), hourly labour productivity levels are slightly higher in France than in the United States, and significantly lower in the United Kingdom (by roughly 10%) and even more in Japan (30%), while TFP levels are very close in France, United Kingdom and the United States, but much lower (40%) in Japan.

Codes JEL : O47, O57, E22, J24, N10.
Key words: Productivity, growth accounting, macro-economic history.

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1. Introduction

Productivity is a key determinant of the wealth of nations. Almost all theoretical and empirical studies that set out to explain the extremely large growth and living standard inequalities between countries focus on the differences in productivity levels and growth rates. These studies are legion and our study is just another one. Like most other studies, it is simply and directly based on the traditional "growth accounting" framework (outlined in the Appendix). Its originality, however, lies in the comparison of productivity in France, Japan, the United Kingdom and the United States over both the very long run (since 1890) and the medium run (since 1980), covering a century during which the United States has replaced the United Kingdom as the leading world economic power, and the past quarter century during which the development of information and communication technologies (ICT) has contributed significantly, though unevenly, to productivity growth..

We have tried to make the best use of the estimates of aggregate historical data series going back in all four countries to the end of the 19th century for output (GDP), employment, working time and investment in physical capital (see Box on Data Sources). As regards the past 25 years, we relied as much as possible on national accounts data. Many of the estimates on which our comparison is based are subject to a great deal of uncertainty and inaccuracy, not only for the most distant periods but also to a significant extent for the more recent ones. Their orders of magnitude, and the ensuing large differentials in productivity levels and growth rates, may nevertheless be considered as relatively reliable. One important reason to be confident is the long tradition of statistics gathering in the four countries. Another is that our comparison is limited to the economies as a whole (and the fact that all four countries had reasonably stable frontiers over our study period). Moreover, given the difficulties of measuring (physical) capital, as well as uncontrolled differences in measurement methods, we considered it more appropriate to simply re-estimate capital stocks and services and their contributions to growth for the four countries on the basis of the available investment series, using constant and equal capital stock depreciation rates and shares of services in GDP (see Box). Similarly, we chose to use the same hedonic price estimates (relative to GDP price indices) for France, Japan and the United Kingdom as those in the United States for computer hardware, software and communication equipment investments.

In short, we examine and compare across the four countries and over different periods the levels and growth rates of three complementary notions of productivity: labour productivity, both per employee and per hour, and total factor productivity (TFP) i.e. joint labour and capital productivity. We consider the long-run productivity trends in Section 2, while we focus on the past 25 years and the key role played by the spread of ICT in Section 3.

Box
Data Sources

The data sources on which we rely in this study are historical or national accounts series, which we put together to construct indicators over the very long term or, in the case of ICTs, over the past few decades. In order to avoid creating breaks in these indicators, we backcasted them on the basis of growth rates for the more distant and more recent periods covered by the available historical and national accounts series.

In order to compare the levels of variables, we first expressed them in constant domestic currency terms on the basis of the year 2000, and then converted them in 2000 constant dollar terms, using the PPP exchange rates derived implicitly from PPP 2000 constant dollar GDP estimates provided by Maddison (2003).

The most commonly used databases are those of Maury and Pluyaud (2004), Cahn and Saint-Guilhem (2006) and Kocoglu (2001), which we respectively denote by (a), (b) and (c) in what follows.

GDP (gross domestic product)
- France: National accounts for the period 1959-2006 and Villa (1994)[a] for the period prior to 1959;
- Japan: National accounts for the period 1994-2006, OECD for the period 1970-1994 and Maddison (2001, 2003) for the period prior to 1970;

- United Kingdom: National accounts for the period 1965-2006[b], Groningen Growth and Development Centre (GGDC)[1] and Feinstein (1976) for the period prior to 1955[a];
- United States: National accounts (BEA) for the period 1929-2006[b] and Mitchell (1998)[a] for the period prior to 1929.

Employment (average number of workers)
- France: National accounts from OECD for the period 1970-2006, GGDC for the period 1959-1970 and Villa (1994)[a] for the period prior to 1959;
- Japan: OECD for the period 1970-2006, GGDC for the period 1959-1970 and Maddison (2001, 2003) for the period prior to 1959;
- United Kingdom: OECD for the period 1970-2006, GGDC for the period 1959-1980 and Feinstein (1976)[a] for the period prior to 1959;
- United States: National accounts for the period 1970-2006[b], GGDC for the period 1959-1970 and Mitchell (1998)[a] for the period prior to 1959.

Working time (average number of hours worked per year, per worker)
For the four countries: OECD for the period 1970-2006; GGDC for the period 1950-1969; Maddison (2001) for 1870, 1913 and 1950; linear interpolation for the periods 1890-1913, 1913-1950.

Investment
- France: National accounts for the period 1959-2006, Maddison (1993) for the period 1935-1959, Levy-Leboyer (1978)[c] for the period 1820-1935. The breakdown of total GFCF between equipment and buildings is taken from Villa (1994) for the period 1820-1935;
- Japan: National accounts for the period 1980-2006 and Maddison (1993) for the period prior to 1980;
- United Kingdom: National accounts for the period 1965-2006[b] and Maddison (1993) for the period prior to 1965;
- United States: National accounts for the period 1967-2006[b] and Maddison (1993) for the period prior to 1967.

ICT investment
- France: GGDC (EUKLEMS) for the period 1970-2005;
- Japan: GGDC (EUKLEMS) for the period 1970-2004;
- United Kingdom: GGDC (EUKLEMS) for the period 1970-2005
- United States: GGDC (EUKLEMS) for the period 1970-2005 and trend from the BEA for the market economy for the period 1959-1969.

Fixed capital
Fixed capital series are constructed on the assumption that the annual depreciation rates are: 2.5% for buildings, 10% for non-ICT equipment, 15% for communication equipment and 30% for computer hardware and software. The coefficients used to take into account WW1 and WW2 damages in France are taken from Villa (1994)[c]. For Japan, WW2 damages are implicitly taken into account by using the Maddison (1993) growth rate for the period prior to 1946. For this country, the WW2 damage coefficients are those proposed by the Bank of Japan (1966), and the Maddison depreciation assumption (1993) are consistent with ours.

Prices of ICT products
The relative ICT price indexes (compared to GDP prices) for France, Japan and the United Kingdom are the same as those taken from the US national accounts (see Colecchia and Shreyer 2001 for detailed discussion about this hypothesis).

2. Comparing long run productivity trends

We first comment in sub-section 2.1 on the average trends over the entire period: 1890-2006. We then consider in sub-section 2.2 the five following sub-periods: from 1890 to 1913, just before WW1; from 1913 to 1950, i.e. including the years of economic reconstruction and recovery after WW2 in order to smooth out the most significant effects of the conflict on production capacities and economic structures; from 1950 to 1973, just before the first oil shock; from 1973 to 1980, i.e. the period between the two oil shocks; and from 1980 to 2006, this period being examined in more details in section 3. In Section 2.2, we also check our productivity estimates against those of a number of other studies.

[1] The June 2007 version of the database may be downloaded at the following address: http://www.ggdc.net.

2.1. …. over the entire period

From 1890 to 2006, the overall growth of labour productivity was remarkable in all four countries. The levels of productivity per employee and per hour increased by a factor of respectively 10 and 20 in France, 25 and 40 in Japan, 5 and 9 in the United Kingdom and 7 and 12 in the United States (see Table 1). The large differentials between the growth rates of employee and hourly productivity can be attributed, in accounting terms, to the large decline in average annual working time: by roughly 50% in France (sliding from 3,110 hours in 1890 to 1,540 hours in 2006), by 45% in the United Kingdom (from 2,990 to 1,670 hours), 40% in the United States (from 2,850 to 1,710) and 35% in Japan (from 2,734 to 1784). Over these (nearly) 120 years, Japan posted the highest average annual growth: 2.8% per employee and 3.2% per hour, and the United Kingdom the lowest: 1.4% per employee and 1.9% per hour, while France and the United States were in an intermediate position, with France (2,1% and 2,7%) ranking above the United States (1.8% and 2.2%).

Table 1
Productivity levels and average growth, 1890-2006 – ppp 2000 dollar.

	Annual average growth rates, In %, 1890-2006				Levels, as a % of the US level					
					1890			2006		
	France	Japan	United Kingdom	United States	France	Japan	United Kingdom	France	Japan	United Kingdom
Labour productivity per employee	2.1	2.8	1.4	1.8	64.7	22.2	129.3	91.0	72.6	86.4
Labour productivity per hour	2.7	3.2	1.9	2.2	59.4	23.2	123.3	100.9	69.7	88.6
Total factor productivity	1,6	1.8	1.0	1.6	65.9	49.9	203.0	90.8	60.6	105.9

Source: Authors' calculation, see Box and Appendix.

In terms of productivity level, few studies are available on a long period to allow some comparison with our results. Concerning the productivity per hour, relatively to the United States level, results from Maddison (2007) seem, for Japan and the United Kingdom, for very close to ours (Table 2 for the results from Maddison, 2007, and Table 1 and Graphs 1 and 2 for our results). Maddison (2007) does not give level comparison for TFP. But the level comparisons given by him for productivity per hour and for capital stock per capita seem to correspond to TFP relative levels close to our evaluation[2].

Table 2
GDP per hour worked, as a % of the US level –
Scope : Economy as a whole – ppp 1990$

	1870	1913	1950	1973	2003
Japan	20	21	16	49	64
United Kingdom	113	84	63	67	79

Source: From Maddison (2007, Table 6.4, p. 305)

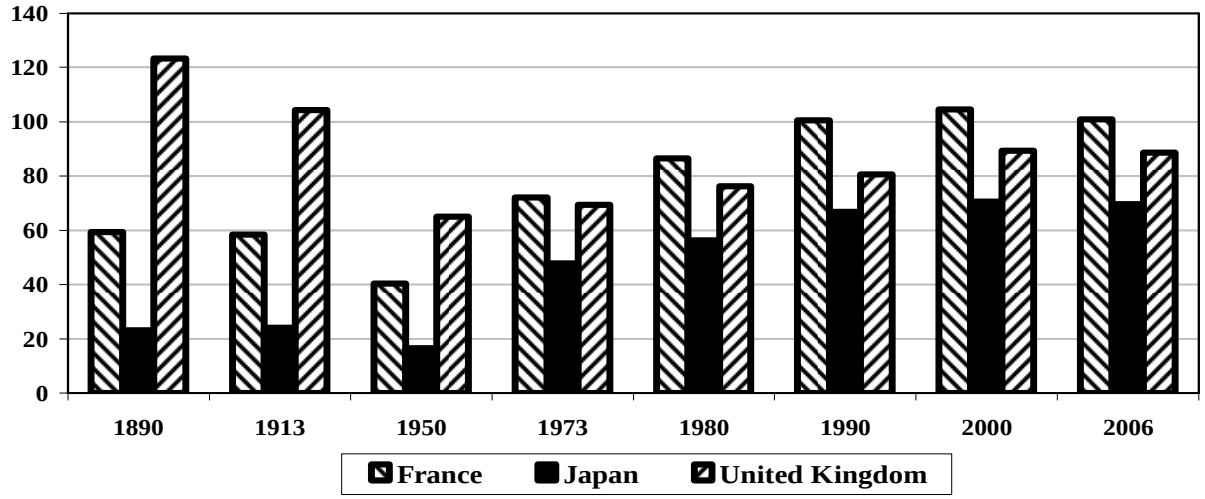
In 1890, the level of US labour productivity, whether per employee or per hour, was about four to five times higher than in Japan, 50% higher than in France, but 25% lower than in the United Kingdom (see Table 1 and Graphs 1 and 2)[3]. At the time, Japan and France had a much larger proportion of their labour

[2] See Maddison (2007, Table 6.4, p. 305). For example, in this evaluation, the capital stock per capita (in 1990$) would have been, in the United Kingdom in 1913, 23% of the US one. This conciliates a higher (by a lot) TFP level and a lower productivity level in the United Kingdom compare to the United States.

[3] The relative productivity levels for France, Japan and the United Kingdom obtained in this study differ somewhat from those mentioned in Cette (2004, 2007). These results do not alter the commented stylised facts. The causes of these differences are two-fold. First, the data sources are different: those used in the present study are detailed

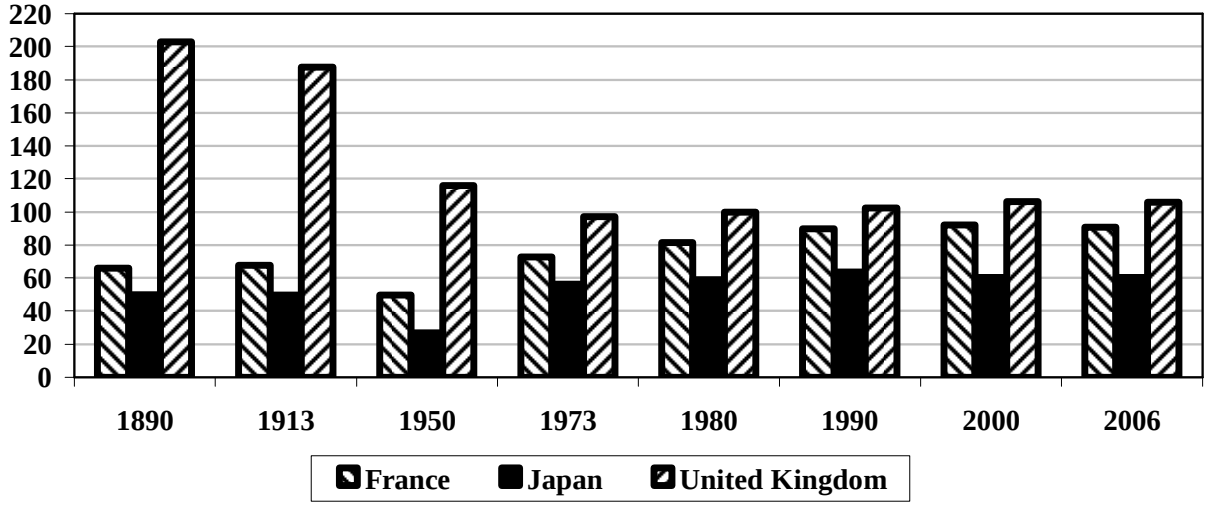
force working in agriculture, as compared with the other two countries. In 2006, these productivity rankings were very different. The Japanese productivity level, though still the lowest, was about two thirds that of the United States, and the French productivity level was close to that of the United States, while the British productivity level was significantly lower (by about 10%) than in the United States and also somewhat than in France[4].

Graph 1
Labour productivity per hour, as a % of the US level
Scope : Economy as a whole - PPP dollar 2000



Source: Authors' calculation, see Box and Appendix.

Graph 2
Total factor productivity, as a % of the US level
Scope : Economy as a whole - PPP dollar 2000



Source: Authors' calculation, see Box and Appendix.

in the Box above and those used in Cette (2004 and 2007) are Maddison (1994, 2001 and 2003). Second, in order to ensure the continuity of historical series, we chose to backcast them on the basis of growth rates (see also Box).

[4] Bourlès and Cette (2005, 2007) have shown that France's strong productivity performance compared to the United States at the end of the period can partly be explained by shorter working hours and a lower employment rate on account of strongly diminishing returns for both variables. After adjusting for the effect of the differentials in these two variables on productivity, it appears that in 2006 hourly labour productivity in France is roughly 5% lower than in the United States.

Growth in total factor productivity (TFP) accounts for a major share of hourly labour productivity growth over the past 120 years in the four countries: roughly 50% to 60% in France, Japan and in the United Kingdom and 70% in the United States, while the contribution of capital deepening appears much smaller (see Table 4). Overall, the factors underpinning TFP as computed, i.e. mainly a better educated and higher skilled labour force, knowledge spillovers, technical and organisational changes, make a much greater contribution to observed productivity gains than capital deepening per se. In 1890, the level of TFP was roughly 100% higher in the United Kingdom, but 35% lower in France and 50% lower in Japan than in the United States. Given that TFP growth was relatively slow in the United Kingdom and fast in France, the level of TFP in both countries was close to that in the United States in 2006. Such remarkable convergence did not occur in Japan, where the level of TFP has levelled off at about 60% of that of the United States since the beginning of the 1970s.

In Japan, the productivity convergence process ended well before that in the other three countries. The convergence of TFP ended in the early 1970s, while that of hourly labour productivity came to a halt in the early 1990s. This can probably partly be attributed to a persistent divergence in sectoral structures. Low productivity activities, such as agriculture, construction, trade and catering account for a larger share of the economy than in the other three countries (see Table 3).

Table 3
Structure of employment, as a % of total employment

	France		Japan		United Kingdom		United States	
	1970	**2004**	**1970**	**2004**	**1970**	**2004**	**1970**	**2004**
- Agriculture and mining	14.3	3.7	20.2	5.4	5.2	1.5	5.2	2.8
- Manufacturing, gas and water	25.8	14.4	26.5	17.7	33.0	12.3	23.2	10.9
- Construction	10.2	6.3	8.1	9.0	7.2	6.8	5.0	6.0
- Wholesale and retail trade, restaurants and hotels	15.5	17.3	20.9	25.5	19.0	23.3	21.6	23.8
- Transport and storage and communication	5.6	6.2	5.6	5.8	6.7	5.9	4.6	4.2
- Other services	28.7	52.0	18.8	36.6	28.9	50.2	40.5	52.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source : Base EUKLEMS

2.2. …by sub-periods

Our estimates of employee and hourly productivity growth and the respective contributions of capital deepening contribution and TFP for the four countries are presented by sub-periods in Table 4, and in the corresponding Graph 3.

Very few analyses make it possible to draw comparisons between several industrialised countries over a whole century. As expected, our results are very close to those of Maury and Pluyaud (2004), as we used largely the data they compiled and harmonized on real GDP and employment to construct the productivity per employee indicator for each country. They are also consistent with the results presented by Gordon (2003), Cette (2004, 2007) and Van Ark, Frankema and Duteweerd (2004) who measure labour productivity growth over different sub-periods using the real GDP and employment estimates calculated by Maddison (2001). Lastly, they are consistent with those of Maddison (2007) who makes some long-term comparisons between Japan, the United Kingdom and the United States (see Table 7), and considers in particular the same two sub-periods 1913-1950 and 1950-1973.

More specifically, as regards France, the estimates by Dubois (1985), which builds on the major work of Carré, Dubois and Malinvaud (1972), are comparable to ours, although they cover only market activities (not the whole economy). According to Dubois (see Table 5), average growth in hourly productivity was about 2.0% in the sub-period 1896-1913, slowing down to 2.0% in 1913-1951 and accelerating to 5,6% in 1951-1973 to slow down again to 3,8% in 1973-1984, while average TFP growth was 1.4% in the sub-period 1896-1913, 1.5% in 1913-1951, 4.2% in 1951-1973 and 2.0% in 1973-1984. The differences with

our estimates are minor, in spite of the different scope as well as our simplified assessment of the contribution of capital deepening to growth.

For the United Kingdom and Japan, our estimates of labour productivity and TFP growth are very similar to the ones of Maddison (2007) over both sub-periods 1913-1950 and 1950-1973 (see Table 7). For the United Kingdom, our estimates are also consistent with those of Crafts (2004a, b and c).

As regards the United States, Ferguson and Wascher (2004) apply a comparable breakdown of hourly productivity growth as we do, but for the non-agricultural market sector and with slightly different sub-periods (see Table 7). Their results and ours are nonetheless not very different. Over the more recent sub-period 1950-1973, our estimates of labour productivity and TFP growth are also similar to the ones of Maddison (2007). However, our estimate of TFP growth over the more distant sub-period 1913-1950 is higher than Maddison's by about 0.7% per year, while our estimate of labour productivity differs 'only' by 0.3% (see Table 6).

Table 4
Average annual labour productivity growth (in %) and contributions (in percentage points), in France, the United Kingdom and the United States
scope: Economy as a whole

A – France

	1890- 1913	1913-1950	1950-1973	1973-1980	1980-2006
GDP	1.9	0.9	5.3	2.9	2.1
Productivity per employee [a]	1.6	1.0	4.7	2.6	1.5
Productivity per hour [b]	1.9	1.8	5.2	3.4	2.2
Contributions to productivity per hour :					
Capital intensity, per hour [c]	0.5	0.3	1.2	1.6	0.9
Total factor productivity [d]	1.4	1.5	4.0	1.8	1.3

B – Japan

	1890- 1913	1913-1950	1950-1973	1973-1980	1980-2006
GDP	2.5	2.2	9.3	3.4	2.3
Productivity per employee [a]	1.8	1.3	7.5	2.6	1.8
Productivity per hour [b]	2.1	1.8	7.4	3.2	2.4
Contributions to productivity per hour :					
Capital intensity, per hour [c]	0.9	1.1	2.0	2.3	1.4
Total factor productivity [d]	1.2	0.7	5.4	0.9	1.0

C – United Kingdom

	1890- 1913	1913-1950	1950-1973	1973-1980	1980-2006
GDP	1.9	1.3	2.9	1.0	2.5
Productivity per employee [a]	0.9	0.7	2.5	0.9	2.0
Productivity per hour [b]	1.2	1.5	2.8	2.1	2.2
Contributions to productivity per hour :					
Capital intensity, per hour [c]	0.3	0.5	1.6	1.6	1.1
Total factor productivity [d]	0.9	1.0	1.2	0.5	1.1

D – United States

	1890- 1913	1913-1950	1950-1973	1973-1980	1980-2006
GDP	4.1	3.2	4.0	2.5	3.1
Productivity per employee [a]	1.6	1.9	2.3	0.2	1.6
Productivity per hour [b]	2.0	2.8	2.5	0.7	1.6
Contributions to productivity per hour :					
Capital intensity, per hour [c]	0.7	0.5	0.8	0.6	0.7
Total factor productivity [d]	1.3	2.3	1.7	0.1	0.9

[b] = [c] + [d]
Source : Authors' calculation, see Box 1 and Appendix.

Table 5
Breakdown of labour productivity growth in France
scope: Business sector – % per year

	1896-1913	1913-1929	1929-1951	1951-1973	1973-1984
Productivity per employee	1,7	1,5	1,3	5.2	2.4
Productivity per hour[b]	2,0	2,5	1,7	5,6	3,8
Contributions :					
Capital intensity, per hour [c]	0.6	0.7	0.5	1.4	1.8
Total factor productivity [d]	1.4	1.8	1,2	4.2	2.0

[b] = [c] + [d].
Source : Dubois (1985, from Tables 6 and 8, p. 14 and 21).

Table 6
Average annual labour productivity growth and total factor productivity growth, per hour (in percentage points)
scope: Economy as a whole

	Labour productivity			Total factor productivity		
	Japan	**United Kingdom**	**United States**	**Japan**	**United Kingdom**	**United States**
1870-1913	2.0	1.2	1.9	-0.2	0.3	0.4
1913-1950	1,8	1.7	2.5	0.2	0.8	1.6
1950-1973	7,7	3.1	2.8	5.1	1.5	1.8
1973-2003	2,6	2.2	1.7	0.6	0.9	0.7

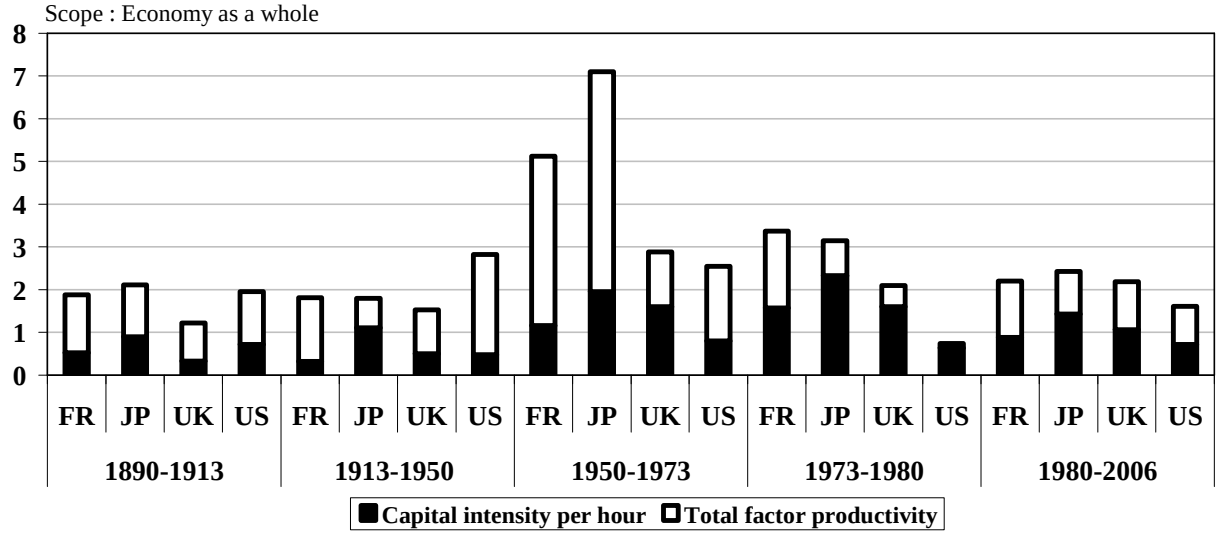
Source : Maddison (2007, Table 6.5, p. 306)

Table 7
Breakdown of US hourly productivity growth
scope: Non-agricultural market sector – % per year

	1890-1917	1917-1927	1927-1948	1948-1973	1973-1995	1995-2003
Productivity per hour [b]	1.5	3.8	1.8	2.9	1.4	3.0
Contributions :						
Capital intensity, per hour [c]	0.7	1.0	0.1	1.0	1.0	1.6
Total factor productivity [d]	0.8	2.8	1.7	1.9	0.4	1.4

[b] = [c] + [d].
Source: Ferguson and Wascher (2004, p. 6).

Graph 3
Average annual hourly labour productivity growth (in %) and contributions in France, Japan, the United Kingdom and the United States - 1890-2006 - in percentage points
Scope : Economy as a whole



Source: Authors' calculation, see Box and Appendix.

If the two sub-periods following the first oil shock are grouped together, our results confirm the "Big Wave" analysis of productivity in the United States offered by Gordon (1999, 2003). Hourly productivity in the United States and TFP accelerate after 1913 relative to the previous period, then slowdown after 1950 and again after 1973, while the contribution of capital deepening to growth is almost unchanged.

Employee productivity displays a similar pattern; however, growth is the fastest during the more recent sub-period 1950-1973, not 1913-1950. In France, Japan and the United Kingdom, we observe a similar "Big Wave", with both hourly and employee productivity growth being faster during the years 1950-1973 than in the previous years 1913-1950. This wave is more pronounced in Japan than in France, and in France than in the United Kingdom. The differences in productivity growth between these three countries and the United States, as reflected in the temporal shift of the Big Wave, can be attributed to several factors, among which the later diffusion of electric energy, the later improvement in the average education and skill level of the workforce (See van Ark, Frankema and Duteweerd, 2004) and a higher degree of protectionism (see Gordon, 2003, for a review of the literature). As in the United States, TFP is the main determinant of employee and hourly productivity growth in France, Japan and the United Kingdom. Capital deepening nonetheless contributes significantly to growth in Japan and in the United Kingdom. It is worth pointing out that over all sub-periods, the contribution of capital deepening to productivity growth is greater in Japan than in the other three countries, reflecting a higher capital accumulation rate.

The underlying factors of the different productivity performance across the four countries vary substantially depending on the sub-periods considered. From 1890 to 1913, France, Japan and the United States recorded similar annual growth rates of productivity per employee (roughly 1.7%) and per hour (roughly 2%). Annual productivity growth was the lowest in the United Kingdom, mainly on account of a smaller TFP contribution and, to a lesser extent, a smaller rise in capital deepening. In the four countries, the shares of the contributions of capital deepening and TFP to productivity growth are very similar (respectively ¼ to ½ and ½ to ¾). Compared with that of the United States, the level of hourly productivity in France and Japan thus remained unchanged at respectively roughly 45-50% and 20-25%, while that in the United Kingdom dropped from around 125% to 105%.

From 1913 to 1950, annual productivity growth (per employee and per hour) was much faster in the United States (where it stood at 1.9% and 2.8% respectively) than in France (1.0% and 1.8%) and Japan (1.3% and 1.8%) and, in particular, the United Kingdom (0.7% and 1.5%). Except for Japan, these discrepancies can be attributed to different TFP contributions, as the contribution of capital deepening was identical in all three countries and almost identical to that in the previous sub-period. In Japan, the contribution of capital deepening is very high during this sub-period (roughly 70% of hourly productivity growth). Consequently, compared to that in the United States, the relative level of hourly productivity dropped in 1950 by a few points for France and Japan to respectively roughly 40% and 20%, and more significantly for the United Kingdom to 65%.

From 1950 to 1973, annual productivity growth (per employee and per hour) was very strong in Japan (7.5% and 7.4% respectively) and in France (4.7% and 5.2% respectively), firm in the United Kingdom (2.5% and 2.8%) and slower in the United States (2.3% and 2.5%). Productivity growth in Japan and the United States can be attributed mainly to TFP growth (for more than 70%), while the rise in capital deepening accounts for about 50% of productivity growth in France and in the United Kingdom. In the United States, the contribution of capital deepening remains quite unchanged. France and Japan thus appear to be rapidly catching up with the other two countries, more via TFP growth than by the spread of more capital intensive production techniques for Japan and the contrary for France. The productivity gap between the four countries can also be explained by changes in the countries' economic structure. For example, it is mainly during this period that the share of agriculture in French GDP declined significantly, more in line with that in the United Kingdom and the United States. Card and Freeman (2002) estimated that between 1960 and 1979, the impact on labour productivity of a change in the weight of employment in the agricultural sector amounted to roughly 0.5 point each year in France, against 0.1 point in the United Kingdom and the United States. Consequently, relative to that in the United States, the level of hourly productivity in France and Japan improved markedly to stand at respectively 70% and 50% in 1973; the level in France was identical to that recorded in the United Kingdom, which had posted slower productivity growth.

During the short period between the two oil shocks (1973-1980), annual productivity growth (per employee and per hour) slowed significantly in the four countries. It was the highest in France (2.6% and 3.4% respectively) and in Japan (2.6% and 3.2%), intermediate in the United Kingdom (0.9% and 2.1%) and very low in the United States (0.2% and 0.7%). Cette and Bourles (2007) have shown that the

slowdown in US productivity growth over this sub-period can largely (for two thirds) be explained by a rise in the employment rate and a smaller decline in working hours, both variables showing strongly diminishing returns. These factors have negatively impacted TFP growth. In Japan and the United Kingdom, the slowdown in productivity growth is also mainly linked to the slowdown in TFP growth, the contribution of capital deepening being almost unchanged for the United Kingdom or even higher in Japan compared with the previous sub-period. In France, the slowdown in productivity growth is mainly linked to the slowdown in capital deepening. In Japan, given that the contribution of capital deepening actually increased, the slowdown in productivity was less pronounced than the slowdown in TFP. France showed the highest TFP gains. Consequently, relative to that in the United States, the level of hourly productivity in France improved markedly to stand at around 85% in 1980 and more slightly in Japan and the United Kingdom to roughly 55% and 75%.

Lastly, during the sub-period 1980-2006, productivity slowed down again in France and Japan but accelerated in the United States. In the United Kingdom, only growth in productivity per employee increased, hourly productivity growth remaining unchanged. The ranking of countries according to average productivity gains varies depending on the indicator used: if one considers productivity per employee, productivity gains are the highest in the United Kingdom (2.0%), followed by Japan (1.8%), the United States (1.6%) and France (1.5%), while in terms of hourly productivity, they are the highest in Japan (2.4%), equivalent in France and the United Kingdom (2.2%) and smaller in the United States (1.6%). The slowdown in productivity can be attributed to the slowdown in both capital deepening and TFP growth in France, and only capital deepening in Japan. In the United Kingdom, TFP accelerated and capital deepening slowed down. The acceleration in US productivity is linked to an acceleration of the TFP. France continued to post the highest TFP gains, in the wake of the trend apparent since World War II. Consequently, the level of hourly productivity relative to that in the United States increased markedly in France to become equivalent to the one in the United States, and to a lesser extent in Japan and in the United Kingdom to roughly 70% and 90%.

3. Looking more closely at productivity growth in the 1980-2006 period

We first focus in sub-section 3.1 on the changes in productivity growth over the shorter sub-periods 1980-1990, 1990-1995, 1995-2000 and 2000-2006, then in sub-section 3.2 on the specific contribution to growth of the rapid and pervasive diffusion of information and communication technologies (ICT) in these sub-periods..

3.1. Changes in productivity growth

Our estimates of employee and hourly productivity growth and the contributions of non-ICT and ICT capital deepening and TFP for the four countries are presented by sub-periods in Table 8, and in the corresponding Graph 4 (in a comparable format as Table 4 and Graph 3 in the previous Section).

During sub-period 1980-1990, employee productivity growth was the highest in Japan with an average rate of 2.7% per year, followed by France and the United Kingdom with a rate close to 2%, and the lowest in the United States with a rate of 1.4% (still, a much higher average rate than the 0.2% recorded in the previous sub-period 1973-1980). Hourly productivity growth was much faster in both Japan and France (close to 3%) than in the United Kingdom (2.0%) and the United States (1.4%). The growth differential in hourly productivity between Japan and France on the one hand and the United Kingdom and the United States on the other can be accounted for by a higher TFP (1.6% and 1.8 as against 1.0% and 0.8%), as well as a greater contribution of capital deepening (1.6% and 1.2 as against 0.9% and 0.6%).

Over the sub-period 1990-1995, productivity growth differed widely across countries. In the United States, it was slightly slower than in the previous sub-period 1980-1990, corresponding to slower TFP growth. In the United Kingdom, employee and hourly productivity growth increased sharply (by 0.7 and 0.8 respectively). A large share of this acceleration (0.6 point) is due to a higher contribution of capital deepening. In France, employee and hourly productivity growth slowed considerably, both by about 1 point. This slowdown reflects almost entirely that in TFP growth (which declined by 1.0%), and probably

corresponds to a strong cyclical component given the decrease in GDP growth. The French characteristic of strong TFP growth as compared to the United Kingdom and the United States thus disappeared from the early 1990s. In Japan, employee and hourly productivity growth also slowed down considerably, by 1.8 point and 0.7 point respectively. As in France this slowdown appears to be mostly related to a corresponding slowdown in TFP growth.

Table 8
Average annual labour productivity growth (in %) and contributions (in percentage points), in France, the United Kingdom and the United States
scope: Economy as a whole

A - France

	1980-2006	1980-1990	1990-1995	1995-2000	2000-2006
GDP	2.1	2.4	1.2	2.8	1.7
Productivity per employee [a]	1.5	2.1	1.2	1.2	1.1
Productivity per hour [b]	2.2	2.9	1.8	1.9	1.6
Capital intensity per hour [c]	0.9	1.2	1.0	0.5	0.7
Non-ICT capital intensity per hour	*0.6*	*0.9*	*0.8*	*0.2*	*0.4*
ICT capital intensity per hour	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*
TFP [d]	1.3	1.7	0.8	1.4	0.9

A - Japan

	1980-2006	1980-1990	1990-1995	1995-2000	2000-2006
GDP	2.3	3.9	1.5	1.0	1.5
Productivity per employee [a]	1.8	2.7	0.9	1.0	1.6
Productivity per hour [b]	2.4	3.1	2.4	1.7	2.0
Capital intensity per hour [c]	1.4	1.6	1.9	1.5	0.8
Non-ICT capital intensity per hour	*1.0*	*0.3*	*1.5*	*0.9*	*0.5*
ICT capital intensity per hour	*0.4*	*0.3*	*0.4*	*0.6*	*0.3*
TFP [d]	1.0	1.5	0.5	0.2	1.2

C – United-Kingdom

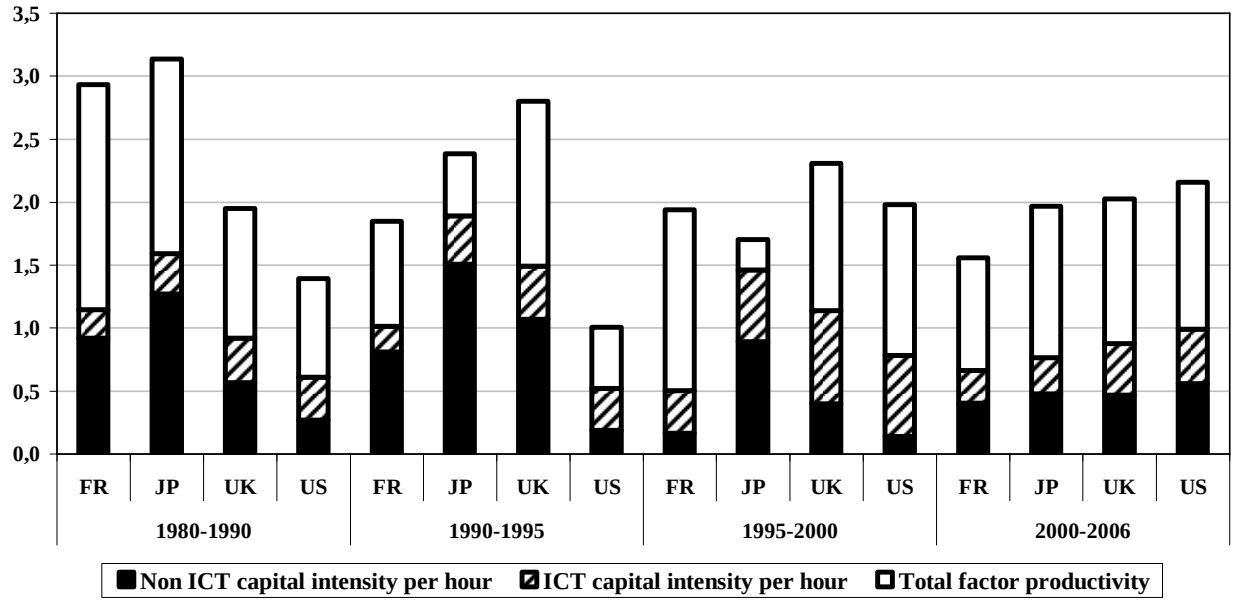
	1980-2006	1980-1990	1990-1995	1995-2000	2000-2006
GDP	2.5	2.6	1.7	3.2	2.5
Productivity per employee [a]	2.0	1.9	2.5	1.9	1.6
Productivity per hour [b]	2.2	2.0	2.8	2.3	2.0
Capital intensity per hour [c]	1.1	1.0	1.5	1.1	0.9
Non-ICT capital intensity per hour	*0.6*	*0.6*	*1.1*	*0.4*	*0.5*
ICT capital intensity per hour	*0.5*	*0.4*	*0.4*	*0.7*	*0.4*
TFP [d]	1.1	1.0	1.3	1.2	1.1

D – United States

	1980-2006	1980-1990	1990-1995	1995-2000	2000-2006
GDP	3.1	3.3	2.5	4.1	2.4
Productivity per employee [a]	1.6	1.4	1.2	2.0	1.9
Productivity per hour [b]	1.6	1.4	1.0	2.0	2.2
Capital intensity per hour [c]	0.7	0.6	0.5	0.8	1.0
Non-ICT capital intensity per hour	*0.3*	*0.3*	*0.2*	*0.1*	*0.6*
ICT capital intensity per hour	*0.4*	*0.3*	*0.3*	*0.7*	*0.4*
TFP [d]	0.9	0.8	0.5	1.2	1.2

[d] = [b]-[c]
Source: Authors' calculation, see Box and Appendix.

Graph 4
Average annual hourly labour productivity growth (in %) and contributions in France, Japan, the United Kingdom and the United States - 1890-2006 - in percentage points
Scope : Economy as a whole



Source: Authors' calculation, see Box and Appendix.

The sub-period 1995-2000 is characterised by a significant rise in GDP growth in France, the United Kingdom and the United States (by roughly 1.5 point per year) but not in Japan where GDP growth slowed even further than previously (by 0.5 point). Like in the first half of the 1990s, productivity growth posted contrasted developments in the four countries. In the United Kingdom, productivity growth slowed by approximately 0.5 point per year, which can be attributed to a lower contribution of non-ICT capital deepening and of TFP. In France, productivity growth remained stable, the acceleration in TFP being offset by a slowdown in non-ICT capital deepening. The latter development could partly result from the implementation of policies designed to enhance the labour intensity of growth, in particular reducing working time and cutting social contributions targeted at low skilled workers (see Cette, 2004). In the United States, productivity growth gained approximately 1 point due to faster TFP growth. According to Gordon (2005), the fact that productivity accelerates in the United States but slows in Europe can be attributed to several factors, among which a predominance of ICT producing industries, public policies that promote entrepreneurship and a better synergy between public research, private research and the financing of innovation. Finally in Japan, since TFP growth remained stable, the slowdown in productivity is entirely due to a slowdown in non ICT capital deepening.

Lastly, the sub-period 2000-2006 is characterised by a slight slowdown in productivity (by approximately 0.4 point) in France and the United-Kingdom and a slight acceleration in productivity in the two other countries (by 0.2 point). The factors underlying these figures are diverse: a smaller contribution of ICT capital deepening in the United Kingdom, of TFP in France, a higher contribution of capital deepening in the United States and of TFP in Japan.

To conclude as regard the catching-up process, productivity per employee and per hour figures show that the growth was higher in the United States over the period 1995-2006 than in three others countries (only over the period 2000-2006 for the United Kingdom for productivity per hour) therefore the catching-up process stopped. We can explain this result by a higher acceleration compared to previous period in capital intensity (ICT and non-ICT) and in TFP (mainly due to ICT producer industries see below). Therefore the success of the United States productivity growth relatively to the three other countries over the period 1995-2006 is not only due to ICT diffusion, even though it is an important element.

3.2. The contribution of ICTs to productivity

A large number of studies (see Cette, Mairesse and Kocoglu 2002 and 2005 for a review of the literature) are devoted to the issue of the contribution of ICTs to the growth of GDP and productivity per employee. These studies conclude that ICTs have had a positive and significant impact over the past two decades. According to the growth accounting framework, this contribution occurs via two channels:

- Substitution effects linked to the accumulation of ICT capital (capital deepening). The latter stems from the continuous and rapid improvements in the productive performances of ICT investments, which lead to a sharp fall in the price of ICT relative to other capital goods and labour. For example, in the United States, the price of computer hardware posted an average annual decrease of 15% over the 1980-2004 period, while the GDP price deflator rose by 3% per year;

- TFP gains predominantly linked to the technological progress achieved in the ICT-producing industries and to the productivity gains in the ICT-using industries via spillover effects.

According to Cette, Mairesse and Kocoglu (2000, 2002), the weight attached to these two effects in growth accounting analyses depends to a large extent on the methodological choices made regarding the volume-price breakdown of ICT investment series in value terms. Schematically, the more the volume-price breakdown takes into account the improvements in ICT performances, via hedonic methods for example, the greater the contribution of capital deepening to productivity gains and the lower that of TFP, and vice-versa. In this analysis, given the lack of sectoral data, we will only look at the first effect.

We will start by briefly presenting the importance of ICT investments in the four countries (a) then the changes in ICT prices (b) and finally the contribution of ICT capital deepening to productivity growth (c).

a) ICT investments

Measuring ICT investment raises a number of methodological problems (see Cette, Mairesse and Kocoglu, 2000, for a detailed review). The main problems concern the availability and reliability of the long series, the breakdown between investment and intermediate consumption of ICT expenditure, the assessment of expenditure on the personalisation of prepackaged software and the development of custom software. The solutions provided by the national accounting systems differ from one country to the next as well as over time. For example, at the time the base 2000 was set up and following the OECD recommendations on the international harmonisation of the methods for measuring software GFCF, INSEE, the French National Statistics Institute, changed the breakdown of software expenditure between intermediate consumption and investment on the one hand, and its method for measuring custom software expenditure on the other. As a result, the amount of software investment in 1999 rose from EUR 11 billion under base 1995 to EUR 21 billion under base 2000, i.e. a 90% increase. In the United Kingdom, Chesson and Chamberlin (2006) showed that the methodological change in the measurement of software investment, particularly own account software, led to a rise in the share of total software investment in GDP from 0.8% to 1.8% in 1999. These methodological aspects also concern, but to a lesser extent, the measure of hardware. Therefore, the result presented here, with the newest statistics, show differences compared to previous studies.

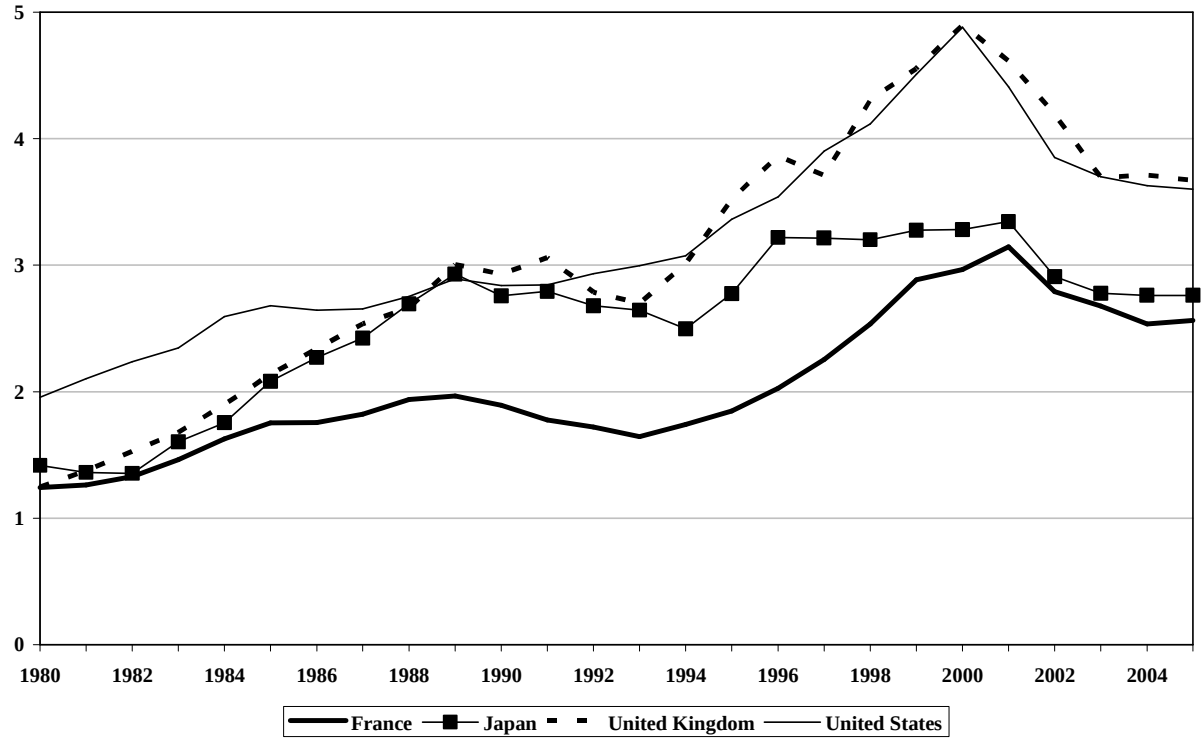
Graph 5 shows the ICT investment ratio in the four countries under review. The following observations can be made:

- In 1980, ICT investment in the United States accounted for 2% of GDP against only 1.2% in France and the United Kingdom and 1.4% in Japan. In 2005, the share of ICT investment in GDP increased by a factor of two in the four countries;

- The ICT investment ratio displayed a relatively similar trend across the four countries. It accelerated from 1980 to 1985 and from 1995 to 2000, and remained stable or even declined from 1985 to 1994 and from 2001 to 2005;

- The bursting of the Internet bubble in 2000-2001 led to a substantial drop in the ICT investment ratio in the four countries. In the United Kingdom and the United States, the most affected countries, the ICT investment ratio slid from 4.9% to 3.6% between 2000 and 2005. This drop may be interpreted as a correction of the over-accumulation of ICT capital at the end of the 1990s, which had been partly fuelled by the financial market euphoria and the fears surrounding the Y2K bug.

Graph 5
ICT investment ratio (in %) in France, the United Kingdom, the United States and Japan- 1980-2005
scope: Economy as a whole



Sources: See Box.

b) <u>Changes in ICT prices</u>

As mentioned above, one of the main difficulties – and consequently uncertainties – of measuring the contribution of ICT to growth lies in the volume-price breakdown of investment expenditure. National accounting systems are gradually adopting hedonic methods to account for the rapid improvements in ICT performance. However, there are substantial differences in the way in which countries apply these methods (see Cette, Mairesse and Kocoglu, 2000, 2002). To prevent these differences from affecting our comparison, we chose to use as price index for each one of the three ICT products in France, Japan and the United Kingdom the price index that corresponded to an equivalent price trend for this product relative to the GDP price deflator used in the US national accounts. This method, also used by Colecchia and Shreyer (2001), implies that the price trend for each ICT product (excl. general inflation) is the same in all four countries.

Table 9 presents ICT price trends by sub-period in the four countries under review. The price of ICT is calculated as the weighted average of the price trends of computer hardware, software and communication equipment. The differences between countries stem from (i) differences in GDP price deflator trends and (ii) the breakdown of ICT investments between computer hardware, communication equipment and software. Computer hardware experienced the largest price fall relative to other ICT

products[5]. Over the 1980-2005 period, the average annual decline in ICT prices was of the same magnitude in the United Kingdom and the United States (roughly 5%). In Japan, prices decreased faster on account of the greater weight of computer hardware[6] and the smaller increase in GDP prices (0.7% compared to 3%). In France, prices decreased to a lesser degree (4% per year on average) because of the smaller weight of computer hardware and a larger increase in GDP prices. The most pronounced price drops were recorded in the 1995-2000 period; they ranged from 6.7% per year in France to 9.5% per year in Japan.

Table 9
Average annual ICT price growth (in %) in France, the United Kingdom, the United States and Japan- 1980-2005

	1980-2005	1980-1990	1990-1995	1995-2000	2000-2005
France	-4.0	-1.5	-5.8	-6.7	-4.5
Japan	-5.7	-3.5	-6.6	-9.5	-5.3
United Kingdom	-5.2	-3.5	-5.9	-8.2	-4.8
United States	-4.8	-3.5	-5.4	-7.4	-4.3

Sources and calculations: See Box.

c) The contribution of ICTs to productivity growth

The contribution of ICTs to labour productivity growth is shown in Table 8 and Graph 4. The main findings are the following:

- Over the entire 1980-2006 period, the contribution of ICT capital to productivity growth per hour is greater as that of non-ICT capital in the United States and lower in the other three countries;

- The contribution of ICT capital to average annual productivity growth (per employee or per hour) ranges, depending on the period, from 0.3 point to 0.7 point in the United States and the United Kingdom, from 0.3 point to 0.6 point in Japan and finally from 0.2 point to 0.3 point in France. The ICT investment ratio is roughly the same in the United Kingdom and the United States (see Graph 5), and the contribution of ICTs to productivity growth is also the same. This important ICT impact can be attributed to the significantly fast average annual growth rate of the capital stock due to the fast decrease in the global ICT price index (see Table 9). Compared to previous studies, the result that contribution to productivity growth of ICT capital deepening was the same in the United Kingdom and in the United States can be attributed to the improvement in the measure of ICT investment in the United Kingdom. The new figure for ICT investment in the United Kingdom takes better account of the importance of the services sector, and particularly financial services, in the UK economy. In France and Japan, the investment ratio is low and the annual growth rate of ICT capital per capita is slightly lower than in the United States;

- In all four countries, the contribution of ICT capital is the largest over the 1995-2000 period. It amounts to roughly 0.7 point in the United States and the United Kingdom, 0,6 point in Japan and 0.3 point in France. At the same time, the contribution of other equipment and buildings declined considerably in France, Japan and the United Kingdom compared with the previous period (about 1 point). The faster decline in ICT prices over this period (Table 9) seems to have accelerated the substitution between ICT capital and non-ICT capital;

- Lastly, after 2000, the fall in ICT investment is directly reflected in the contribution of ICT capital to productivity growth. This effect is the less pronounced in France (-0.1 point and -0,2 to -0,3 point in the other three countries). Except in Japan, this period was also marked by an increase in the contribution

[5] Between 1980 and 2005, computer hardware prices in the United States posted an average annual decline of 15%, compared with roughly 1% for software and communication equipment.

[6] On average over the 1980-2005 period, computer hardware accounted for 25% of ICT investment in France, against 40% in the United Kingdom, 28% in the United States and 45% in Japan.

of non-ICT capital deepening to productivity growth in all countries, particularly in the United States (about 0.4 point).

On the whole, the results presented here are in keeping with those obtained in the most recent international comparative studies, such as those by Jorgenson and Kuong (2005), the OECD (2003) or Van Ark and Piatkowski (2004), presented in Table 10. As regards France, they are consistent with our previous assessments (see Cette, Mairesse and Kocoglu, 2005b). For the United Kingdom, they are not directly comparable with the recent assessments by Oulton and Srinivasan (2005) on the market economy; although their profile is similar, the contribution of ICTs is lower than in our estimates. According to these authors, the contribution of ICT capital deepening accounts for 0.7 point of the average annual increase in hourly labour productivity between 1979 and 1990 and for 1 point over the 1990-2000 period. As regards the United States, our results are, considering the scope difference, very close to those of Jorgenson, Ho and Stiroh (2006, 2008), and Oliner, Sichel and Stiroh (2007) presented in Table 11. As regards Japan, our estimates are close to those of Jorgenson and Kuong (2005) for the 1990s but show a higher decrease in the contribution of ICT capital deepening to growth during the period 2000-2006.

Table 10

Average annual ICT contribution to the growth of GDP or labour productivity (in %) in France, United Kingdom, United States and Japan

Results of some international comparisons

	Jorgenson and Kuong (2005)*			**OECD (2003)***		**Van Ark and Piatkowski (2004)****	**Van Ark, O'Mahony and Timmer (2008)**
	1989-1995	**1995-2000**	**2000-2004**	**1990-1995**	**1995-2001**	**1995-2001**	**1995-2004**
France	0.2	0.4	0.4	0.2	0.3	0.3	0.5
Japan	0.3	0.8	0.6	0.3	0.6	na	na
United Kingdom	0.3	0.8	0.3	0.3	0.6	0.6	1.0
United States	0.5	1.0	0.6	0.5	0.9	0.7	0.8

* Contribution to GDP growth, ** Contribution to the growth of the labour productivity per employee.
Scope: Whole economy

Table 11

Average annual labour productivity growth (in %) and contributions (in percentage points)
In the United States

	Oliner Sichel and Stiroh (2007)*			**Jorgenson, Ho ans Stiroh (2008)****				
	1973-1995	**1995-2000**	**2000-2006**	**1959-2006**	**1959-1973**	**1973-1995**	**1995-2000**	**2000-2006**
Productivity per hour	1.47	2.51	2.86	2.14	2.82	1.49	2.70	2.50
Capital intensity per hour	0.76	1.11	0.85	1.14	1.40	0.85	1.51	1.26
Non ICT capital intensity per hour	*0.30*	*0.02*	*0.24*	*0.70*	*1.19*	*0.45*	*0.49*	*0.69*
ICT capital intensity per hour	*0.46*	*1.09*	*0.61*	*0.43*	*0.21*	*0.40*	*1.01*	*0.58*
TFP	0.71	1.40	2.01	0.75	1.14	0.39	1.00	0.92

* : non farm business sector
** : private economy

As mentioned above, national accountants are faced with a number of methodological problems when assessing ICT investment expenditure and establishing the volume-price breakdown. However, since national accountants have been following the recommendations of the OECD-Eurostat Software Task Force, the measure of investment in software is more homogenous across countries. For example, the share of software in total ICT investment is comparable in the four countries (between 50% and 60%), while the previous data indicated that this share was twice as high in the United States as that in France (see Cette, Mairesse and Kocoglu 2002a). Although this international harmonisation has made international comparisons of ICT contributions to productivity growth more robust, progress still needs to be made with regard to the measurement of own account software and the quality effect.

4. Conclusion

The results of our study, despite being extremely aggregated and global, are nevertheless rich and difficult to summarise. The most striking findings are the following. The past 120 years have been characterised by very important economic growth and productivity gains in the four countries under review, the remarkable catching-up of the United States by France, the fact that the United Kingdom has reached a par with the United States and France after a long relative decline, and the impressive catching-up of Japan which came to a stop in the 1990s.

At present, total factor productivity is very close in the countries under review except Japan, where it is still significantly lower. However, hourly labour productivity is slightly higher in France than in the United States and significantly lower in the United Kingdom, and even lower in Japan. Furthermore, productivity per employee is slightly lower in France than in the United States, much lower in the United Kingdom and even lower in Japan. These performances reflect the more or less contrasting developments during the various periods of the analysis, associated with varying contributions of capital deepening and the downward trend in working hours.

Between 1890 and 2006, the faster drop in working time accounts for roughly 25% of the differential in the growth of productivity per employee between France and the United States, and just about 5% of that between the United Kingdom and the United States. Similarly, over this same period, the lower contribution of capital deepening explains 15% of the differential in the growth of productivity per employee between France and the United States and almost 25% of that between the United Kingdom and the United States. The other growth factors included in the concept of total factor productivity account for 100% of France's catching-up with US labour productivity and for 40% of the decline in British labour productivity compared with the United States. These other growth factors (the decline in working hours and capital deepening being equal) would thus account for the almost three-fold increase in French labour productivity compared with the United Kingdom, i.e. an average annual growth differential over 116 years of 1.0%.

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Appendix

The breakdown of the effects of TFP and capital deepening and the growth accounting approach[7]

Solow (1956, 1957) was one of the first to put forward the breakdown of the effects of TFP and capital deepening on GDP and the growth accounting approach. The following equations concern the breakdown in level and growth rate terms of GDP and productivity, but for reasons of simplicity, the commentary only covers the breakdown of growth. We assume that the production possibilities may be represented using a total production function with a total factor productivity TFP variable (or autonomous technical progress). Production (or output Y) can be written as:

$Y = TFP.\ F(K_j, L_i)$

where K_j and L_i represent respectively the volume of j-type capital and i-type labour (or inputs). Assuming that the production function is a Cobb-Douglas production function in linear log form and labour is homogeneous (which is the case in the present study), we obtain the following relation:

$y = tfp + \sum_j \alpha_j.k_j + \beta.l$ first difference: $\Delta y = \Delta\, tfp + \sum_j \alpha_j.\Delta k_j + \beta.\Delta l$

where y, k_j, l and tfp represent the logs of the volume of output, j-type capital, labour and TFP, where Δ is the first difference (or annual rate of change) and where α_j and β represent the elasticities of output with respect to the inputs K_j and L. We assume unit (constant) returns to scale: $\sum_j \alpha_j + \beta = 1$.

The growth rate of the economy can be written as the sum of the growth rate of each input weighted according to its production elasticity and the growth rate of TFP (or technical progress). Growth accounting can also be presented identically in terms of labour productivity accounting (assuming constant returns to scale), as follows:

$(y - l) = tfp + \sum_j \alpha_j.(k_j - l)$ first difference: $(\Delta y - \Delta l) = \Delta tfp + \sum_j \alpha_j.(\Delta k_j - \Delta l)$

where $\alpha_j\ (k_j - l)$ represents the contribution of j-type capital deepening to labour productivity.

In order to apply this breakdown, it is necessary to obtain estimates of production and its factors. In macroeconomic analyses, these data are available in national accounts. The sources used in this study are detailed in Box 1. It is also necessary to measure the elasticities of production with respect to inputs. In addition to the hypothesis of constant returns to scale, it is generally admitted that production factors are remunerated at their marginal productivity (at least over the medium to long term), which means that it is possible to estimate the factor elasticities on the basis of the share of their remuneration (cost) in total income (or total cost). Given that labour costs (wages and related social security contributions) represent roughly two thirds of income, it is assumed that $\sum_i \alpha_i = 0.3$ and therefore $\beta = 0.7$.

We assume that the capital K used in year t is the stock of capital installed at the end of year t-1.

TFP is measured as a residual: it measures the contribution to labour productivity that is not attributable to factor inputs. These types of breakdown are mainly descriptive. Although they do not provide any causal explanations, they are useful for making comparisons and explaining any differentials in productivity levels and growth rates between periods and countries.

In our study, the volume of labour L is written as L = N.H where N is the level of employment and H the average annual working time. The suggested breakdowns of productivity concern alternately productivity per employee or productivity per hour, and are conducted on the basis of the respective relations (where the contribution of TFP is identical):

$(y - n) = tfp + \sum_j \alpha_j.(k_j - n) + (1 - \sum_j \alpha_j).h$ first difference: $\Delta(y - n) = \Delta tfp + \sum_j \alpha_j.\Delta(k_j - n) + (1 - \sum_j \alpha_j).\Delta h$

$(y - l) = tfp + \sum_j \alpha_j.(k_j - l)$ first difference: $\Delta(y - l) = \Delta pgf + \sum_j \alpha_j.\Delta(k_j - l)$

[7] For a history of growth accounting and TFP ("the residual"), see Griliches (1996) and Maddison (2007).