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Information Technology and Productivity Growth Across Countries and Sectors

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The extraordinary success of the U.S. economy and the parallel growth slowdown of the large European countries and Japan in the 1990s bear a simple rationale. The United States has eventually benefited from the effective adoption of information technologies. The introduction of the newly installed IT capital has not instead enhanced aggregate capital accumulation and TFP growth in Europe and Japan. At least on impact, IT capital has mainly displaced existing capital and methods of production rather than supplementing them. The limited growth-enhancing effects from information technologies in countries other than the United States have occurred in the IT-producing sectors, while the IT-using industries have contributed the bulk of productivity gains in the United States.

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I. Information technology and productivity growth: the aggregate evidence

I.1 Aggregate productivity growth across countries

As nicely pointed out by Robert Gordon, the extraordinary productivity performance of the U.S. economy in the second half of the 1990s has been a reason of pride for the Americans and a source of envy for the citizens of the other Industrial countries. Few figures suffice to vividly document the extent of this phenomenon, both along a time series and a cross-sectional dimension.

INSERT TABLE 1 ABOUT HERE

As shown in Table 1, the growth rate of GDP per employed person in the U.S. economy reached 2.3% in 1996-2001. This marks a clear acceleration compared to the past, when the U.S. labor productivity growth rate stalled at about one per cent per year for more than twenty years (1.1% in 1990-95, 1.0% in 1973-90).

As apparent in column [1] of the same Table, to match the 1996-2001 productivity growth rate, one has to go backwards in time to 1950-73, the period recently dubbed by Angus Maddison as the ‘golden age of growth’. Yet, at that time, the U.S., Canada and the UK, with their growth rate of 2.4% per year, were the slowest growing economies in the G-7 group. Productivity growth in Germany, France and Italy was about twice as much as that in the Anglo-Saxon group of countries. Japan’s growth rate was more than three times bigger.

Reaching a growth rate of 2.3% per year in 1996-2001 makes instead the United States the economy with the fastest growing productivity in the G-7 group (see column [4] of Table 1). Nowadays, the large countries in Continental Europe (France, Germany and Italy) barely reach 1% per year, while the Japanese economy has been stagnating with productivity growth rates hovering around zero for years.

A concise measure of such time series and cross-country considerations is in column [5] of Table 1, where the changes in productivity growth rates between the most recent five-year period (1996-2001) and the first half of the decade (1990-95; 1991-95 for Germany) are contrasted. The U.S. exhibits a positive growth acceleration of +1.1 percentage points, while the other G-7 countries present negative figures, except for Canada (+0.2%). Italy and Japan stand out with an average growth deceleration of about one percentage point.

What is behind this sharp turnaround of growth performances? What can account for productivity growth changes in excess of two percentage points between Japan and Italy, on one side, and the USA on the other?

It is by now common wisdom to identify the diffusion of information technologies and their contributions to both capital deepening and TFP growth as a crucial factor for the growth revival in the U.S. economy. In their 2000 article in the *Journal of Economic Perspectives*, Stephen Oliner and Dan Sichel attributed a large fraction of the US growth resurgence of the second part of the 1990s to the enhanced capital accumulation and the acceleration in the pace of technical change enabled by the production and diffusion of information technologies. Almost in parallel, in their *Brookings Papers on Economic Activity* paper, Dale Jorgenson and Kevin Stiroh reached roughly similar conclusions using a slightly recombined set of national accounting data.

Although reaching firm conclusions as to the permanent nature of the productivity hike of the late 1990s remains debatable, few would object to indicating information technologies as an important engine of the recent developments of labor productivity growth in the U.S. economy. This holds in particular when the time series of productivity growth in the U.S. is taken in isolation. Whether the IT-based story maintains its explanatory power in a cross-country dimension as well is a less investigated issue, instead, to which the bulk of this chapter is devoted.

I.2 IT diffusion across countries

A first-hand presumption is that, as long as information technologies are the new engine of growth, the disappointing growth performances of the other OECD countries documented above should be associated to a delayed diffusion of information technologies in these economies. Has this been the case?

To answer this question, one can take a look at the available cross-country data on IT spending and investment. In fact, as information technologies spread across the economy, households, firms and the various tiers of government are supposed to spend more on IT goods and services, driving up the share of IT spending over GDP. A possibly important aspect of the IT revolution is the extent to which IT spending is divided between investment and consumption of services. In order for there to be large growth-enhancing effects from information technologies, their diffusion should also be associated to higher shares of IT equipment investment in total investment and GDP.

Data for IT spending - the total sales of hardware, software and related IT services, both external and internal to the firm, plus telecommunications – are reported in WITSA's Digital Planet (2002 Edition). In its studies, WITSA (World Information Technology and Services Alliance) - a private consortium of 48 IT industry associations – relies on the work of the International Data Corporation (IDC), a private consulting company specializing in the high-tech industries' research.

INSERT TABLE 2 ABOUT HERE

WITSA data span over the whole of the Internet decade so far (1992-2001). Table 2 reports the GDP shares of IT spending for the G-7 countries throughout the decade, as well their period variation between the most recent years and the first part of the 1990s.

In 1992, right after the Internet protocol was signed, IT spending was clearly higher in countries such as the US, the UK, and Canada than in other non-English-speaking OECD countries. IT spending was already 7-7.5% of GDP in the Anglo-Saxon countries, with France, Germany and Japan spending about 5.5% of their GDP and Italy 3.8%. Such differences are not surprising. After all, Robert Solow's famous saying that computers could be seen everywhere in the United States (although not in the productivity statistics) appeared in the *New York Review of Books* already in 1987. That in 1992 the American citizens were spending a relatively larger fraction of their income in IT goods and services than Italians or Germans cannot come as a big surprise.

About ten years after, however, cross-country differences in IT spending appear to have leveled off to a large extent among six of the G-7, Italy being the only country lagging behind. In 2001, the UK and Japan devoted 9.7% of their respective GDP to the purchase of IT goods and services. This is about one percentage point more than France and Canada, two points more than the US and Germany and five points more than Italy. Hence, as of 2001, the Americans are no longer comparatively bigger IT spenders than other people in the G-7 group of countries.

All in all, if one takes the period changes between the first and the second half of the 1990s (as is done in column [6]), not much is seen of the alleged IT revolution in the United States. The U.S. nominal share of spending in IT goods and services has in fact barely changed over the decade (+0.6 percentage points since 1992). In parallel, the IT spending shares of the other G-7 countries rose substantially, by an extent varying between 1.4 and 3.2 percentage points (respectively, Italy and Japan).

INSERT TABLE 3 ABOUT HERE

Some elements indicating that the catching up of the other OECD and, in particular, of the large countries in Europe may still be incomplete come from the IT investment data in Table 3. While the IT equipment share in non-residential gross fixed capital formation was already much higher, by ten through fifteen percentage points, in the U.S. than in other OECD countries in the first half of the decade, this gap has even widened over time. The share of IT equipment investment over total investment has in fact gone up by nearly 4 percentage points in the United States, by about 2.5 percentage points in France, Japan and the UK, and by less than 1.5 percentage points in Germany and Italy.

Similar differences would emerge as well when looking at the GDP shares of IT investment. The major cut in IT investment outlays which has followed the 2000 IT investment overhang in the U.S. was not fully matched by analogous declines in Europe, though. This has brought about a (possibly temporary) closing of the cross-country gaps in terms of IT investment GDP shares.

Altogether, there is some evidence of some catching up of the other OECD countries (mostly in terms of IT spending) with respect to the United States. This is however not necessarily at odds with the widely accepted idea that the U.S. has been a front-running country as to the diffusion of IT in the last few years.

When interpreting the figures in Table 2 and 3, it should in fact be borne in mind that the spending and investment ratios reported there are denominated in current prices. Looking at current price shares is regarded as a safe accounting practice at times when existing statistical methods are undergoing major but unevenly paced reforms. This is why nominal shares are most frequently looked at.

It remains that a given amount of money may buy more IT goods and services in the US than elsewhere, hence partly invalidating the evidence of an ongoing catching up of the other OECD countries. Evidence has indeed accumulated, though, on the sharp decline of the quality-adjusted price of computers and computer-related goods in the USA. As reported by Oliner and Sichel, computer prices fell at rates close to 30% per year in 1995-99, while business investment in computers and peripheral equipment rose by more than fourfold in real terms over the same period of time.

The outright unavailability of cross-country comparable quality-adjusted price deflators for IT goods and services makes it impossible to precisely evaluate such claims for the other OECD countries. In the meanwhile, as long as appropriate IT deflator data are not produced by the various statistical offices, the possibility that a fraction of the apparent IT spending catching up (and overturn, in some case) of the other OECD countries with respect to the US in the second part of the 1990s is simply a statistical artifact should be at least seriously considered.

I.3 Has Solow’s productivity paradox fled the US and moved to Europe and Japan?

The data in Table 2 and 3 altogether imply that Europe’s and Japan’s catching-up in IT diffusion has been faster than most observers would have anticipated some time ago. The persisting growth gap suffered by European countries and Japan with respect to the US would thus appear *prima facie* not associated to sharply lower accumulation of information technology capital. Solow’s ‘productivity paradox’ on the lack of correlation between the increasingly high profile of computers in business and the anemic growth rate of productivity might have fled the United States to migrate to Europe and Japan.

There may be two possibly complementary reasons for the failure of the catch-up in IT spending to be reflected in high productivity growth outside the United States.

IT investment may be simply unproductive on impact and generate no additional output upfront. While – as emphasized by Paul David, Boyan Jovanovic and Jeremy Greenwood for the U.S. economy - the productivity gain may show up with a lag, when contrasted over the same time period productivity growth and IT investment data may exhibit no relation, if not a negative one.

The second possibility is that IT investment does have instead a positive growth effect, but other factors in the economy act in parallel to hamper aggregate economic growth. As a result, despite the growth acceleration triggered by IT investment, productivity growth may still lag behind these other countervailing negative effects.

The growth accounting methodology, pioneered by Solow in his "Technical change and the aggregate production function" - published in the *Review of Economics and Statistics* in 1957 - can be usefully employed to assess which of these two channels is relevant here. Before going through the available evidence to evaluate which of these possibilities is the most plausible rationale for the data, it is worth spending a few words describing how growth accounting works.

The growth contribution of IT capital in speeding up labor productivity growth can be singled out by decomposing the growth rates of total or per-capita output into their capital, labor and technical change components. Initially, starting with Solow, most authors found that growth was predominantly explained by technical change, *i.e.* the fraction of GDP growth unexplained by factor accumulation. In their 1967 paper in the *Review of Economic Studies*, Jorgenson and Zvi Griliches showed instead that allowing for changes in capital and labor quality may absorb the bulk of the (unexplained) residual growth within the (explained) factor accumulation component. The above quoted papers by Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) evaluate the role of information technologies in the U.S. economy within this framework of analysis.

Growth accounting exercises decompose GDP growth into its labor (hours worked), capital and total factor productivity (TFP) components. In turn, the contribution of capital accumulation to growth may be further attributed to three components (communications equipment, hardware and software) related to information technology, and a residual item, *i.e.* 'other capital'. This other term lumps together the various categories of non-IT productive capital. The decomposition of growth contributions by input, under the standard assumptions of constant returns to scale and perfect competition, is the following:

$$(1) \qquad g_q = (1 - s_K) g_l + s_{COM} g_{kCOM} + s_{HW} g_{kHW} + s_{SW} g_{kSW} + s_{OTK} g_{kOTK} + g_{TFP}$$

where s_C is the capital income share of capital good C (C= COM, HW, SW, OTK) averaged over time t and t-1; s_K is the capital share computed from national accounts; g_y is the growth rate of y, with $y = q, l, k_{COM}, k_{HW}, k_{SW}, k_{OTK}, TFP$, *i.e.* respectively output, total hours worked, capital in communication equipment, hardware, software, other (non-IT) capital and total factor productivity.

The g_{TFP} term represents the well known ‘Solow residual’ - a residual item aimed at measuring disembodied technical change. Its size is possibly affected by the a variety of assumptions necessary to compute it from actual data. In addition to constant returns and perfect competition, equation (1) as usually implemented may embody a correction for changes in the composition of the labor force, unobserved changes in utilization of factors other than labor, reallocation of inputs across uses and adjustment costs to changing inputs. If it does not, the TFP term is biased by the omission of these potentially important factors. This is why Edward F. Denison once called the Solow residual a ‘summary of our ignorance’.

The value added share of each capital good *k* (s_k) is computed, as in Robert Hall and Jorgenson’s “Tax policy and investment behavior” published in 1967 in the *American Economic Review*, as follows:

(2) $$s_k = (r + \delta_k - \dot{p}_k)\frac{P_k K}{PY}$$

i.e. the product of the gross rate of return on capital (the term in parentheses) and the capital-output ratio in nominal terms. In turn, *r* is the nominal market rate of return on investment, δ_k is the depreciation rate of good *k*, dotted p_k is the capital gain or loss on the possess of capital good *k,* and P_k equals the purchasing price of a new capital good (p_k being its log). The expression in parentheses times P_k is Jorgenson’s user cost of capital, *i.e.* the rental price charged if capital good *k* were to be rented for one period.

Equation (1) can be slightly rewritten to emphasize the decomposition of productivity growth per man hour into the capital deepening and TFP components suggested by the production function approach to productivity issues:

(3) $$g_q - g_l = s_{COM}(g_{kCOM} - g_l) + s_{HW}(g_{kHW} - g_l) + s_{SW}(g_{kSW} - g_l) + s_{OTK}(g_{kOTK} - g_l) + g_{TFP}$$

= capital deepening + TFP growth

The TFP term represents the shifts of the production function caused by technical change (or any other efficiency improvement) for any given level of the capital-labor ratio. The ‘capital deepening’ part, *i.e.* the first four terms on the right-hand side of (3), represents the shifts enabled by capital accumulation along a given production function. Each one of the four terms is the contribution (in per-worker terms) of a capital good to productivity growth. The contribution of IT capital to labor productivity growth is instead the sum of the first three terms on the right-hand side of (3).

Altogether, equation (1)-(3) usefully clarify that the growth contribution from IT capital goods may be high for three reasons: *(i)* fast capital accumulation, *(ii)* a high gross rate of return, *(iii)* a high capital-output ratio. This is important to point out, for it may well be the case that fast accumulation of IT capital does not result in a large growth contribution from IT capital as long as the rate of return on investment or the initial IT capital-output ratio are low in that country.

In Table 4, the results from one of such decompositions for five countries in the G-7 group (USA, France, Germany, Italy and UK) are reported. Such figures are derived from slightly rearranging the data contained in the report “ICT investment and growth accounts for the European Union, 1980-2000” written by Bart van Ark, Johanna Melka, Nanno Mulder, Marcel Timmer and Gerard Ypma on behalf of the European Commission, where the latest (as of July 2002) national accounting data and OECD estimates for IT investment are used. While the actual size of the growth effects of IT in other countries than the United States is still surrounded by large measurement error, the overall picture from the available aggregate data is not. Leaving aside the imperfect comparability with the data reported in Table 1 (labor productivity in Table 4 is GDP per man hour, while it was GDP per employed person in Table 1), the qualitative implications of the results in the table are similar to those obtained in other studies and do not crucially hinge on the specific implementation features of the exercise underlying this Table.

INSERT TABLE 4 ABOUT HERE

Table 4 reports the computed values of the growth contributions of IT and non-IT capital in per-man-hour terms and the growth of total factor productivity. These data are available for 1990-95, 1995-2000, as well as their period differences. In addition to that, the specific contribution of TFP growth in the IT producing sectors to the change in TFP growth rates is singled out as well. By adding up the growth contribution from IT capital ('IT capital deepening') and the growth contribution from the IT-producing sectors (those producing computers, telecommunications equipment and semiconductors), the overall contribution of information technologies to the growth rate of labor productivity can be calculated for the five countries in each time period.

Since the goal of this section is to address the question of why the US experienced accelerating growth rates while other OECD countries did not, the *changes* in such growth contributions only matter here. This is why the remarks below exclusively focus on the bolded numbers in column [3], [6], [9], [12] and [13] in Table 4.

The figures in Table 4 roughly confirm the Oliner-Sichel-Jorgenson-Stiroh result that the U.S. growth revival of the late 1990s was essentially an IT story. The overall growth contribution from information technologies is about equal to 0.8 percentage points per year – the sum of 0.3 percentage points from capital deepening and about 0.5 from IT-originated TFP growth. This is about eighty per cent of the acceleration in the U.S. productivity growth in the late 1990s. Notably, the growth contribution from non-IT capital to the productivity growth acceleration is instead close to zero.

In the four large European countries, the picture looks perhaps slightly rosier for France and the UK than for Germany and Italy. Yet the growth contributions from IT in such countries tend to convey a message common to all countries. It can be summarized in three main points.

First, in the face of no aggregate productivity acceleration or outright deceleration in the second half of the decade, the changes in the overall growth contributions from information technologies – inclusive of their capital deepening and TFP components - proved positive in all non-US countries. This varies between +0.45 percentage points in the UK to +0.11 percentage points in Germany, with France and Italy in between.

Second, this contribution did not originate so much from IT capital, but rather from the TFP gains enabled by IT production. While aggregate TFP growth sharply declined by a variable extent (between one half and one and a half percentage points) in Germany, Italy and the UK, changes in the growth contributions from TFP growth in the IT-producing sectors were moderately positive in all countries, in the interval between 0.1 and 0.2 percentage points.

Third, the decline or stalemate in aggregate labor productivity growth essentially originated from negative contributions from non-IT capital and non-IT TFP growth. The non-IT capital negative contribution was just mild (one tenth of a percentage point per year) in the UK and more pronounced (close to one half of a percentage point) in the other EU countries. The contribution to TFP growth from non-IT sectors was instead sharply negative (about -1.7 percentage points) for Germany and Italy in particular.

To sum up, the growth slowdown of the large European countries in the second half of the past decade bears a simple rationale. The introduction of the newly installed IT capital - while already bearing some productivity gains - has not enhanced aggregate capital accumulation and TFP growth. At least on impact, IT capital has mainly displaced existing capital and methods of production rather than supplementing them. On the total factor productivity side, though, the changes in the growth contributions from the European IT-producing sectors did not prove much smaller than those arising from their U.S. counterparts.

II. Information technology and productivity growth: sector evidence

In the previous section, the cross-country and time series evidence on productivity growth has been contrasted with the available data on IT spending and investment. This was done within a growth accounting framework to make sense of the claim that cross-country differences in aggregate growth may have some roots in cross-country differences in IT diffusion.

Another strand of literature has tackled these same issues looking at sector data. Exploring the evidence at the sector level is potentially very important to disentangle the relation between IT and growth. In fact, the diffusion of the IT revolution crucially hinges on the extent to which labor and total factor productivity gains in the innovating sectors extend to other sectors in the economy. If such gains remain confined to the few sectors where the innovations originate, the beneficial effects of information technology will likely die out as the source of technical change dries up.

Gordon has investigated the relation between technology and economic growth in the American economy in two important papers ("Does the New Economy measure up to the Great Inventions of the past?" in the same issue of the *Journal of Economic Perspectives* as Oliner and Sichel's paper; as well as in another still unpublished work: "Technology and economic performance in the American economy"). As forcefully argued there, the alleged spill-over effects from TFP growth in the IT-producing sectors to the rest of the U.S.

economy are indeed fairly small, at least once the influence of business-cycle fluctuations is accounted for.

In another paper, forthcoming in the *American Economic Review*, Stiroh has instead found a significant confirmation of the existence of trend breaks in the U.S. time series of productivity growth rates in the IT-using industries as well. These results obtain for labor productivity growth, starting from a classification of the U.S. industries in IT intensive and non-IT intensive. An industry is labeled ‘IT-intensive’ if its share of IT investment over total investment falls above the 50% threshold (the median) in the IT intensity sector ranking compiled by himself and Jorgenson in their previous study. By this criterion, both prominent services (‘Financial intermediation’, ‘Business services’, ‘Wholesale and retail trade’) and manufacturing (‘Machinery and equipment’ at large, ‘Printing and publishing’, ‘Wearing apparel, dressing and dying of furs’) sub-sectors are included in the list of the IT intensive sectors.

Stiroh’s methodology and results proved very influential and indeed shaped the format and the scope of the few studies on the same topic undertaken for other OECD countries. In two recent OECD-originated working papers, van Ark and Dirk Pilat and Frank C. Lee decomposed aggregate productivity growth into its sector determinants, grouping sectors in IT producers and users, and - within these categories - in IT manufacturing and IT services, for many European and OECD countries.

A contentious issue here is the extent to which a sector classification based on the U.S. IT intensity can extend to other countries as well. In a recent unpublished paper “’Changing gear’ productivity, ICT and service industries: Europe and the United states”, van Ark, Robert Inklaar and Robert McGuckin appropriately raise this question, reporting national accounting data for the shares of IT investment over total investment at the sector level for the USA, France, Germany, the Netherlands and the UK in the same Table. Using their data, one can compute the correlation between the rankings of the same thirty sectors for the USA and Germany. This is, reassuringly, high (0.75). Moreover, if one were to draw a list of IT intensive sectors in Germany based on the U.S. ranking indicated in that Table, it appears that twelve of the actual fifteen IT-intensive sectors would be captured. The classification of sectors into one category or another cannot but remain a contentious issue, anyway, as testified by the variability in the IT intensity classifications presented in the various studies conducted so far.

Bearing these caveats in mind, it is anyway worth considering a decomposition of the aggregate productivity growth rates into their sector components, with special emphasis on their IT-producing and IT-using components. The contributions of IT-producing and IT-using industries to aggregate productivity growth can be easily evaluated decomposing the contribution of each sector to productivity growth (measured in terms of each sector's value added per employed person) in a 'pure productivity' and a 'reallocation' effect, as follows:

$$(4) \qquad g_q - g_l = \sum_j s_{VA}^j (g_q^j - g_l^j) + \sum_j \left(s_{VA}^j - s_l^j\right) g_l^j$$

The symbols in (4) are as above, except that the superscript *j* refers to sectors, and s_{VA}^j and s_l^j are the shares of sector *j* in aggregate value added at current prices and total employment. Equation (4) says that any given sector may contribute to aggregate productivity growth in two ways. If $s_{VA}^j = s_l^j$ (*i.e.* if the level of labor productivity in sector *j* is the same as the economy-wide average), then aggregate labor productivity growth is simply the weighted average of each sector's productivity growth, with the fixed weights equal to the nominal value added shares in some base (usually initial) year. If $s_{VA}^j \neq s_l^j$, though, labor re-allocation across sectors does also have an impact on aggregate productivity, holding other things constant. This re-allocation effect may positively contribute to aggregate growth if sector j is expanding (respectively, contracting) employment and its level of labor productivity is higher (respectively, lower) than the economy-wide average.

Hence, the contribution of sector *j* to aggregate productivity growth is computed as the sum of these two effects as decomposed on the right-hand side of (4). Hence in addition to the pure growth and re-allocation effects, the overall contributions from IT production and IT use to the change of productivity growth in the second half of the 1990s can be easily computed. The results from such decompositions are reported in Table 5.

INSERT TABLE 5 ABOUT HERE

Table 5 shows that about 0.9 points (out of a total acceleration equal to 1.1 percentage points) are accounted for by IT-producing and IT-using sectors. IT-using sectors, in particular, account for the bulk of such acceleration (0.8 percentage points), with a bare 0.1 percentage points left to IT-producing industries.

This is quite different from the evidence available in the same Table for the other G-7 countries, where the (definitely smaller) contribution of information technologies to the changes in productivity growth between the two halves of the past decade mostly came from IT production, not from IT use. Significantly, IT usage appears to have even contributed negatively to (the change in) aggregate productivity growth in Canada, Italy and Japan. This finding is entirely consistent with the findings of the previous section where the evidence from aggregate data was analyzed. In that section, the large EU countries exhibited very small growth contributions of capital deepening to growth.

Another notable feature of the results in Table 5 concerns the relative weights of the pure productivity vs. reallocation effects. While the pure productivity effects indeed represent the bulk of the growth contributions from information technology, reallocation effects are usually positive as well for most countries. In the U.S. economy, about one fourth (0.2 percentage points) of the total contribution of IT to the acceleration of productivity growth occurs through reallocation effects. This implies that both IT-producing and, mostly, IT-using industries while expanding their employment levels featured relatively high labor productivity levels to start with.

Such reallocation effects are similarly rather high in the other Anglo-Saxon countries, such as Canada and the UK, while they tend to be more limited in the large countries in Continental Europe, and practically nil in Japan.

Table 6 completes the picture in Table 5 by presenting details as to the disaggregation of the two components of pure productivity effects, *i.e.* the sector growth rates of labor productivity and the sector value added shares at the beginning of the second half of the decade (in 1995).

INSERT TABLE 6 ABOUT HERE

Data in Table 6 unambiguously show that IT-producing industries grew faster than the rest of the economy everywhere. In the USA, however, the growth rate of labor productivity in these industries, although high, remained constant over time. Hence, in spite of their relatively larger value added share (7%, which compares with a G-7 average of about 5%), the ‘pure productivity’ contribution to the growth acceleration of the late 1990s of IT-producing sectors is small.

The opposite applies to the other G-7 countries, where sharply increasing growth rates more than offset the relatively small value added shares of these industries, producing a comparatively large ‘pure productivity’ effect in these countries.

The large 'pure productivity' effect of IT-using industries in the U.S. economy and not elsewhere is explained by the same token. In the USA, IT-using sectors represent about one fourth of total value added in 1995 and their growth acceleration was close to three percentage points per year (from 1.3% in 1990-95 to 4.2% in 1995-2000). In the other G-7 countries, the very small or even negative contributions to the changes in productivity growth arise from very low or negative growth rates, which compound with either low (Italy) or high (UK, Japan) value added shares in generating the summary figures reported in Table 5.

Sector data help fill in the picture of the relation between IT and productivity growth. Strikingly enough, the picture originating from the data for the U.S. economy and the other economies in the G-7 could hardly be more diverse.

Available evidence unambiguously shows that the extraordinary labor productivity performance of the United States found its roots in particularly fast industry-specific productivity growth in the IT-using sectors, as well as in a more extensive reallocation of labor from low to high productivity sectors. Whether the spectacular growth rates enjoyed in some services sub-sectors in the U.S. economy are signaling something more permanent than favorable cyclical circumstances remains to be seen and is perhaps the biggest question mark confronted by the U.S. policy-makers in the next few years.

The (limited) contribution of information technology to productivity growth in the other G-7 countries almost exclusively originated instead from fast growth rates in IT-producing industries, with little role for labor reallocation across sectors. The main policy problem for these other economies is how to raise the productivity effects of IT investments.

III. Conclusions

It is hard to escape the conclusion that, despite the catching-up in IT diffusion experienced by Europe and Japan in recent years, information technologies have so far delivered little aggregate productivity gains outside the United States.

The other G-7 countries have possibly suffered from the same disease that hit the U.S. economy in the productivity slowdown period, when a novel all-purpose technology had to be effectively adopted, with prevailing displacement of existing capital and not much aggregate productivity gains upfront. This motivated Solow's productivity paradox in the first instance. Now it looks as though if this same paradox had moved to Europe and possibly Japan.

Whether the current productivity growth *impasse* outside the U.S. economy is the transitional side effect of an ongoing learning process (as was seemingly the case for the USA a few years ago) or instead a symptom of more worrisome technological or institutional backwardness unlikely to be bridged soon remains to be seen.

The idea that the implementation of new technologies entails possibly high costs of adjustment, with adverse effects on the stock market and productivity growth for some time until the new invention has been absorbed, is a potentially useful hypothesis for Europe and Japan in the same fashion as it was for the USA some time ago. This is unfortunately still hard to evaluate, for the upsurge in IT spending is still too recent, and must be necessarily left to future research in this area.

Further readings

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Table 1: Aggregate growth of labor productivity in the G-7, 1950-2001

	[1]	[2]	[3]	[4]	[5]
	Growth rate of GDP per employed person				Δ (growth rate of GDP per employed person)
(% points)	**1950-73**	**1973-90**	**1990-95**	**1996-2001**	**1996-2001 vs. 1990-95**
USA	2.4	1.0	1.2	2.3	+1.1
Canada	2.4	0.7	1.2	1.4	+0.2
UK	2.4	1.6	1.9	1.5	-0.4
France	4.6	2.1	1.3	1.1	-0.2
Germany (*)	4.7	1.5	1.4	1.0	-0.4
Italy	4.8	2.0	2.1	0.7	-1.4
Japan	7.5	2.7	1.2	0.0	-1.2

Labor productivity is measured as aggregate GDP divided by total employment.

(*) 1990-95 data for Germany in fact refer to 1991-95.

Source: my calculations from data in Maddison (2001, p.349) for column [1] and [2]; the OECD Economic Outlook database for column [3] through [5].

Table 2: IT spending in the G-7
GDP shares, current prices

	[1]	[2]	[3]	[4]	[5]	[6]
(% points)	**1992**	**1995**	**1998**	**2000**	**2001**	**(1996-2001) - (1992-95)**
USA	7.49	7.53	8.19	8.09	7.88	+0.54
Canada	6.84	7.00	8.36	8.41	8.66	+1.56
UK	7.21	7.59	7.87	9.15	9.69	+1.51
France	5.81	5.83	6.88	8.73	9.05	+2.40
Germany	5.40	5.12	6.16	7.86	7.94	+2.06
Italy	3.68	4.13	4.48	5.72	5.74	+1.40
Japan	5.65	5.29	7.97	8.31	9.62	+3.16

Source: my calculations from data in WITSA, Digital Planet, 2002, vol.3

Table 3: IT investment in the G-7
Shares of non-residential gross fixed capital formation, current prices

	[1]	[2]	[3]
(% points)	**1990-95**	**1995-2000**	**[2] – [1]**
USA	24.3	28.0	+3.7
Canada	15.0	19.2	+4.2
UK	12.9	15.4	+2.5
France	10.1	12.7	+2.6
Germany	13.7	14.7	+1.1
Italy	14.1	15.4	+1.3
Japan	12.4	14.9	+2.5

Primary source: data in OECD, Measuring the information economy, Paris, 2002

Table 4: Decomposition of aggregate labor productivity growth in five OECD countries

	Growth of GDP per hour worked			Growth contribution from: **Capital deepening**						Growth contribution from: **TFP growth**			
				IT capital per man hour			**Non-IT capital per man hour**			**Total**			of which: **IT production**
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]
	1990-95	1995-00	[2] - [1]	1990-95	1995-00	[5] - [4]	1990-95	1995-00	[8] - [7]	1990-95	1995-00	[11] - [10]	
USA	1.20	2.21	**+1.01**	0.30	0.61	**+0.31**	0.15	0.20	**+0.05**	0.74	1.39	**+0.65**	**+0.48**
France	1.38	1.35	**-0.03**	0.16	0.24	**+0.08**	0.74	0.22	**-0.52**	0.48	0.89	**+0.41**	**+0.21**
Germany	2.90	1.80	**-1.11**	0.27	0.27	**+0.00**	0.88	0.36	**-0.52**	1.73	1.14	**-0.59**	**+0.11**
Italy	3.00	1.13	**-1.87**	0.24	0.30	**+0.06**	0.80	0.37	**-0.43**	1.96	0.46	**-1.50**	**+0.15**
UK	2.70	1.80	**-0.90**	0.25	0.50	**+0.25**	0.53	0.42	**-0.11**	1.88	0.84	**-1.04**	**+0.20**

Labor productivity is measured as aggregate GDP divided by the number of total hours worked.

Primary source: data in B. van Ark, J. Melka, N. Mulder, M. Timmer and G. Ypma, "ICT investment and growth accounts for the European Union: 1980-2000", Final Report for the DG Economics and Finance of the European Commission, mimeo, September 2002

Table 5: Growth contributions of IT-producing and IT-using sectors in the G-7

			Productivity growth contributions from:								
		Economy	IT producers *and* IT users			IT producers			IT users		
		Productivity growth	Total	Pure productivity	Reallocation	Total	Pure productivity	Reallocation	Total	Pure productivity	Reallocation
USA	1990-95	1.2	0.80	0.75	0.06	0.48	0.47	0.02	0.32	0.28	0.04
	1995-00	2.3	1.72	1.45	0.26	0.59	0.49	0.10	1.13	0.97	0.16
	(1995-00)-(1990-95)	**+1.1**	**+0.92**	**+0.71**	**+0.20**	**+0.11**	**+0.02**	**+0.08**	**+0.81**	**+0.69**	**+0.12**
Canada	1990-95	1.2	0.63	0.58	0.05	0.17	0.13	0.03	0.46	0.45	0.01
	1995-00	1.4	0.37	0.26	0.11	0.23	0.22	0.01	0.14	0.04	0.09
	(1995-00)-(1990-95)	**+0.2**	**-0.26**	**-0.22**	**+0.05**	**+0.06**	**+0.09**	**-0.02**	**-0.32**	**-0.41**	**+0.08**
UK	1990-95	1.9	0.83	0.82	0.01	0.47	0.48	-0.01	0.36	0.35	0.01
	1995-00	1.5	1.02	0.84	0.18	0.60	0.53	0.07	0.42	0.31	0.11
	(1995-00)-(1990-95)	**-0.4**	**+0.19**	**+0.01**	**+0.18**	**+0.13**	**+0.05**	**+0.08**	**+0.06**	**-0.03**	**+0.09**
France	1990-95	1.3	0.26	0.28	-0.02	0.17	0.18	-0.01	0.09	0.10	-0.01
	1995-00	1.1	0.56	0.52	0.04	0.41	0.41	0.01	0.15	0.12	0.03
	(1995-00)-(1990-95)	**-0.2**	**+0.30**	**+0.24**	**+0.06**	**+0.24**	**+0.23**	**+0.02**	**+0.06**	**+0.02**	**+0.04**
Germany	1990-95	1.4	0.63	0.69	-0.06	0.35	0.40	-0.04	0.28	0.29	-0.01
	1995-00	1.0	0.95	0.93	0.02	0.61	0.64	-0.03	0.34	0.29	0.05
	(1995-00)-(1990-95)	**-0.4**	**+0.32**	**+0.24**	**+0.08**	**+0.26**	**+0.24**	**+0.02**	**+0.06**	**-0.01**	**+0.06**
Italy	1990-95	2.1	0.34	0.39	-0.05	0.10	0.10	0.00	0.24	0.29	-0.05
	1995-00	0.7	0.53	0.50	0.03	0.39	0.37	0.02	0.14	0.13	0.01
	(1995-00)-(1990-95)	**-1.4**	**+0.18**	**+0.11**	**+0.07**	**+0.29**	**+0.27**	**+0.02**	**-0.11**	**-0.17**	**+0.06**
Japan	1990-95	1.2	0.73	0.66	0.07	0.49	0.46	0.02	0.24	0.20	0.04
	1995-00	0.0	1.02	0.94	0.08	0.85	0.81	0.03	0.17	0.13	0.05
	(1995-00)-(1990-95)	**-1.2**	**+0.29**	**+0.28**	**+0.01**	**+0.36**	**+0.35**	**+0.01**	**-0.07**	**-0.07**	**+0.00**

Source: my calculations from data in B. van Ark, R. Inklaar and R. McGuckin,, "'Changing gear' productivity, ICT and service industries: Europe and the United States", mimeo, May 2002. Totals may not add up due to rounding

Table 6: Sector growth of labor productivities and sector value added shares in the G-7

	Economy			ICT-producing sectors				ICT-using sectors			
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	1990-95	1995-2000	[2]-[1]	1990-95	1995-2000	[5]-[4]	Value added share, 1995	1990-95	1995-2000	[9]-[8]	Value added share, 1995
USA	1.2	2.3	+1.1	7.0	7.0	+0.0	0.070	1.3	4.2	+2.9	0.230
Canada	1.2	1.4	+0.2	3.2	5.2	+2.0	0.043	2.2	0.2	-2.0	0.206
UK	1.9	1.5	-0.4	8.4	9.0	+0.6	0.059	1.6	1.4	-0.2	0.222
France	1.3	1.1	-0.2	3.6	8.2	+4.6	0.049	0.5	0.6	+0.1	0.193
Germany	1.4	1.0	-0.4	7.3	13.0	+5.7	0.049	1.4	1.4	+0.0	0.206
Italy	2.1	0.7	-1.4	2.3	6.9	+4.6	0.054	1.9	0.9	-1.0	0.141
Japan	1.2	0.0	-1.2	7.7	13.8	+6.1	0.059	0.9	0.6	-0.3	0.213

Source: my calculations from data in B. van Ark, R. Inklaar and R. McGuckin,, "'Changing gear' productivity, ICT and service industries: Europe and the United States", mimeo, May 2002