THE SPREAD OF ICT AND PRODUCTIVITY GROWTH
IS EUROPE REALLY LAGGING BEHIND IN THE NEW ECONOMY?

(edited by Stefano Scarpetta)

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INTRODUCTION AND OVERVIEW

Over the past decade, the economic performance of some OECD countries, most notably the United States, has renewed the interest of analysts and policy makers in what drives economic growth and on how policy can eventually support it. Indeed, a number of "stylised" facts about economic growth have increasingly been challenged by events in the 1990s. For example, macroeconomists once largely agreed about the hypothesis of convergence in output per capita and productivity levels, at least among OECD countries that share common technologies, have intense inter-country trade and substantial foreign direct investment. But OECD countries have shown significant growth divergence over the 1990s, with some affluent countries pulling ahead of the others. Along the same lines, economists have struggled for many years to find a rationale for the so-called *productivity paradox* (generally attributed to Robert Solow). Namely, why, when we are confronted by rapid changes in the quality and variety of high tech products in our day-to-day lives, do the macro data show an inexorable slowing down in total factor productivity (a proxy for technological progress)? Yet, in the 1990s, a number of countries, including the United States – the one that was already at the world productivity frontier in many industries -- showed clear signs of a pick up in multifactor productivity growth rates. In addition, the experience of the 1980s in a number of European countries gave rise to the idea that expanding the employment base could only be achieved at the expense of labour productivity growth, since unemployment and inactivity were largely

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concentrated amongst the low skilled. Again, the 1990s have challenged this view by showing that strong productivity growth can be accompanied by sustained employment growth: e.g. the United Stated and Ireland experienced very low unemployment rates with high and growing labour productivity growth rates, in the second half of the decade.

Recent studies seem to agree that the observed changes in growth patterns in some countries are largely the result of the information and communication technology (ICT) revolution. In particular, it is argued that countries that have developed an ICT-producing industry, and/or where other industries have been quick in adopting highly productive ICT equipment, have been able to shift to higher output and productivity growth paths. In this respect, the United States and some smaller countries (e.g. Australia, Ireland) have benefited the most from this ICT revolution, while most large European economies are still lagging behind. In some circles this has been explained by the fact that "old institutions" have somehow slowed down the spread of ICT in Europe: e.g. rigidities in product, labour and financial markets have all reduced incentives to rapidly shift to ICT and to adjust production processes accordingly.

The economic slowdown of the past two years has added additional elements to the discussion about the ICT revolution. It has certainly laid to rest one myth -- the end of the business cycle due to the spread of ICT. Two characteristics of ICT are generally thought to have an impact on business cycles. First, the short life of most ICT equipment might flatten investment cycles. Second, faster and broader communication amongst producers, on the one hand, and between producers and consumers, on the other hand, might improve the matching between demand and supply. Neither factor, has been able, at least so far, to prevent the OECD economies from experiencing cyclical fluctuations, although the last recession has been one of the mildest of the post-war history. However, the fundamental issue is whether, behind cyclical patterns, there has been any structural shift at least in some countries and, if so, whether this shift has been encouraged (or discouraged) by policy and institutional settings and reforms therein.

This study utilises harmonised macro and sectoral data for OECD, a unique cross-country dataset developed for the OECD Growth Project with firm turnover and related measures at the sectoral-level, and establishment level micro data for the U.S. and German manufacturing sectors. These various data allow us to examine recent growth trends and analyse the link between ICT investment and productivity at the macro, sectoral and micro levels. In particular, we use aggregate data to assess whether or not there is evidence of growing disparities and what is driving them. This, in turn, enables us to better focus our research by identifying specific areas of the economy (sectors and markets) and specific institutional and policy settings that require further investigation. We use the firm-turnover measures and related decompositions of industry-level productivity dynamics to explore the role of flexibility and adaptability in growth and productivity. Finally, we use establishment-level data to examine how individual businesses are are dealing with ICT with a focus on the role of market experimentation as evidenced by wage, productivity, and workforce differences across businesses.

This information allows us to address a number of questions. What factors explain differences in output and productivity performance across OECD countries? What roles do the ICT-producing industries and ICT-driven capital deepening play in explaining the different growth patterns of countries? Is there a relationship between innovation intensity (e.g. R&D) and the spread of ICT? Does the adoption of ICT require organisational changes and/or changes in the composition of inputs? What is the contribution of new firms to overall productivity growth in general and in ICT-related sectors? Do ICT-industries show stronger firm and employment turnover rates? In this respect, is there any relationship between the spread of ICT and institutional features of the product and labour markets? For example, do stringent regulations on start-ups (as well as those affecting incumbents) affect the diffusion of ICT? Do differences in labour market policy and institutions explain different patterns of adoption of new technologies?

We begin our analysis (**Chapter 1**) by reviewing recent aggregate growth trends and decompose them into the main driving forces using a standard growth accounting technique. Albeit simple in theory, this task is difficult in practice. First, there are differences in the way countries treat statistical problems related to the measurement of output in some service sectors, and quality changes in information technology products. Second, business cycles have been largely unsynchronised across OECD countries over the past decade, and this makes it difficult to compare growth patterns internationally. Our study relies largely on cyclically adjusted series and, whenever possible, on harmonised price deflators for ICT equipment.

Macro data clearly point to widening disparities in growth performance across the OECD countries, even using cyclically-adjusted series. These disparities are related to differences in labour utilisation rather than to widening differences in labour productivity growth rates: i.e. higher growth rates in output per capita observed in a number of countries have been accompanied by improvements in the utilisation of labour, while sluggish employment in others (mainly in continental Europe) have not been fully compensated by higher labour productivity growth, thereby leading to a further slowdown in output growth.

There are also some new factors behind the observed disparities in growth performance across the OECD countries. In particular, multifactor productivity (MFP), a proxy for technological change, accelerated in a number of OECD countries, most notably in the United States and Canada, but also in some small economies (e.g. Australia, Ireland). The acceleration of MFP growth seems to have started initially as a pure 'disembodied' phenomenon (i.e. the productivity acceleration of the ICT-producing industry), consistent with the idea of a slow diffusion of a new general-purpose technology. As the ICT revolution progressed, intensive ICT-using industries increasingly contributed to overall productivity growth (although data limitations about the users of ICT by industry make this inference difficult). The slow diffusion hypothesis is also consistent with the fact that MFP growth accelerated somewhat later in other OECD countries that did not have a sizeable ICT-producing industry.

Why have some countries, including some small European ones, been able to develop an ICT-producing industry and, even more importantly, quickly adopt the IC technology? To address this question, in **Chapter 2** we go beyond aggregate data and look at the sectoral evolution of the OECD economies. We focus on the role of firm dynamics (the entry, expansion and exit of firms in each market) for productivity growth and adoption of technologies. Our results indicate that aggregate productivity patterns are largely the result of within-industry and even within-firm performance in most countries. This is not to say that some industries (both producers and users of ICT) have had stronger than average productivity growth over the past decade, and have made a major contribution to overall productivity growth in manufacturing and some service sectors. In turn, this strong productivity growth of ICT-related industries has also been driven by the entry of high performing new firms, while in other, more mature, industries the contribution of new firms has been more varied across countries.

Our sectoral analysis also reveals important cross-country differences. The U.S. economy seems to be better able to acquire comparative advantage in rapidly growing ICT market segments than most of its trading partners. The U.S. also has experienced a more widespread productivity acceleration of ICT-user industries, while the only notable acceleration in Europe has occurred in the finance sector. At the micro level, there seems to be a different degree of "market experimentation" in the United States compared with Europe, even if aggregate firm turnover rates are similar. In particular, the distinguishing features of firms' behaviour in the US markets are: *i*) a smaller (especially relative to industry average) size of entering firms; *ii*) a lower (albeit with greater variability) level of labour productivity of entrants relative to the average incumbent; and *iii*) a much stronger (employment) expansion of successful entrants in the initial years. Put in another way, our findings suggest that in the U.S. new firms tend to be smaller (relative to average incumbent) and less productive when compared with their European counterparts, but, if successful, they also tend to grow much more rapidly.

The analysis in **Chapter 3** is based on confidential micro establishment level micro data from the U.S. and Germany. We find evidence suggesting U.S. manufacturing establishments experiment with different ways of conducting business to a greater extent than their German counterparts. There is greater experimentation amongst young businesses and there is greater experimentation among businesses actively changing their technology. This experimentation is evidenced in systematic differences in the dispersion in productivity and in the related dispersion in key choices like skill mix and the role of Internet access. The evidence also indicates the mean impact of adopting new technology greater in U.S. than in Germany. Putting the pieces together suggests that U.S. businesses choose a higher mean, higher variance strategy in adopting new technology.

The sectoral and micro evidence we find reinforces our belief that cross-country differences in recent growth patterns may, at least partially, be related to differences in underlying market and institutional framework conditions. In **Chapter 4** we draw on economic theory to conceptually establish which institutional and policy factors are most likely to bear some responsibility in influencing innovation and adoption of new technologies by incumbent firms as well as the degree of market experimentation of both new entrepreneurs and existing firms. We see that product market competition affects the share of firms willing to undertake risky innovative investments. In a related manner, labour market regulations may be such that it becomes costlier up front to partake in the innovative activity. This can occur either because it is difficult or expensive to adjust the labour force to match the new technology, or because it is expensive to increase or decrease the labour force to adjust output following the uncertain outcome of the innovative gamble. Further, factor market regulations may restrict the degree to which firms are able to experiment in finding the best combination of technology, organisational structure, and relationship with customers and suppliers.

Although there is a consensus that increased product market competition and market-friendly institutional settings are likely to have positive effects on innovation and the adoption of new technologies, there is no agreement on their empirical relevance. **Chapter 5** checks some of the predictions of the theoretical analysis by looking at the comparative experience of the OECD countries in terms of sectoral multifactor productivity and the intensity of innovative activity (as proxied by R&D intensity). To date, the empirical evidence on the linkages between product market competition and productivity and innovation is limited due to a lack of adequate indicators of the intensity of competition, especially in a cross-country context. Commonly used indicators of competition (such as mark-ups or concentration indexes) are typically endogenous to productivity and innovation and it is often difficult to find suitable instruments. In addition, these indicators are likely to be non-monotonic with respect to common notions of competition and, in any event, do not have a direct link to policy or regulations, making it difficult to draw clear policy conclusions from their use. In light of these problems, we take a different approach. Namely, since the degree of competition in the product market and the adaptability of labour markets are not directly measurable, we use some of their possible policy determinants as proxies, e.g. regulatory provisions. This is made possible by a novel set of quantitative indicators of cross-country differences in the stringency of the product and labour market regulatory environments in OECD economies.

Our results suggest that stringent regulatory settings in product and labour markets may help explain cross-country differences in innovation activity and technology adoption, thus providing an interpretation for the growth patterns discussed in the first three chapters of our study. It should be noted, however, that the impact of regulations and institutions on productivity performance and innovation seems to depend on certain market and technology conditions, as well as on specific firm characteristics. In particular, the burden of strict product market regulations on productivity seems to be greater the further a given country/industry is from the technology frontier. That is, strict regulation hinders the adoption of existing technologies, possibly because it reduces competitive pressures or technology spillovers, and restricts the entry of new high-tech firms. In addition, strict product market regulations have a significant negative impact on the process of innovation itself. Thus, given the strong impact of R&D on productivity, there is also an indirect channel whereby strict product market regulations may reduce the scope for productivity enhancement.

The effect of high hiring and firing costs (proxied by the strictness of employment protection legislation, EPL) on productivity and innovation is less clear cut, and largely depends on the institutional system in which firms operate and the type of technology used in the sector. Firms facing high hiring and firing costs will tend to rely more on the internal labour market (e.g., training) than on the external one if they have to adjust the workforce to exploit a new technology. However, if they cannot rely on an institutional device to tackle possible free-riding problems (e.g., in un-coordinated regimes), then investing in internal labour market is risky, because other firms may poach on the pool of trained workers. Thus, when institutional settings do not allow wages or internal training to offset high hiring and firing costs, then the latter may lead to sub-optimal adjustments of the workforce to technology changes and lower productivity performance. Consistent with this view, we find that strict EPL has a negative impact on innovation in countries lacking co-ordination, while we find no significant impact of labour market flexibility in co-ordinated countries (or even a negative impact in some industries).

Where do these findings leave us with respect to our initial questions as to the existence of a structural shift in the growth patterns in some countries and the possible role of policy and institutions in influencing this shift? We can argue that the observed growing disparities in growth patterns across the OECD countries are due to a combination of "traditional" and "new" economy factors. Therefore, a combination of traditional and new therapies may be required for those countries, including most large European economies that are lagging behind in terms of output and productivity growth. The traditional part of the story largely refers to the inability of some countries to employ certain groups in the labour force, namely the low skilled. This has been the subject of a vast literature and policy prescriptions to overcome this pathology have been formulated by many academic researchers and international institutions. The good news is that the recent experience of certain countries suggests that it is possible to widen the employment base without necessarily facing deterioration in productivity performance. It may be argued that this is because of the spread of ICT that has enhanced labour productivity potentials even amongst the low skilled segments of the workforce. The spread of ICT has been, however, very different across countries and this has also contributed to widening growth disparities. Moreover, in certain industrial relations regimes, innovation and adoption of new technologies seem to be negatively affected by the stringency of certain regulations in the labour market, creating a possible synergy between labour market reforms, the spread of ICT and ultimately improvements in employment and output.

In the paper we also provide evidence that strict regulations in the product market, by reducing competitive pressures, have a negative impact on innovation and adoption of new technologies, including ICT. In particular, anti-competitive regulations seem to hamper productivity growth, and the effect is stronger in those industries where countries have accumulated significant technology gaps (possibly including ICT industries). In turn, these gaps are also explained by the effects of strict product and labour market regulations on the process of innovation that, among the high-tech industries, seem to be more negative in industries with multiple technological trajectories. To the extent to which important domains of the ICT industry are dominated by the frequent changes in the leading technology (e.g. in the software industry), these results may help to explain why some European countries, while enjoying leading positions in industries with cumulative technologies (such as aircrafts or motor vehicles) have been slow in moving into the ICT industry.

The micro evidence reported in the paper offers additional elements in our discussion of a growth-enhancing policy setting. Our results seem to suggest that certain institutional and regulatory settings may reduce the degree of *market experimentation* by firms. This, in turn, could lower the speed with which a country shifts to a new technology, thereby offering an interpretation to the observed differences in innovation and adoption across the Atlantic. For example, low administrative costs of start-ups and not unduly strict regulations on labour adjustments in the United States, may stimulate potential entrepreneurs to start on a small scale, test the market and, if successful with their business plan, expand rapidly to reach the minimum efficient scale. In contrast, higher entry and adjustment costs in Europe may stimulate a pre-market selection of business plans with less market experimentation. In addition, the more market-based financial system in the United States compared with Europe may lead to a lower risk aversion to project financing, with greater financing possibilities for entrepreneurs with small or innovative projects, often characterised by limited cash flows and lack of collateral. On the basis of available data, it is difficult for us to conclude that greater market experimentation is always good for economic growth. On the one hand, greater experimentation may strengthen innovation in new areas and quicken adoption of new technologies. On the other hand, however, it may lead to excessive dynamics, with 'stepping on toes' and business stealing also producing negative externalities. Nevertheless, in a period (like the present) of rapid diffusion of a new general-purpose technology (ICT), greater experimentation may allow new ideas and forms of production to emerge more rapidly. Moreover, if ICT equipment also fosters innovation activity in other areas, then having a lead in its development may generate important synergies, with additional positive effects for the economy as a whole. These are amongst the research issues that may be worth developing in future studies.

I. WHAT IS THE ROLE OF ICT IN SHAPING RECENT GROWTH PATTERNS IN THE UNITED STATES AND OTHER OECD COUNTRIES? - SOME AGGREGATE EVIDENCE

This chapter presents some evidence on aggregate economic patterns in the OECD countries and on the role of the information and communication technology (ICT). Recent papers from the U.S. suggest that ICT has played an important role in driving the better performance of the economy, especially in the second half of the 1990s, and some suggest that it will continue to boost potential output over the medium term. More sceptical reports from European countries either deny the link between ICT and growth or show that they have not yet materialised. This chapter reviews cross-country evidence for several indicators of aggregate economic growth: real GDP (the usual summary measure of economic activity); GDP per capita (an indicator of the average economic welfare of the population); labour productivity; and multifactor productivity (a pointer to, among other things, technological progress). Next, indicators of the production and use of ICT show how its importance varies over time and across OECD countries. Finally, the chapter concludes with an indication of how ICT impacts on the observed aggregate growth patterns.

1.1 Some stylised facts about GDP growth and its main drivers

To set the stage for the remainder of this chapter, and indeed this report, we need to confront our opinions and hunches on the 'new economy' with the aggregate evidence on economic performance in recent years relative to historical patterns. Before starting our discussion on the observed growth patterns across the OECD countries, it is important to recall how difficult it is to do such comparisons. Indeed, the coverage and depth of analysis in all this report is constrained by the availability, accuracy and international comparability of economic statistics at the different levels of the analysis (macro, sectoral and micro).

Despite continuous efforts to improve the quality and international comparability of time series of outputs, inputs and productivity, a number of measurement issues still arise at the aggregate and especially at the disaggregated levels. Two general issues that affect international comparisons of output measures are: i) the independence of output from input measures; and ii) the use of chain and fixed-weighted indices. The first issue is important especially for those industries that mainly comprise non-market producers (such as health or education), where output volume series are often based on the extrapolation of input measures, generating a downward bias within each country.[2] Moreover, annual chain-weighted indices are used in a small number of OECD countries instead of fixed base years for the construction of time series of outputs, inputs and productivity. Annual chain-weighted indices minimise the substitution bias implicit in fixed-weight price and volume indices that occurs in periods of rapid change of relative prices and quantities or over long time periods. Finally, the method to construct price indices of computers and peripheral equipment varies between OECD countries (see Box 1.1).

2. The extent of the underestimation is difficult to determine, although BLS suggests that the order of magnitude is unlikely to be very large (Dean, 1999).

This paper uses data provided by the national authorities and included in the Analytical Data Base (ADB) of the OECD which takes into account changes to the new SNA. Adjustments were necessary to improve international comparability, especially with respect to the way in which changes in the quality of ICT is taken into account (see Box 1.1).[3] Notwithstanding the efforts made, statements about relative growth performance, in particular at the sectoral level, have to be read with these caveats in mind, and results should be interpreted with the necessary care.

Box 1.1. **Price indices for ICT goods**

One element that is particularly important for our analysis is the treatment of price indices of information technology products, in particular computers. The significant quality improvements associated with technological advances in ICT have to be taken into account in the construction of ICT price indices. The use of hedonic deflators is generally considered as the best way to address this problem, and number of OECD countries use them to deflate output in the computer industry.[4] In the case of the United States, hedonic deflation methods are applied to most components of ICT investment. Other countries (e.g. Canada, Japan, France) have recently introduced some hedonic adjustment for the measurement of real computer investment and sometimes base their deflators on the US ones. Other countries make no adjustment for quality changes in ICT investment.

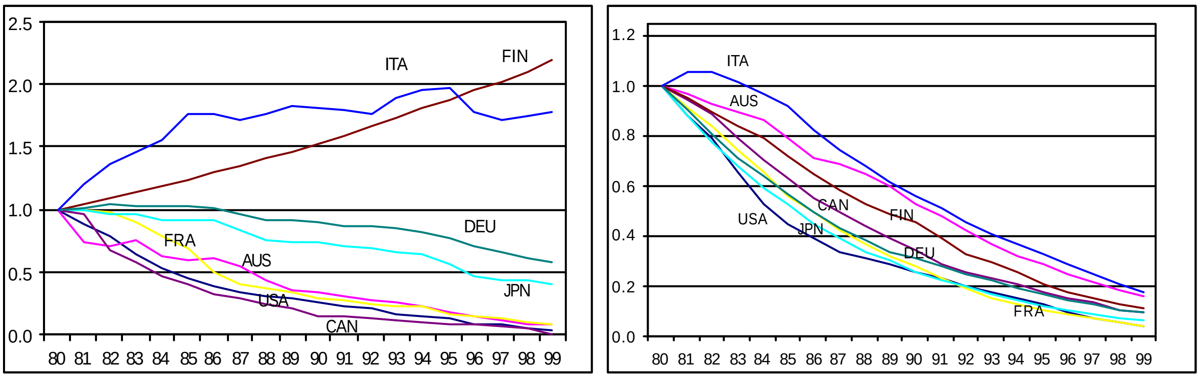
Any international comparison of ICT cannot overlook this problem but, at the same time, the harmonisation of deflators is not an easy task, not least because there are differences in industrial specialisation; i.e. only few countries produce computers or semi-conductors, many only produce peripheral equipment. Bearing this caveat in mind, our analysis uses "harmonised" price indices for ICT products to control for some of the international differences in deflation methods that might affect the comparability of the results. The "harmonised" series assumes that price ratios between ICT and non-ICT products have the same time patterns across countries, with the United States as the benchmark. For more details on this approach see Schreyer (2000). The Figure below shows the actual and harmonised price deflators for computers used in this study for the 8 countries for which details on different types of capital are available.

3 Details are discussed in Scarpetta et al. (2000)

4. Hedonic deflators are not the only measurement problem for the ICT manufacturing sector. The correct measurement of input prices for these industries is also quite complicated, and demands detailed input-output tables as well as hedonic deflators for certain inputs.

Current and harmonised price indexes for computers

Price indexes for computers **Estimated "harmonised" price indexes**



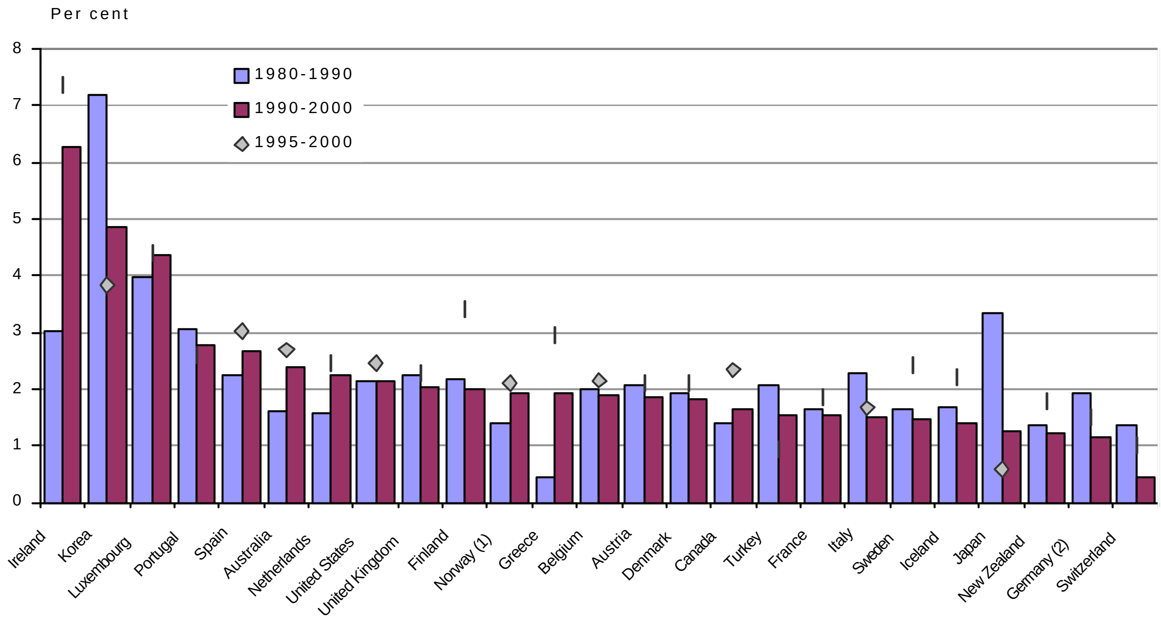
Source: Colecchia, 2001

A final issue that is important in an international comparison of growth performance in the short to medium term is that cross-country differences in output growth rates and levels may reflect differences in cyclical positions as well as underlying differences in performance (see e.g. Gordon, 2000, 2002). This problem was particularly relevant in the 1990s when business cycles were largely unsynchronised across OECD countries. In order to account for differences in the cyclical position of countries, we largely rely on *trend series* as opposed to actual series. Trend series have been estimated using an extended version of the Hodrick-Prescott filter (Hodrick and Prescott, 1997) where the well-known end-of-sample problem is minimised by prolonging the time series out of sample using OECD medium term projections. Given the assumptions included in the OECD projections, this can be considered as a prudent approach, insofar as it underestimates sharp deviations from the historical pattern in the neighbourhood of the end of the sample. This is particularly important at present, since the significant slowdown in the U.S. economy in the past two years has raised concerns as to the sustainability of the growth patterns of the late 1990s in the U.S. over the medium term.

Bearing these caveats in mind, our first pass at the data is to look at the development of GDP per capita over time to see whether there is any evidence of shifts in the growth path of OECD countries owing to increased penetration of ICT throughout the economy. Figure 1 suggests that, for the OECD area as a whole, trend GDP per capita growth rates slowed down in the 1990s compared with the previous decade. However, there has been a fairly widespread pick up in growth in the second half of the decade (with the exception of Korea, Japan and Turkey). This aggregate pattern, however, hides persistent differences across countries. Amongst the G-7, Canada and to a lesser extent the United States were able to reverse the slowdown in growth performance observed since the early 1970s, while the other countries experienced declining growth (particularly Japan and Italy). Outside the G-7, however, several smaller OECD countries also were able to reverse the slowdown in GDP per capita growth. It is noticeable that disparities in growth performance were particularly marked within Europe, with most of the large countries experiencing a significant slowdown in GDP per capita growth and some (mainly small) economies showing acceleration in growth.

Figure 1. **Growth of GDP per capita in the OECD area over the past two decades**

Average annual rates of change, cyclically adjusted series



1. Including offshore activities.

2.1991-2000 instead of 1990-2000.

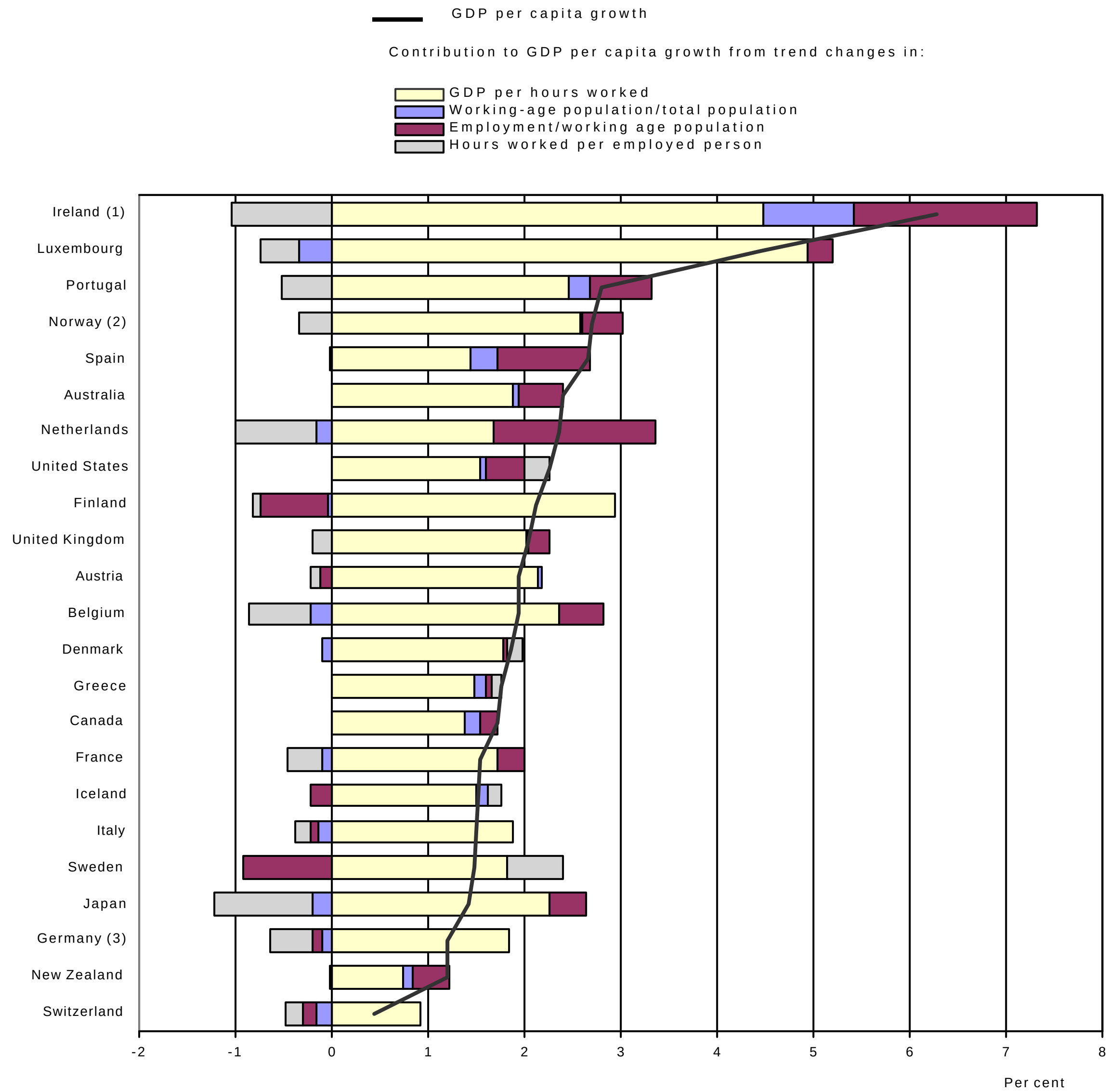
Labour utilisation and productivity lay behind widening growth disparities

From an accounting point of view, aggregate GDP per capita growth can be decomposed into four elements:

- Changes in the ratio of persons of working-age (15–64 years) to the total population;
- Changes in the ratio of employed persons to the working-age population, *i.e.* the employment rate;
- Changes in the number of working hours per person employed;
- Changes in GDP per hour worked.

Figure 2 presents a breakdown of growth of GDP per capita in these components for most OECD countries over the period 1990-2000.

Figure 2. **Growth in trend GDP per capita and its components, 1990-2000**



Coefficient of variation:

	GDP per capita		GDP per hours worked	
	1980-1990[4]	1990-2000[5]	1980-1990[4]	1990-2000[5]
OECD24	0.36	0.55	0.40	0.47
EU15	0.37	0.55	0.36	0.45

1. 1990-1999.
2. Mainland only.
3. 1991-2000.
4. Excluding Iceland, Switzerland and Turkey.
5. Excluding Turkey.

As the period considered is quite short, the impact of changes in demographic structure is limited. For most countries, the share of the working-age population in the total population changed only marginally over the 1990s. However, the slight decline in this share in a number of old OECD countries reversed the post-war trend and mechanically reduced the growth of GDP per capita. Countries with significant changes are those with a rapidly evolving age structure due to strong population growth (Korea) and changes in migration flows (*e.g.* Ireland).

Participation rates for the OECD countries as a whole have been rather stable over the recent past, with rising prime-age female participation rates largely compensated by falling participation rates among older workers and youths. In a few countries, the rise in part-time work (most notably in the Netherlands) has been associated with increasing participation rates, especially, amongst women (see OECD, 1999*a*). In the other countries, participation rates made more modest contributions to growth or even fell in some of those with high levels (notably in most of the Nordic countries).

Although some theoretical consideration link labour force participation with ICT, the new economy story is mostly related to what is happening to the last component of GDP per capital, namely GDP per hour worked. Labour productivity growth accounts for at least half of GDP per capita growth in most OECD countries and considerably more than that in many of them. Notwithstanding differences in labour productivity growth rates across countries, it is noticeable that the overall dispersion did not change in the 1990s as compared with the 1980s, despite the significant widening of GDP per capita growth rates discussed above.

A key factor to reconcile growing disparities in GDP per capita growth rates in a context of broadly stable differences in labour productivity growth is a divergence in the shares of the working-age population in employment. The 1990s witnessed striking differences in the evolution of employment rates. Significant increases in labour utilisation (employment plus hours) in Ireland, the Netherlands, Spain, the United States and Australia (above one half of a percentage point) contrast sharply with slumps in Japan, Germany, Finland and, to a lesser extent, Switzerland, Austria and Sweden.[5] Notably, the United States is the only clear case where both hours worked and employment rates increased in the past decade by a significant amount.

Enhancement in human capital contributed to boost labour productivity

The simple measure of output per hour worked is only a crude approximation of productivity, insofar as workers show great differences in education, experience, sector of activity and other attributes that greatly affect their marginal productivity. To refine our analysis we use a measure of labour input in efficiency units obtained by weighting different types of labour by their marginal contribution to the production activity in which they are employed.[6] Since these productivity measures are generally not observable, information on relative wages by characteristics was used to derive the required weights to aggregate different types of labour. The difference between the weighted and un-weighted series yields an index for the compositional change of labour input, or its quality.

5. These patterns resulted from generally negative changes in hours worked in most countries (Sweden and the United States being exceptions) and wide differences in the growth of the employment rate.

6. See Scarpetta *et al.,* (2000) for more details.

To take into account the effect of changes in the composition of the labour input six different types of labour have been considered, based on gender and three different educational levels: below upper-secondary education; upper-secondary education and tertiary education. Relative wages are used to proxy for relative productivity. Two additional assumptions have also been made to construct a measure of labour input: *i)* workers with different levels of education are assumed to work the same (average) number of hours; and *ii)* relative wage rates are assumed to be constant over the sample period. To the extent that these are a reasonable assumption, the measured labour input controls for changes in the "quality" of the workforce over time. Compared with other proxies available in the literature (largely for the United States) this decomposition is rather crude, but it does shed light on the role of compositional changes in labour input consistently for a range of OECD countries, thereby permitting cross-country comparisons.

Table 1 decomposes changes in total labour input into a component that reflects un-weighted changes in total hours and a second component reflecting the changing educational composition of labour, as well as changes in the relative wages earned by different workers. Given data availability, the decomposition covers only a selected number of OECD countries over the 1990s. The labour composition effect is positive in most cases, implying that quality-adjusted hourly labour input grew faster than total hours.[7] In most European countries, sluggish employment growth and falling hours worked have been accompanied by a significant up-skilling of the workforce. This raises the suspicion that productivity gains have been achieved in part by dismissing or not employing low-productivity workers.[8] By contrast, in other countries with greater labour utilisation (e.g. Ireland, the Netherlands) the skill upgrading has played a relatively modest role in total labour productivity growth. Improving labour market conditions and structural reforms have widened the employment base in these countries, especially in the 1990s, allowing low skilled workers to get a foothold into employment, but reducing the overall process of skill upgrading.[9]

7. The result for Germany reflects the discrete fall in the average education level of the workforce in the aftermath of the unification with the Eastern Länder.

8 . Indeed, Scarpetta *et al.* (2000) show that for a number of Continental European countries there has been a general tendency towards skill-biased employment growth: i.e. the increase in share of workers with high education levels has been higher amongst in the employed population than in the overall working age population.

9. As shown in a recent paper (OECD, 1999) in these countries (as well as in Australia, New Zealand, and Ireland) the unemployment rate of the low educated fell as much as the overall unemployment rate, while in most of the other countries the low educated experienced relatively smaller reductions or greater increases in unemployment than the average.

Table 1. **Trends in labour input, total hours and labour composition, 1990-2000**

(average annual percentage change)

	Total labour input (adjusted for compositional change)	Total hours	of which: Persons engaged	of which: Average hours per person	Labour composition
United States	2.0	1.6	1.3	0.3	0.3
Germany	-0.4	-0.4	0.0	-0.5	0.0
France	0.6	0.1	0.5	-0.4	0.5
Italy	0.3	-0.3	-0.1	-0.2	0.6
United Kingdom	1.2	0.4	0.6	-0.2	0.8
Canada	1.5	1.3	1.3	0.0	0.3
Australia	1.7	1.6	1.6	0.0	0.0
Denmark	0.5	0.3	0.2	0.1	0.2
Finland	-0.2	-0.7	-0.6	-0.1	0.5
Ireland	2.3	2.3	3.3	-1.0	0.0
Netherlands	1.0	1.1	2.1	-0.9	-0.2
New Zealand	1.5	1.6	1.6	0.0	-0.1
Norway	0.7	0.5	0.8	-0.3	0.2
Portugal	1.8	0.5	1.0	-0.5	1.3
Sweden	0.2	-0.1	-0.6	0.6	0.3

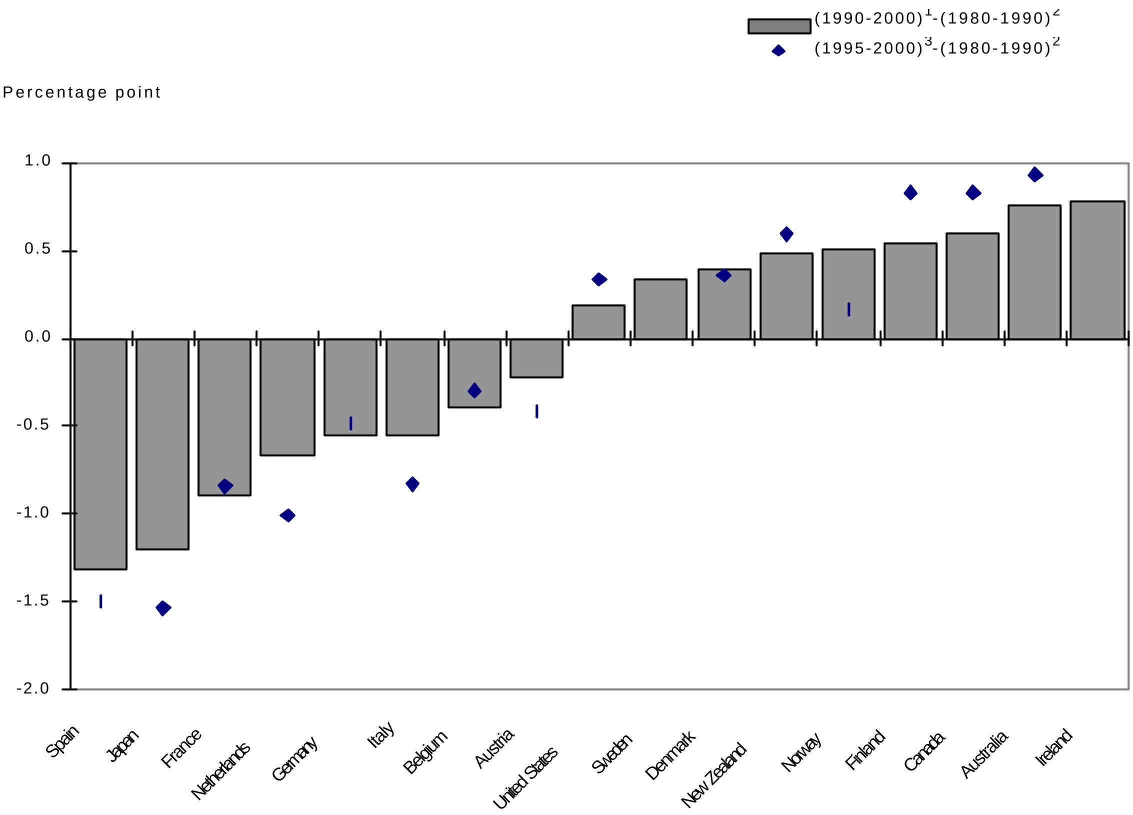
To summarise, our examination of recent trends in output and labour productivity indicates that the OECD have experienced quite different growth experiences over the past decade. GDP growth disparities have tended to widen, and stable hourly labour productivity in some European countries has been associated with low or falling employment levels. Amongst the major economies, the United States was an exception in the 1990s combining significant acceleration in labour productivity growth rates with rising labour utilisation even among low-skilled workers. In many Continental European economies there is some evidence of a skill-biased employment performance with low-skilled workers been trapped into unemployment or inactivity.

Changes in MFP growth also play a role in shaping aggregate performance across countries

Labour productivity growth provides only partial insights into overall economic efficiency. First of all, changes in labour productivity growth rates may occur because of changes in the capital/labour ratio, which in turn depends upon the rate of growth in fixed capital formation and/or changes in employment. Output growth also depends on the productivity of physical capital, which measures how this input is used in providing goods and services.

A standard way to assess changes in the overall efficiency in the economy is to look at the growth rate of output that is not explained by changes in the quantity and quality of production factors, *i.e.* multi-factor productivity growth (MFP, also referred to as total factor productivity. Figure 3 reports MFP growth rates in the business sector in a large sample of countries computed using total hours worked and gross capital stock as factor inputs (*i.e. without any adjustment for* changes in the quality and composition of labour and capital inputs).[10] This is the broadest measure of productivity growth that incorporates the effects of progress in human capital as well as embodied (in physical capital) and disembodied technological progress.[11]

Figure 3. **Changes in MFP growth rates, (1990s[1] vs.1980s [2])**



Difference in average MFP (broad measure) growth rate between 1980-1990 and 1990-2000

1. 1990-1996 for Ireland and Sweden, 1990-1997 for Austria, Belgium and New Zealand, 1990-1998 for Netherlands, 1990-1999 for Australia, Denmark, France, Italy, Japan and 1991-2000 for Germany.
2. 1982-1990 for Finland, 1983-1990 for Belgium, Denmark and Ireland, 1985-1990 for Austria and New Zealand.
3. 1995-1997 for Austria, Belgium and New Zealand, 1995-1998 for Netherlands, 1995-1999 for Australia, Denmark, France, Italy, Japan.

10. The focus on the business sector is due to the inherent difficulties in measuring output and capital stock for the government sector. Moreover, trend series avoid picking up idiosyncratic movements in output and inputs.

11. For countries that use hedonic (or similar) price indices for certain investment goods (*e.g.* ICT), this measure of MFP growth rate does not incorporate technological progress embodied in them (as the capital stock is augmented by the improvements in quality of ICT goods). Bassanini *et al.* (2000) try to identify this component of broad MFP growth by considering the differences in growth rates of hedonic and non-hedonic price indexes of ICT. For the United States, the embodied part of MFP growth would be about 0.2 percentage point in the 1980-90 period and about 0.3 percentage point in the 1990-96 period.

Figure 4 suggests that Ireland, Australia, Canada, Finland, Norway and New Zealand all experienced an acceleration in the average growth rates of MFP of at least 0.5 percentage points over the past decade (in most cases from relatively low levels in the 1980s). The United States recorded a somewhat smaller recovery in MFP growth that, however, reversed a longstanding downward trend. Conversely, MFP growth rates decreased significantly in a number of countries, including all the other G7 countries. In the most recent years (1995-2000), MFP seems to have accelerated more strongly in Canada, United States, Australia and Finland.

It should be stressed, however, that these MFP growth patterns are associated with quite different economic developments. For example, in Australia, Ireland, Canada, Norway, New Zealand and the United States improvements in the growth rate of MFP have gone hand in hand with high and often rising labour utilisation and rapid GDP per capita growth. In contrast, in Sweden and Finland, increases in MFP growth rates have been accompanied by a significant slow down in GDP per capita growth rates and significant falls in employment rates.[12]

I.2 The role of ICT

Most of the recent debate about the 'new economy' has centred around the continuous technological advances in information and communication technology, largely relying on evidence for the United States. Here we would like to assess evidence on the role of ICT in influencing aggregate growth for a broader set of countries. Conceptually, ICT can raise output or output growth via several routes: i) an increase in productivity growth in the ICT-producing sectors themselves,[13] and/or an increase in size of the fast-growing ICT-producing sectors in the economy; ii) capital deepening driven by high levels of investment in ICT equipment; and iii) increases in efficiency in ICT-using sectors that successfully adopt this new technology.

The ICT-producing industry is generally small, but has grown rapidly over the past decade

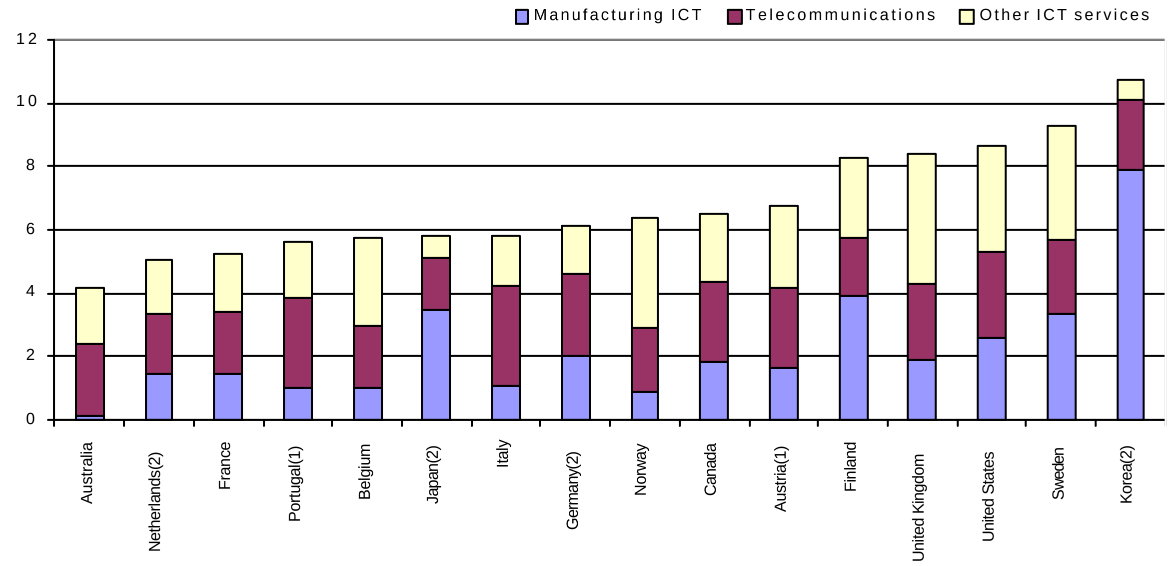
The ICT sector accounts for a relatively small share of total value added in the OECD business sector (Figure 4): from less than 5 per cent in Australia to more than 8 per cent in Finland, United Kingdom, United States, Sweden and Korea. More interestingly, the composition of the broad ICT-producing industry varies considerably across the board: differences in the size of telecommunication industry are

12. In these latter cases, severe crises in the early 1990s (in Finland largely due to the collapse of the Soviet market) most likely led to cleansing the least productive activities with major employment losses but also with an increase in the recorded average MFP growth. Hence, their pattern of MFP growth does not reflect only an acceleration of technical change but also a one-shot reduction of inefficiencies.

13. The ICT-producing sector includes the following industries according to the International Standard Industry Classification (ISIC) Revision 3: **Manufacturing** (ISIC Rev3 3000) Manufacture of office, accounting and computing machinery; (ISIC Rev3 3130) Manufacture of insulated wire and cable; (ISIC Rev3 3210) Manufacture of electronic valves and tubes and other electronic components; (ISIC Rev3 3220) Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy; (ISIC Rev3 3230) Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods; (ISIC Rev3 3312) Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment; (ISIC Rev3 3313) Manufacture of industrial process control equipment. In **Services** (ISIC Rev3 5150) Wholesale of machinery, equipment and supplies; (ISIC Rev3 7123) Renting of office machinery and equipment (including computers); (ISIC Rev3 6420) Telecommunications; (ISIC Rev3 7200) Computer and related activities. See OECD (2000*b*).

rather modest, while countries differ significantly in the size of ICT manufacturing and in ICT-related services.

Figure 4. **The share of the ICT sector in total GDP, 1998**



1. Including all of wholesale of machinery, equipment and supplies (ISIC 5150).
2. Excluding all of wholesales of machinery, equipment and supplies (ISIC 5150).
3. Calculated for the 24 countries for which data are available.

Source: OECD (2000), *Measuring the ICT Sector*.

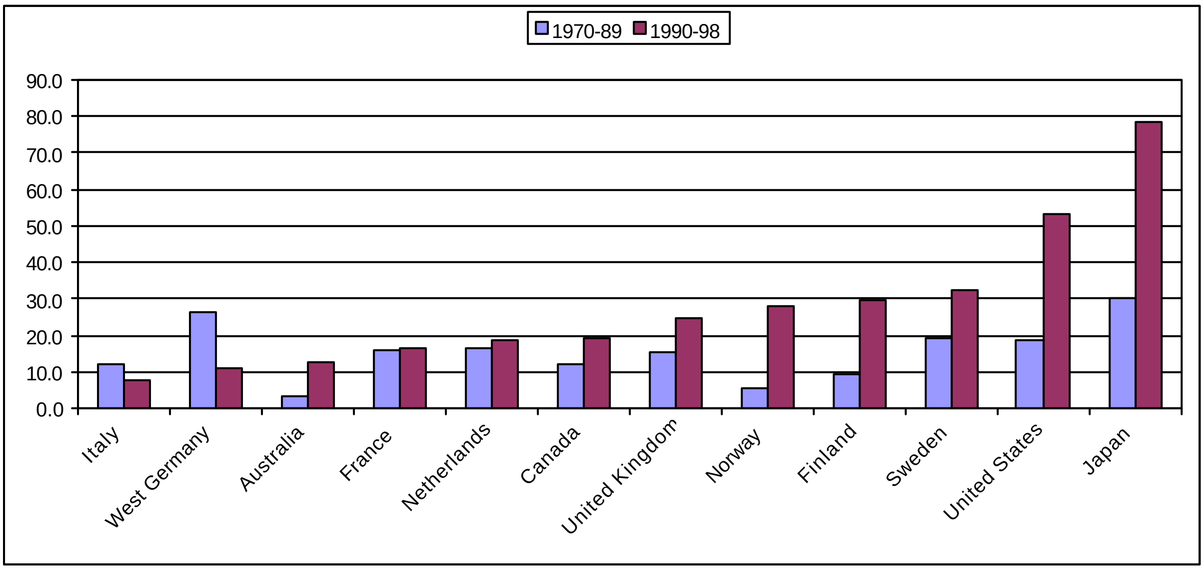
Notwithstanding the small share in total value added, the ICT-producing industry contributed significantly to a surge in productivity in a number of countries, especially in the latter part of the 1990s. Figure 5 shows the contribution of the broad *electrical equipment* industry -- which comprises most of the ICT-producing industries -- to total manufacturing labour productivity growth in the previous decade and in the 1990s. The contribution of this industry to aggregate labour productivity has increased in the 1990s in most countries. More generally, the services part of the ICT sector tended to have more rapid productivity growth than the service sector as a whole.[14] Other studies for the United States and a few European countries suggest that there has been a further substantial increase in contributions from ICT-producing industries in the second half of the 1990s.[15]

14. There is also additional evidence on the role of the ICT-producing industry in country studies. For example, Forsman (2000) suggests that the mobile telephone producer Nokia accounted for more than one-fourth of GDP growth of 4% in Finland in 1999. Moreover, the Bank of Korea find that about 40% of recent GDP growth in Korea came from the ICT sector, five times its 1999 share in GDP (Yoo, 2000).

15. OECD data only allow to assess the role of ICT-producing industries in Denmark, Finland and Germany (see Pilat and Lee (2001). In Finland and Germany, the contribution of the ICT producing sector increased dramatically in the second half of the 1990s compared to the first half the 1990s. For the United States, see Jorgenson and Stiroh, (2000); Oliner and Sichel (2000).

Figure 5. **Contribution of the electrical machinery industry to total labour productivity in manufacturing**

(% of total labour productivity growth)



Source: Calculations on the basis of the OECD STAN database.

There has also been a strong process of capital deepening boosted by falling prices of ICT

The next channel through which ICT operates on output and productivity is through capital deepening. Technological progress has manifested itself, in part, through falling prices of ICT equipment. Falling prices have boosted the real investment, through a mixture of income and substitution effects resulting from the changing relative price structure of inputs to production; thus increasing the amount of ICT capital used in production.

The availability of rapidly improving ICT capital goods has certainly had an impact on investment patterns across OECD countries. Unfortunately, no official data sources provide time series of ICT investment in real and nominal terms for the OECD countries. The following makes use of work done at the OECD to collect and analyse cross-country ICT investment on the basis of data from statistical offices national accounts (Colechia and Schreyer, 2001).[16]

In the G-7 countries, the share of IT capital goods in total investment expenditure rose steadily over the 1990s, and ranged from 3 to more than 8 per cent of total non-residential gross fixed capital formation in 2000. The share of communication equipment also increased, though less rapidly (with the exception of Finland where it rose dramatically), and accounted for around 4 to 8 per cent of total non-residential

16. Other sources of ICT investment data are Daveri (2001), Schreyer (2000) and Van Ark (2001).

investment.[17] Software investment also rose rapidly: from being a marginal component of total investment in the 1980s to one main driving force (especially in the United States).

Moreover, at constant prices, volume growth rates of IT capital investment progressed at an annual rate from 20 to more than 30 per cent over the 1995-2000 period, while communication equipment and software investment progressed at an annual rate generally above 10 per cent over the same period. This fast growth is due to an annual decline in IT price indices of about 20 per cent annually (much less for communication equipment and software), reflecting rapid quality improvements and technical progress embodied in these capital goods.

Table 2 - **ICT investment, 1980 - 2000**

Percentage share of ICT investment in total non-residential investment

Current prices, 1980-2000

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
IT equipment	1980	2.2	3.9	2.0	2.5	4.6	4.1	3.3	2.9	5.1
	1990	5.5	4.5	3.6	3.5	5.5	4.2	3.8	6.0	7.0
	1995	8.4	5.7	4.0	3.9	4.6	3.5	4.6	8.6	8.7
	2000	7.2	7.9	2.9	4.4	6.1	4.2	5.2	8.4	8.3
Communication equipment	1980	4.0	3.0	3.2	2.9	3.9	4.0	3.4	1.6	7.1
	1990	3.8	3.8	3.9	3.2	4.8	5.7	4.0	2.0	7.5
	1995	4.7	4.0	9.3	3.5	4.2	6.7	5.3	3.6	7.3
	2000	5.6	4.2	15.3	3.9	4.3	7.2	6.9	3.6	8.0
Software	1980	1.1	2.2	2.6	1.3	3.6	1.7	0.4	0.3	3.0
	1990	4.6	4.9	5.2	2.6	3.7	3.8	3.1	2.1	8.0
	1995	6.4	7.1	9.2	3.5	4.5	4.3	4.0	3.5	10.1
	2000	9.7	9.4	9.8	6.1	5.7	4.9	3.8	3.0	13.6

Source : Colecchia and Schreyer (2001).

This strong ICT-led process of capital deepening has contributed to boost output growth in most OECD countries for which data are available. The contribution of ICT equipment and software to output growth of the business sector has been between less than 0.4 (France, Italy, Japan) and almost 0.9 percentage points a year over the second half of the 1990s. In terms of shares in overall output growth this translates in an average contribution that ranges between 12 and 35 per cent across countries in the sample (see Figure 6). The contribution on the second half of the 1990s was particularly high in absolute terms in the United States, more than doubling with respect to the 1980-85 period. However, strong contributions also emerged in Australia, Finland and Japan.

It is also worth noting the increasing contribution of software capital to output growth. Over the second half of the 1990s, the accumulation of software capital accounted for a third of the overall contribution of ICT capital to output growth. What is remarkable is that this result holds across all OECD countries in the sample, with the exception of Japan.[18] In particular, the percentage contribution of software capital to

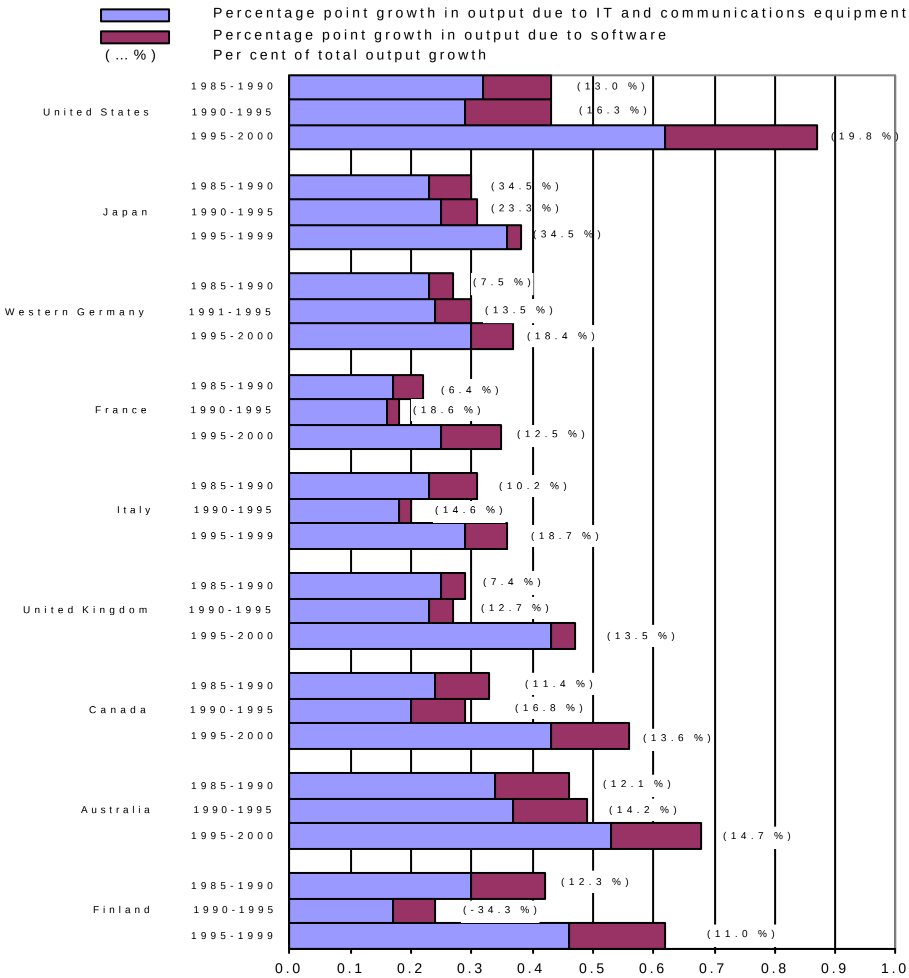
17. Methodologies to measure the price change in ICT capital goods vary a great deal across the OECD countries. The figures reported are based on a harmonised deflator constructed on the assumption that the differences between price changes for ICT capital goods and non-ICT goods are the same across countries. See Colecchia and Schreyer (2001) for more details.

18. This is partly due to the fact that software investment in Japan is underestimated.

output growth almost doubled from the second-half of the 1980s to the second half of the 1990s in the United States, and increased significantly also in Germany, and France.[19]

Figure 6. **The contribution of ICT capital to output growth**

Business sector, based on harmonised ICT price index



Source: Authors' calculations from Colecchia and Schreyer (2002)

19. It should be stressed that measurement on soft ware capital differs greatly across countries and in some countries it is likely that existing figures grossly underestimate it. In addition, the price indexes of software equipment do not fully account for quality improvements in this asset. In summary, the contribution of software capital to output growth should be considered as a lower bound estimate of the real contribution. Jorgenson and Stiroh (2000) perform some simulations with three alternative scenarios for software price indexes (baseline, modera te price decline and rapid price decline). They find that the contribution of software to capital accumulation in the US in 1995-98 would increase from 0.17% in the *baseline* scenario to 0.37% and 0.48% in the *moderate* and *rapid decline in price* scenarios.

All in all, these results indicate that the United States was not alone in experiencing an ICT-led growth in the second-half of the 1990s: in particular, Australia, Canada and Finland all experienced some acceleration in growth because of a strong ICT capital deepening. However, the impact of ICT in the other countries in the sample, was less marked. If anything, the distinguishing feature of the United States is that a stronger role to the overall impact of ICT to output growth was played by software capital accumulation. This might be linked to the rapid diffusion of Internet applications, an issue to which we will return later in this chapter.

ICT investment also contributed to embodied technological progress

Changes in the composition of the capital stock resulting from the shift towards ICT equipment also allow us to shed light on the role of embodied part of technological progress. The estimates of MFP growth presented above do not take into account quality changes in factor inputs and thus capture both embodied and disembodied technological and organisational improvements that increase output for given amount of inputs. Data on the composition of the capital stock into seven different assets, and availability of quality adjusted and non-adjusted price indexes for ICT equipment allow to assess how shifts towards ICT have contributed to the observed pick up in MFP growth observed in some countries. The shift towards ICT assets, whose relative prices have been falling, implies that with the same amount of foregone consumption it is possible to acquire a greater amount of productive capital services. We can tentatively term "embodied" technological change the expansion of the productive capacity resulting from this process.[20] It should be stressed that in doing so we assume that changes in the quality and composition of capital assets fully reflect improvements in the productivity capacity of new vintages and not other influences, *e.g.* changes in consumer preferences.

In the same vein as the correction for changes in the composition and quality of physical capital, the evolution of the total labour input can be decomposed into changes in the quality-constant hours worked and quality changes due to shifts towards more skilled workers. Indeed, improvements in human capital can be seen as reflecting a widening of the knowledge base that could be added to the embodied part of technological change. However, as discussed above, the observed changes in the skill composition of the workforce do not only represent a progress in the knowledge base of the working age population but also a skill-biased evolution of employment that has left out relatively low-skilled worked.

From these considerations, we complement the measure of MFP growth presented above with two alternative measures. The first shifts back changes in labour quality from MFP to the labour input. The second measures fully disembodied technological change and is computed by subtracting growth in factor inputs that are fully adjusted for changes in quality and composition from output growth (this is what Jorgenson, 1966, would consider as the only identifiable component of technological progress.

Table 3 suggests that one-third of the acceleration in MFP in the United States from the first to the second half of the 1990s was due to embodied technical progress, while the contribution of this factor was generally smaller (with the exception of Finland) in the other countries. However, for the U.S. the contribution of embodied technical progress was also strong in the second half of the 1980s. To better

20. In particular, embodied technological change includes both changes in the composition of physical capital and changes in the quality of the different assets. From the discussion above, a proxy for total (embodied and disembodied) technological change can be computed as the residual from a growth accounting exercise in which we use the standard measure of capital stock (deflated at real acquisition prices). This can be justified from a theoretical point of view on the basis of the work of Solow (1960) and Fisher (1965). For a more detailed discussion on this issue see Bassanini *et al.* (2000).

assess the role of the different components, Figure 7, plots the different measures of MFP growth for the U.S. The first point to notice is that the end of the productivity slowdown should be dated back to the early 1980s and not to the nineties as often stressed on the basis of unadjusted series. This holds whatever measure of MFP growth is considered. Moreover, the contribution of ICT to embodied technological progress has increased over time to peak in the second half of the 1990s, as a result of a faster pace of ICT adoption.

Table 3. **Estimates of MFP growth rates 1980-2000**

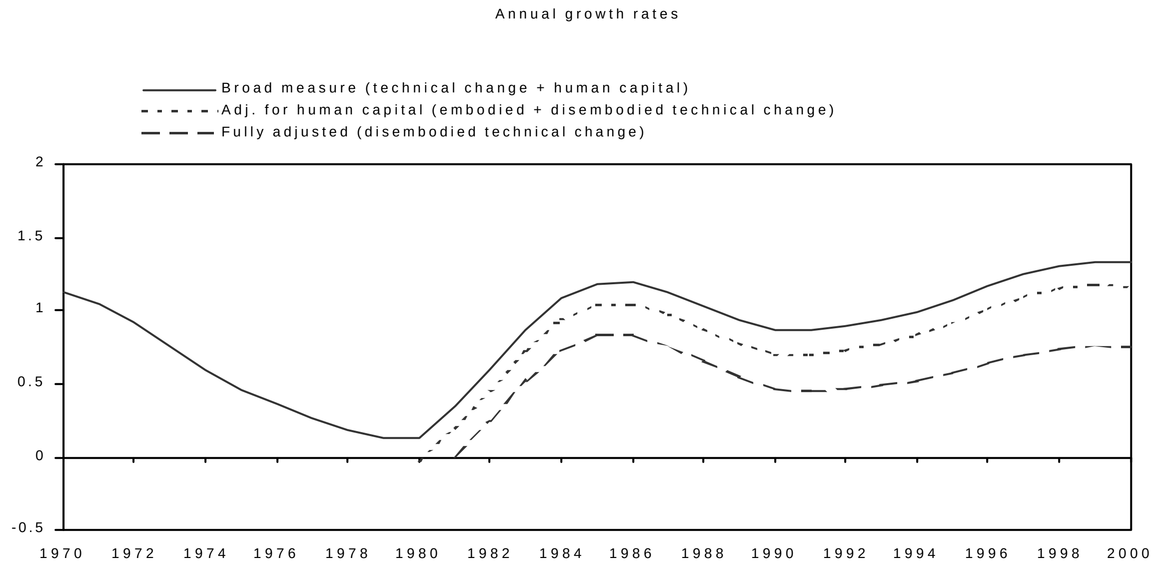
Average annual growth

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
Broad measure	1980-1985[1]	0.68	0.49	2.46	2.00	1.15	1.53	1.92	..	0.82
(technical change + human capital)	1985-1990[2]	0.46	0.77	2.36	1.71	1.46	1.57	2.38	1.01	1.03
	1990-1995[3]	1.18	1.00	2.76	0.92	0.65	1.22	1.22	0.63	0.95
	1995-2000[4]	1.50	1.45	3.11	1.02	0.84	0.72	0.62	0.93	1.28
Adjusted for human capital	1980-1985[1]	..	0.32	2.20	1.82	..	..	..	..	0.67
(embodied + disembodied technical change)	1985-1990[2]	..	0.61	2.01	1.36	..	..	..	0.66	0.87
	1990-1995[3]	1.12	0.79	2.37	0.44	0.67	0.76	..	0.02	0.79
	1995-2000[4]	1.36	1.24	2.79	0.60	0.87	0.27	..	0.29	1.12
Fully adjusted	1980-1985[1]	..	0.12	2.01	1.66	..	..	..	..	0.47
(disembodied technical change)	1985-1990[2]	..	0.40	1.82	1.18	..	..	..	0.46	0.65
	1990-1995[3]	0.79	0.58	2.12	0.26	0.47	0.58	..	-0.19	0.50
	1995-2000[4]	1.01	0.97	2.52	0.41	0.66	0.08	..	0.04	0.72
Memorandum item:	1980-1985[1]	0.22	0.20	0.19	0.16	0.14	0.17	0.14	..	0.20
embodied technical change	1985-1990[2]	0.28	0.21	0.19	0.18	0.17	0.19	0.20	0.20	0.22
	1990-1995[3]	0.33	0.22	0.26	0.18	0.19	0.17	0.23	0.21	0.29
	1995-2000[4]	0.35	0.28	0.38	0.20	0.22	0.19	0.23	0.25	0.40

1. 1982-1985 for Finland.
2. 1987-1990 for the United Kingdom.
3. 1991-1995 for Germany.
4. 1995-1997 for the United Kingdom,1995-1999 for Australia, France, Italy and Japan.

Source: Bassanini and Scarpetta (2002).

Figure 7. **Different measures of trend MFP growth rates for the United States, 1970-2000**

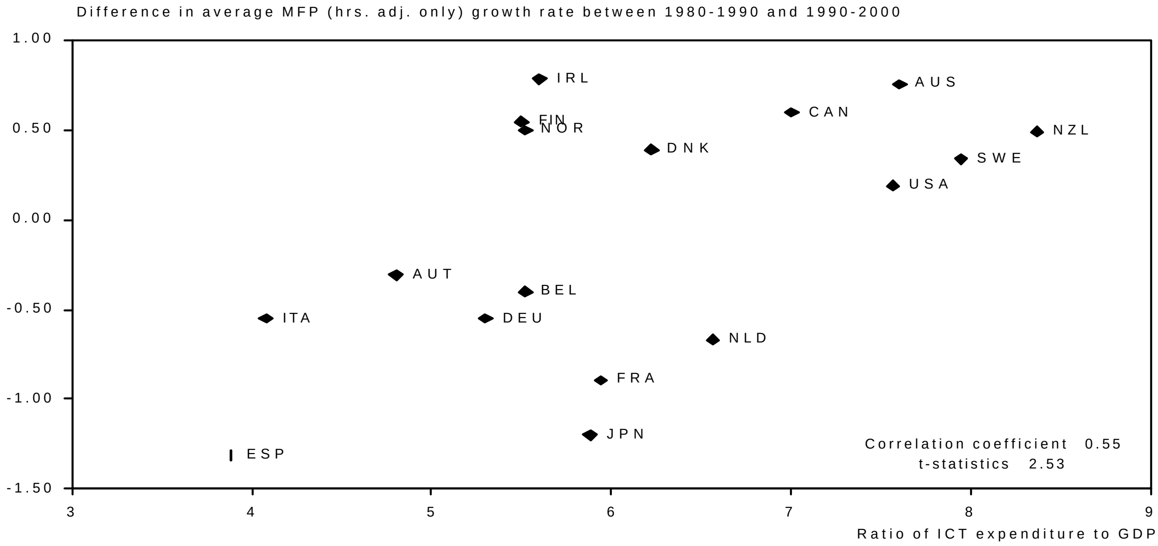


Source: Bassanini and Scarpetta (2002).

Table 3 above also suggests an acceleration in MFP growth in a number of countries even in fully disembodied technical progress. This is encouraging because it suggests that even countries without a sizeable ICT-producing industry have benefited from the spread of ICT, by shifting towards this more productive technology. Indeed, if the acceleration in fully-adjusted MFP growth due to ICT were merely a reflection of rapid technological progress in the production of computers, semi-conductors and related products and services, there would be no visible effects of ICT on MFP in countries that do not have a sizeable ICT-producing industry. For ICT to have visible effects on MFP in countries that do not produce ICT goods, it requires to have spillover effects -- or network externalities -- linked to its use in other sectors of the economy.

Figures 8 and 9 shows some additional light on this issue. They indicate some *prima facie* evidence of a possible relationship between the acceleration of MFP growth and the overall intensity of ICT, the latter proxied by either total ICT expenditure or by a more specific indicator of the intensity of PC use by the population. Indeed, countries with greater expenditure in ICT and greater PC intensity were also those characterised by acceleration of MFP growth over the past decade.

Figure 8. **Change in MFP growth and ICT expenditure, 1990-99**

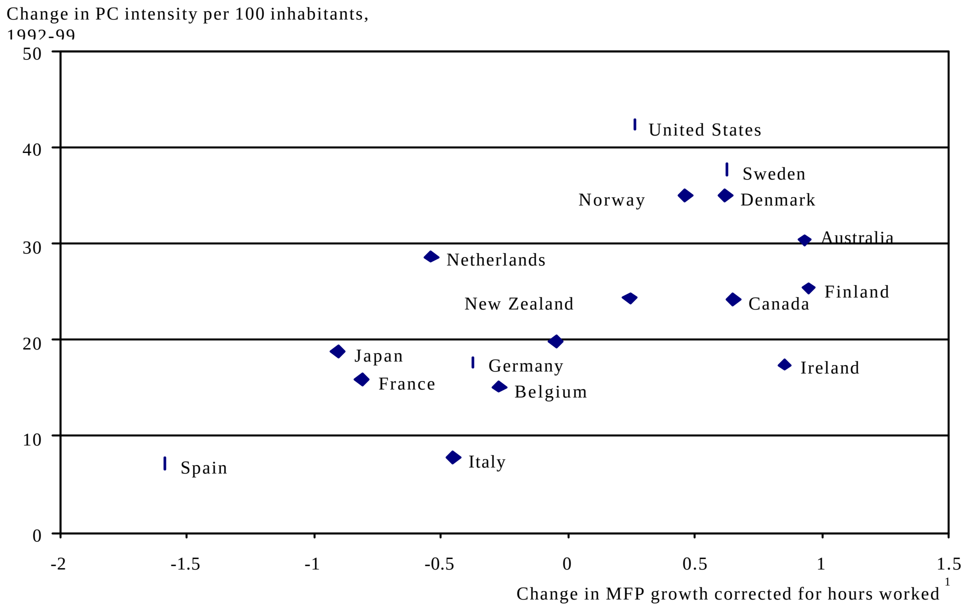


The indicator of administrative burdens to start-ups used in this figure is based on the following dimensions: number of procedures, number of services, maximum delays, minimum direct and indirect costs. The indicator takes also into accounts differences in regulation for corporations and sole proprietor firms and refer to 1998 (see Nicoletti *et al.*, 1999, for a complete description). ICT intensity is the average of the ratio of ICT expenditure to GDP in the 1990s.

Source: OECD

Figure 9. **Change in MFP growth and change in PC intensity, 1990-99**

Correlation coefficient: 0.63



1.3 Summary

In this chapter we have shed some light on recent growth trends in the OECD countries and, in particular, in our comparison of the United States with Europe. We identify a number of stylised facts that will guide our empirical investigation in the following chapters, including:

- Per capita GDP growth was uneven across the OECD in the 1990s. While some economies experienced an acceleration of growth (e.g. Ireland, Australia, the Netherlands, the United States and Canada) others, including the large ones in continental Europe, persisted along the slow growth path observed since the 1970s.

- Compared to per capita GDP, labour productivity growth rates across countries were fairly persistent across countries in the 1980s and 1990s. The explanation for these seemingly conflicting patterns is the diversity in the trends in labour utilisation: in general, an acceleration in GDP growth rates have been accompanied by improvements in the utilisation of labour. In the countries where labour productivity picked up as well, employment usually fell or stagnated. In this context, the United States stands out with respect to large Continental European countries not much in terms of labour productivity, but as having an acceleration in labour productivity growth being accompanied by growth in hours and employment.

- There are also some new factors behind the observed disparities in growth performance across the OECD countries. In particular, multifactor productivity (MFP), taken as a proxy for technological change, accelerated in a number of countries, most notably in the United States and Canada, but also in some small economies (e.g. Ireland, Australia). In the United States, the acceleration of MFP growth seem to have started initially as a pure 'disembodied' phenomenon, consistent with the idea of a slow diffusion of a new general purpose technology. Later on, an increasing contribution to overall productivity growth seems to result from greater use of highly productive ICT equipment by other industries. The slow diffusion hypothesis is also consistent with the fact that MFP growth accelerated somewhat later in other OECD countries that did not have a sizeable ICT-producing industry.

- The intensity of investment in ICT (either relative to GDP or to total investment) has increased in most countries, but still varies across the board. The United States does not stand out in this respect, as number of (small) European countries have experienced a surge in the most recent years. What distinguished the United States from most large European economies is the larger (and more productive) ICT-producing industry.

- Providing further support to the role of ICT in shaping recent growth trends, we also show a positive link between ICT expenditure and the acceleration of MFP growth across countries.

2. SCRAPING THE SURFACE: WHAT LIES BEHIND AGGREGATE GROWTH PATTERNS? INDUSTRY- AND FIRM-LEVEL EVIDENCE

As discussed in the previous chapter, the impact of ICT on growth can follow three paths: the rapid growth of the broadly defined ICT industry, the ICT-induced process of capital deepening, and the improvements in efficiency in ICT-using sectors. In this chapter we aim at shedding further light on why countries have had such different performance along these paths, although we will not be able to disentangle the latter two paths. We use industry-level data, which are available for several OECD countries, as well as firm-level data for a selected sample of countries. First, we assess how shifts of resources across industries have contributed to the observed productivity performance. Then we look more closely at the ICT-producing industries and assess whether, despite their different size across countries, they consistently boosted aggregate productivity. We then descend to firm-level data and assess how firm dynamics (entry, exit and post-entry growth) has contributed to manufacturing and industry-specific performance with a particular focus on ICT industries.

2.1 The composition of aggregate productivity growth: the ICT sector and beyond.

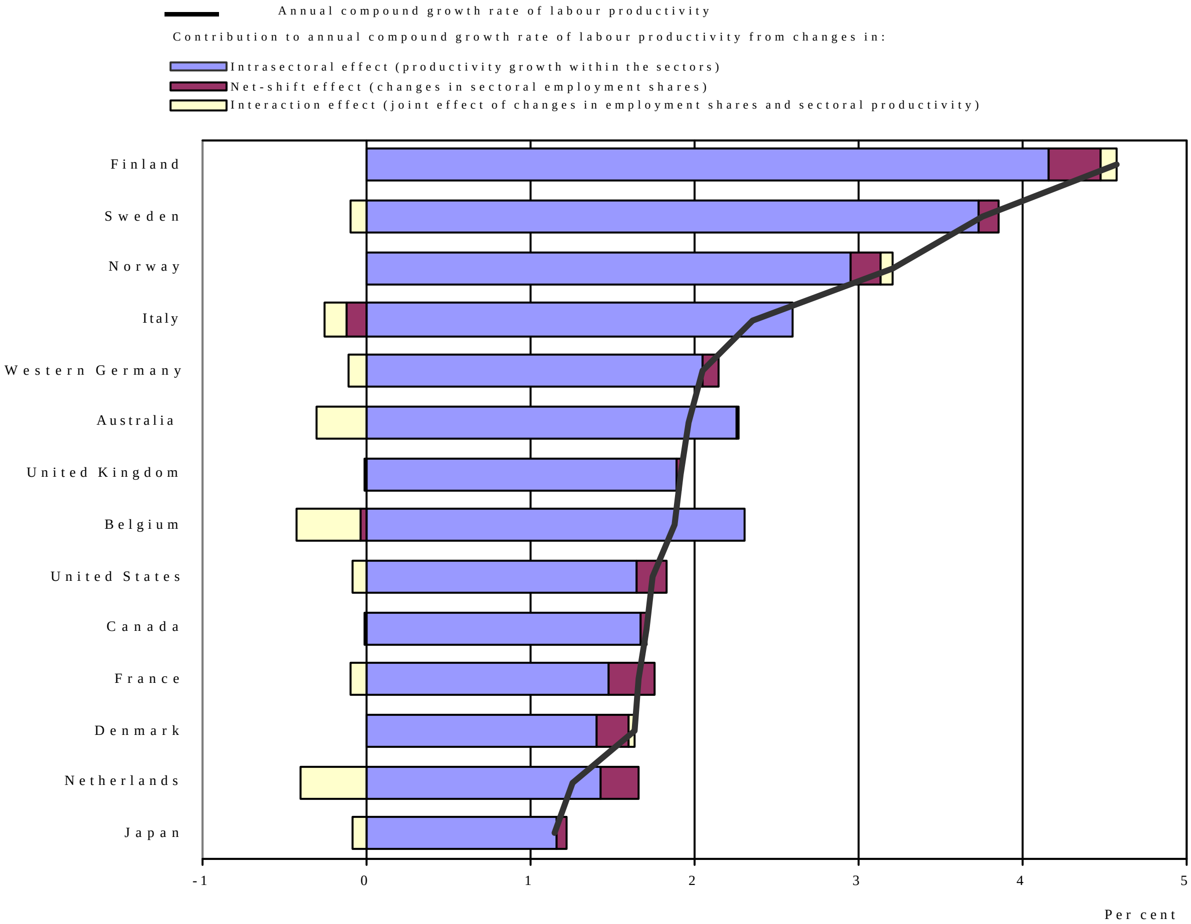
Aggregate productivity growth patterns depend on within-industry productivity performance as well as shifts of resources across industries. Historically, structural shifts were an important factor, as resources moved from a low-productive agricultural sector to a more productive manufacturing sector. More recently, the evidence from aggregate data seems to suggest that a large contribution to overall productivity growth patterns comes from productivity changes within industries rather than as a result of significant shifts of employment across industries (van Ark, 1996). For the purpose of an international comparison, Figure 1 presents a decomposition of labour productivity growth in the business sector in three factors using the most disaggregated sectors available in STAN (2-digit ISIC for services and a 3-4 digit ISIC for manufacturing):[21]

- An "intra-sectoral effect", that measures productivity growth within industries;
- A "net-shift effect", that measures the impact on productivity of the shift in employment between industries;
- And a residual third effect, the "interaction effect". This effect is positive when sectors with growing productivity have a growing employment share or when industries with falling relative productivity

21. The shift-share analysis presented has limitations other than the lack of detail for services (Timmer and Szirmai, 1999). First, it focuses on labour productivity, and not on multi-factor productivity. Second, it assumes that marginal productivity of factor inputs moving in or out an industry is the same as average productivity. Finally, if output growth is positively related to productivity growth (the Verdoorn effect), the impact of structural change may be underestimated, since part of the shift to rapid - growth sectors will be counted in the within-effect.

decline in size. It is negative when industries with growing relative productivity decline in size or when industries with falling productivity grow in size.

Figure 1. Breakdown of compound growth rate of labour productivity into intra-sectoral productivity growth and inter-sectoral employment shifts, total business sector (1990-98)



Bearing in mind the limits of a decomposition based on rather broad industries, the results of these calculations show that the intra-industry effect is the most important contributor to productivity growth in the non-farm business sector. The net-shift effect did not make an important contribution during this period.[22] The interaction effect tends to be negative for most countries.

The evidence that productivity growth is a matter of performance improvement within industries is perhaps not surprising for the countries examined in Figure 1, as around 70 per cent of value added in these countries is already in services. However, other OECD economies, including Ireland and Japan as well as some low-income countries have much smaller service sectors, suggesting that there may be further scope for structural change. In addition, there is likely to be scope for further structural change and

22. The net-shift effect was more significant over the 1970-79 and 1979-90 periods.

improved resource allocation within the industries considered in Figure 1. Indeed, in reading the figure, it should be stressed that the disaggregation of the service sector is limited, and it is possible that considerable structural changes are occurring within some broadly defined industries (*e.g.* business services).[23]

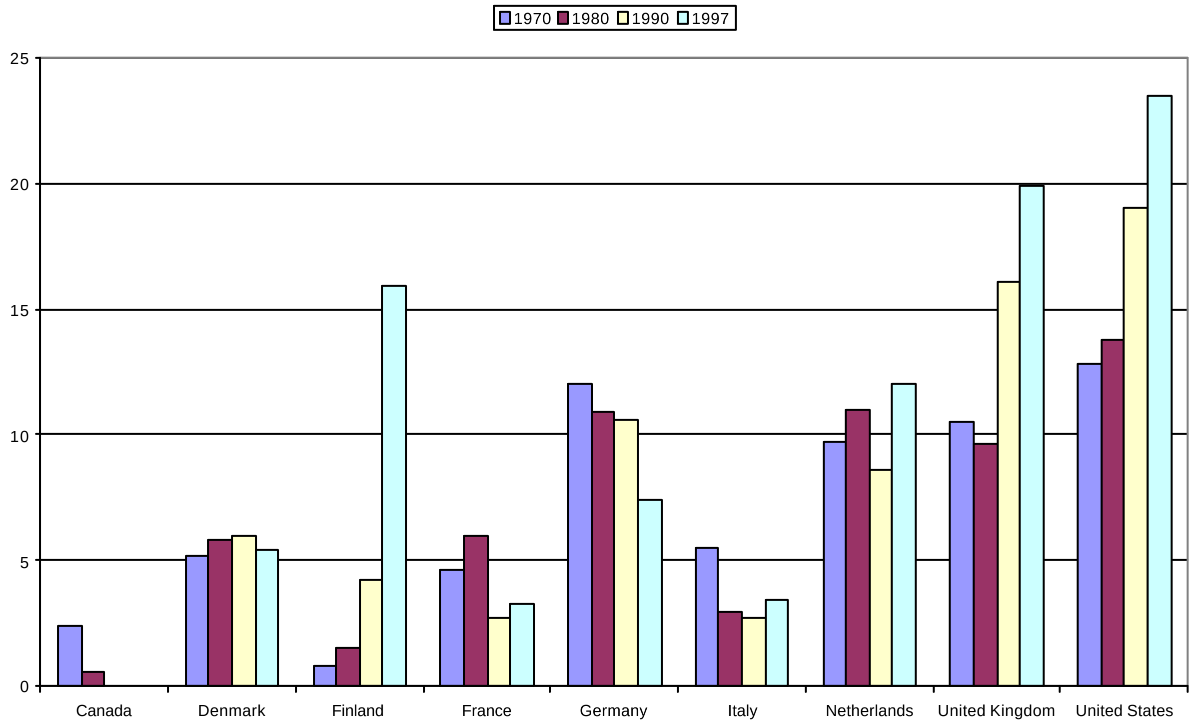
Even though aggregate productivity growth has been largely driven by within-industry performance, the differences across countries in the size of the ICT producing sector, and the intensity of ICT-use in other sectors, make it important to analyse the sectors separately. These are treated in turn in the next two sections.

How rapidly countries shift to expanding sectors?

As discussed in Chapter 1, the United States and a few smaller economies have a larger ICT-producing industry than most of the European countries. Why is this the case? One way to address this issue is by looking at the ability of countries to shift to rapidly expanding sectors. Comparative advantage indicators -- such as the Balassa index (BI) -- can assess this 'ability', as suggested by Bartelsman and Hinloopen (2002). The BI index is defined as the share of a particular product in a country's export-basket relative to that product's world-wide share of world-trade. A BI index larger than unity denotes that a country has a relative comparative advantage in the production of that product. In Figure 2 we look over time at the percentage of a country's value of exports that are generated by ICT products for which the country has a relative comparative advantage. We calculate these figures using bilateral trade flow data for detailed products (Feenstra, 2000), and our assignment of these products to the ICT category following the OECD definition of ICT products (see Chapter 1).

23. To shed some light of the sensitivity of the decomposition of between and within effects to changes in the industry details, the shift-share analysis was replicated for the United States with three different industry breakdowns: 1) 1-digit data; 2) details for manufacturing but broad aggregates for services and mining (i.e. close to the decomposition used in the text); and 3) the maximum detail of 58 industries (4 mining industries, construction, 20 manufacturing industries and 33 service industries). The results do not show a high sensitivity of results to the degree of industry detail used, confirming the strong role of within-industry changes in productivity in explaining aggregate patterns. Data used are from US Department of Commerce, Bureau of Economic Analysis, Industry Economics Division. http://www.bea.doc.gov/bea/dn2/gpo.htm.

Figure 2. Comparative advantage in ICT products



From Figure 2, we see that in the United States in 1997, nearly a quarter of the value of exports was in ICT products for which the U.S. enjoys a relative comparative advantage. Furthermore, this percentage has been increasing steadily from earlier periods. Having a relative comparative advantage in the export of a product often indicates that a country has a cost advantage in producing the good, or that the quality of the good is appreciated in international markets. If the distribution of the BI for a certain product is near uniform worldwide, then it has become a commodity that everyone has the ability to produce: likely profit margins will be small. In contrast, if the distribution of BIs for a product is highly skewed, then margins are likely to be large. For the ICT products for which the U.S. has a comparative advantage, few other countries have a BI above unity. The only additional country that has been able to increase its comparative advantage in ICT products in the most recent years in Finland, but arguably this has occurred in a smaller segment (mobile phones) of the ICT market.

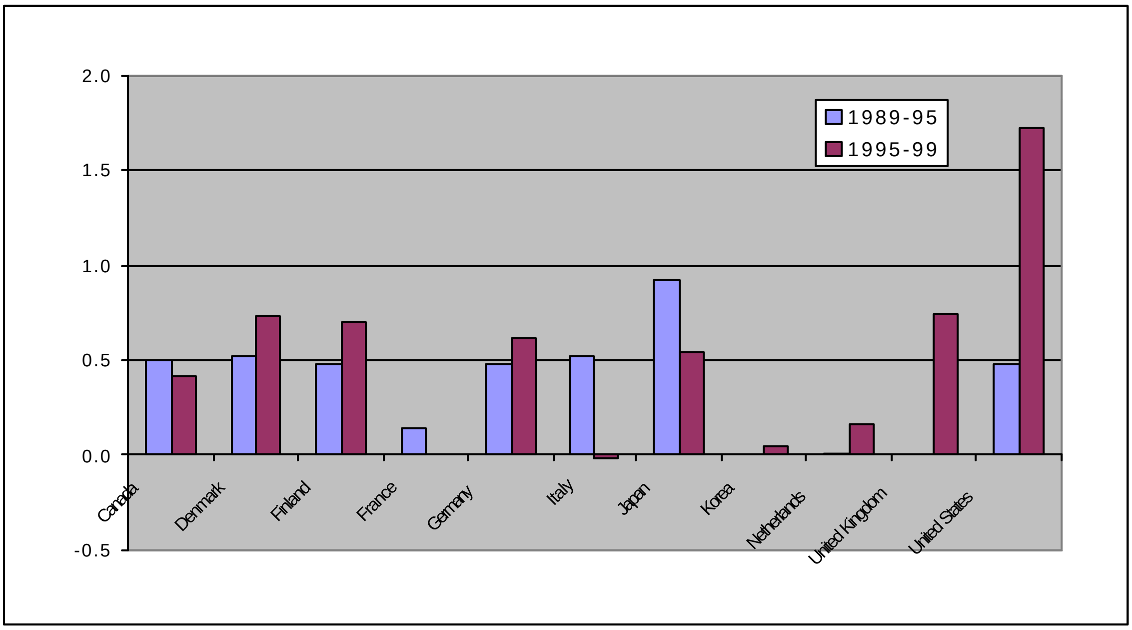
The role of ICT-using industries

ICT equipment is readily available in the world market and, in theory, all firms can acquire them at fairly similar prices, wherever they are located. Here we focus on productivity performance of ICT-using industries, which could be taken as a proxy for the ability to adopt a highly productive new technology. In addition the focus is on services industries, because the distinction between ICT-producers and ICT-users is more difficult within manufacturing. In particular, we consider wholesale and retail trade, finance, insurance and business services (see Figure 3). As stressed by the Council of Economic Advisors (2001), in the U.S. more than two-thirds of all information technology products are purchased by these two broad sectors.

Figure 3 suggests that in most countries for which data are available, ICT using industries increased their contribution to overall labour productivity growth, though the effect has been particularly marked for the United States. If we then look at the two sectors separately, we can observe that in the U.S. both sectors contributed substantially to the acceleration in labour productivity over the second half of the 1990s, while for the other countries the contribution mainly came from finance, insurance and real estate sector. Finland also experienced substantial productivity gains in wholesale and retail trade and in finance and insurance, but the overall contribution of ICT-using services to productivity improved only slightly, due to a strong negative contribution from business services. The strong improvement in Finland's ICT-using services does, however, emerge from an examination of MFP growth rates. This shows that ICT-using services accounted for just over one-third of the pick-up in MFP growth from 1995-99. This contribution is considerably larger than in the 1970s or 1980s, and is due to strong productivity growth in wholesale and retail trade, and financial intermediation.

Figure 3. **Labour productivity growth in ICT-using services, 1989-95 and 1995-99**[1]

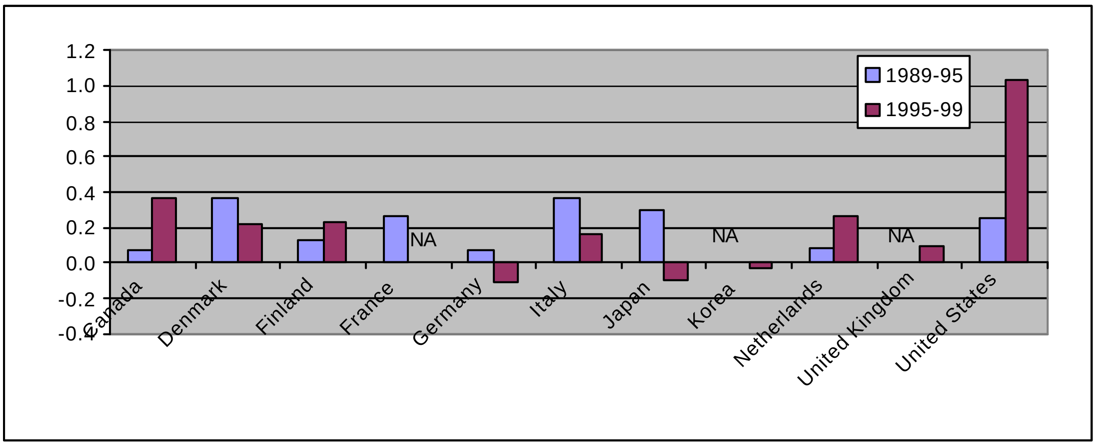
Contribution of ICT using sector to total (% point)



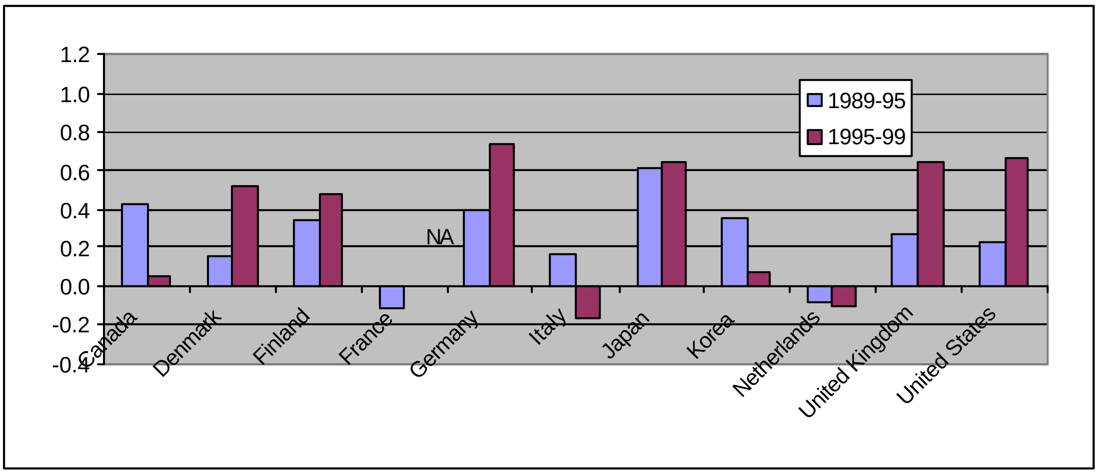
Note: 1991-95 and 1995-97 for Germany; 1995-98 for Japan. Employment-based labour productivity growth is used for the U.S. since hours worked is not available for ICT-using industries.
Source: Pilat and Lee, (2001).

Figure 4. **Labour productivity contributions by selected service industries (% point)**[1]

Panel A: ***Wholesale and retail trade; repairs***



Panel B: ***Finance, insurance, real estate and business services***



Note: 1991-95 and 1995-97 for Germany; 1995-98 for Japan.
Source: Pilat and Lee, 2001

All in all, the evidence reported in this section suggests that, amongst the large OECD economies, the United States has been better able to switch to the rapidly expanding ICT products and enjoy a stronger boost to overall productivity growth. Moreover, there is evidence to suggest that the United States as well as some smaller economies (e.g. Finland) have experienced a stronger increase in productivity of ICT-using sectors, most likely because of a stronger process of ICT-driven capital deepening. Is there something inherent in the characteristics of manufacturing and ICT-user service industries in the U.S. that make them more able to develop and adopt these new technologies? We try to shed some further light on this issue by reporting some firm-level evidence in the next section.

2.2 Firm dynamics and productivity growth: evidence from firm-level data

As suggested by growing micro evidence, industry performance (especially in a highly dynamic context) may hide a wide heterogeneity of individual firms' behaviour, and it is precisely the different features of this firm heterogeneity that may explain cross-country difference in industry-wide performance. In particular, various formal models have emphasised the importance of a "Schumpeterian" process of 'creative destruction' for innovation and adoption of new technologies.

One class of these models focuses on the learning process (either active or passive) due to experimentation under uncertainty. In the *passive learning model* (Jovanovic, 1982) a firm enters a market without knowing its given potential profitability *ex ante*. Only after entry does the firm start to learn about the distribution of its own profitability, based on (noisy) information from realised profits. By continually updating such learning, the firm decides to expand, contract or exit. One of the main implications of this model is that smaller and younger firms should have higher and more variable growth rates. In the *active learning model* (Ericson and Pakes, 1995) a firm actively explores its economic environment and invests to enhance its profitability under competitive pressure from both within and outside the industry. Its potential and actual profitability changes over time in response to the stochastic outcomes of the firm's own investment, and those of other actors in the same market. The firm grows if successful, and shrinks or exits if not. In any event, because of the inherent uncertainty in experimentation, even an entrant who is very successful, *ex post*, will typically begin small. The accumulation of experience and assets, in turn, strengthens survivors and lowers the likelihood of failure.

One variant of the creative-destruction process is described by vintage models of technological change. These models stress that new technology is often embodied in new capital, which, however, requires a costly retooling process in existing plants. Related to this idea are models that emphasise the potential role of entry and exit: at the extreme, if new technology can only be adopted by new establishments, growth occurs only via entry of new units of production that displace outpaced establishments. The existence of sunk costs implies that high-tech new firms coexist with older and less productive firms generating the observed heterogeneity.

Despite the clear attractiveness of firm-level analyses of technological innovation and adoption, their implementation has often been constrained by the lack of cross-country comparability of the underlying data. While many studies exist for the United States, evidence for most other countries is often scattered and based on different definitions of key concepts or units of measurement (see Caves, 1998 and Ahn, 2001 for surveys). In this section we use a specially-constructed firm-level data for ten OECD countries (United States, Germany, France, Italy, United Kingdom, Canada, Denmark, Finland, Netherlands and Portugal). In particular, we look at certain features of firm dynamics (entry, exit and survival) and how they influence industry-wide productivity growth in total manufacturing and in ICT-related industries.[25]

25. For more details see Bartelsman, Scarpetta and Schivardi (2002) and Barnes, Haskel and Maliranta (2002).

Box 2.1 The OECD firm-level study

Firm-level data have been assembled by national experts as part of a two-year project, co-ordinated by the OECD, in which one of the key aims has been to minimise inconsistencies along different dimensions (*e.g.* sectoral breakdown, time horizon, definition of entry and exit, etc.). Notwithstanding the efforts made to harmonise the data, there remain some differences that have to be taken into account in the international comparison

Sources of data

Available data at the firm level are usually compiled for fiscal and other purposes and, unlike macroeconomic data, there are few internationally agreed definitions and sources, although harmonisation has improved over the years (see Bartelsman et al. 2002 for more details on the OECD firm-level project). The analysis of firm entry and exit for this study is based on business registers (Canada, Denmark, France, Finland, Netherlands, United Kingdom and United States) or social security databases (Germany and Italy). Data for Portugal are drawn from an employee-based register containing information on both establishments and firms. These databases allow firms to be tracked over time because addition or removal of firms from the registers (at least in principle) reflects their actual entry and exit. The decomposition of aggregate productivity growth requires a wider set of variables and has been based on production survey data, in combination with business registers.

Definition of key concepts

The entry rate is defined as the number of new firms divided by the total number of incumbent and entrant firms in a given year; the exit rate is defined as the number of firms exiting the market in a given year divided by the population of origin, *i.e.* the incumbents in the previous year.

Labour productivity growth is defined as the difference between the rate of growth of output and that of employment and, whenever possible, controls for material inputs. Available data do not allow the control for changes in hours worked, nor do they distinguish between part- and full-time employment. Multifactor productivity (MFP) growth is the change in gross output less the share weighted changes in materials, capital and labour inputs. Changes are calculated at the firm level, but income shares refer to the industry average in order to minimise measurement errors. The capital stock is based on the perpetual inventory method and material inputs are also considered. Real values for output are calculated by applying 2-4 digit industry deflators.

Comparability issues

Two prominent aspects of the data have to be borne in mind while comparing firm-level data across countries:[1]

Unit of observation: The data used in this study refer to 'firms' rather than 'establishments'. More specifically, most of the data used conform to the following definition (Eurostat, 1995) "an organisational unit producing goods or services which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources". Nevertheless, business registers may define firms at different points in ownership structures; for example, some registers consider firms that are effectively controlled by a "parent" firm as separate units, whilst others record only the parent company.[2]

Size threshold: While some registers include even single-person businesses, others omit firms smaller than a certain size, usually in terms of the number of employees but sometimes in terms of other measures such as sales (as is the case in the data for France and Italy). Data used in this study exclude single-person businesses. However, because smaller firms tend to have more volatile firm dynamics, remaining differences in the threshold across different country datasets should be taken into account in the international comparison.[3]

1. For more detail on the comparability of the firm-level data, see Bartelsman *et al.*, (2002).

2. In a sensitivity analysis, the decomposition of productivity growth has been repeated for the United States, on the basis of establishment data instead of firm data. The results are largely unchanged, at least with respect to the sign and broad magnitude of the different components.
3. However, a sensitivity analysis on Finnish data, where cut-off points were set at 5 and 20 employees, reveals broadly similar results for the productivity decomposition and aggregate entry and exit rates.

The role of firm dynamics in industry productivity growth

We use two alternative approaches to decompose labour productivity growth: the approach proposed by Griliches and Regev (1995, GR henceforth); and that proposed by Foster, Haltiwanger and Krizan (1998, FHK henceforth) (see Box 2). The analysis is based on 5-year rolling windows for all periods and industries for which data are available.

Box 2.2 **The decomposition of productivity growth**

One approach used to decompose productivity growth is from Griliches and Regev (1995): in this decomposition, each term is weighted by the average (over the time interval considered) market shares as follows:

$$\Delta P_t = \sum_{Continuers} \overline{q_i} \Delta p_{it} + \sum_{Continuers} \Delta q_{it} (\overline{p_i} - \overline{P}) + \sum_{Entries} q_{it} (p_{it} - \overline{P}) - \sum_{Exits} q_{it-k} (p_{it-k} - \overline{P}) \qquad [1]$$

where D means changes over the k-years' interval between the first year (t – k) and the last year (t); q_{it} is the share of firm i in the given industry at time t (it could be expressed in terms of output or employment); p_i is the productivity of firm i and P is the aggregate (*i.e.* weighted average) productivity level of the industry.[1] A *bar* over a variable indicates the averaging of the variable over the first year (t – k) and the last year (t). In equation [1], the first term is the <u>within component</u>; the second is the <u>between component</u>, while the third and fourth are the <u>entry and exit component</u>, respectively.

Another decomposition has been proposed by Foster, Haltiwanger and Krizan (1998). It uses base-year market shares as weights for each term of the decomposition, and includes an additional term (the so-called "covariance" or "cross" term) that combines changes in market shares and changes in productivity (it is positive if enterprises with growing productivity also experience an increase in market share) as follows:

$$\Delta P_t = \sum_{Continuers} q_{it-k} \Delta p_{it} + \sum_{Continuers} \Delta q_{it} (p_{it-k} - P_{t-k}) + \sum_{Continuers} \Delta q_{it} \Delta p_{it} + \sum_{Entries} q_{it} (p_{it} - P_{t-k}) - \sum_{Exits} q_{it-k} (p_{it-k} - P_{t-k}) \qquad [2]$$

One potential problem with this second method is that, in the presence of measurement error in assessing market shares and relative productivity levels in the base year, the correlation between changes in productivity and changes in market share could be spurious, affecting the within- and between-firm effects. The averaging of market shares in the GR method reduces this error. However, the interpretation of the different terms of the decomposition is less clear-cut in the GR method. If market shares indeed change significantly over the five-year interval, the 'within' effect in fact also includes a reallocation effect.

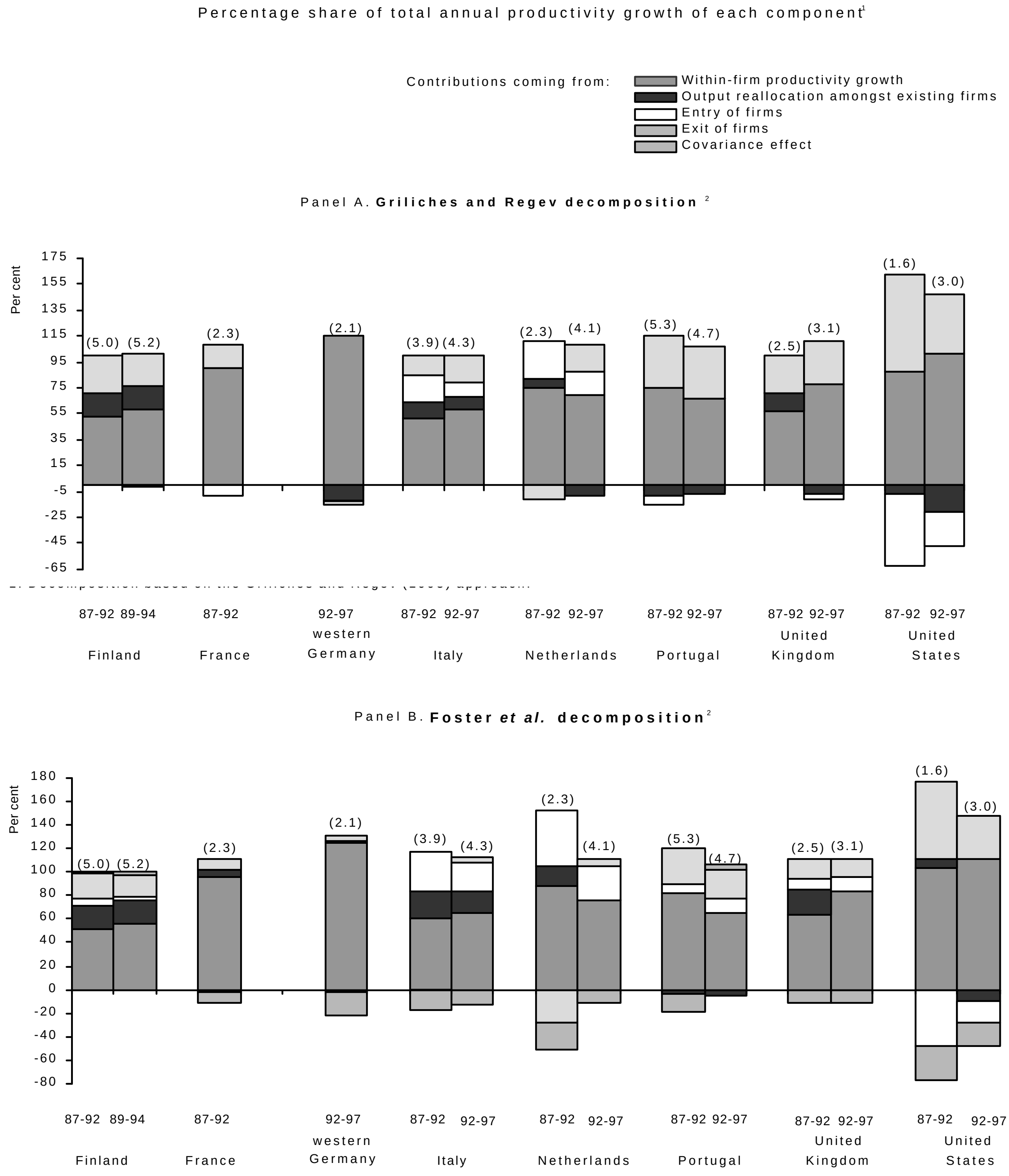
1. The shares are based on employment in the decomposition of labour productivity and on output in the decomposition of total factor productivity.

Figure 5 presents the decomposition of labour productivity growth in manufacturing sectors for two five-year intervals, 1987-92 and 1992-97. Both the GR, and especially the FHK decomposition method, suggest that labour productivity growth within each firm accounted for the bulk of total growth (from 50 to 85 per cent of the total). Consistent with our sectoral analysis above, the impact on productivity *via* the reallocation of output across existing enterprises (the "between" effect) is typically small especially if one does not consider the "cross-effect" in the FHK decomposition. The cross effect is mostly negative, implying that firms experiencing an increase in productivity were also losing market shares, i.e. their productivity growth was associated with restructuring and downsizing rather than expansion. Finally, the net contribution to overall labour productivity growth of the entry and exit of firms (net entry) is positive in most countries (with the exception of western Germany over the 1990s), typically accounting for between 20 per cent and 40 per cent of total productivity growth.

There are significant differences in the contribution of entries to productivity growth. Leaving aside France and Italy, where data are to some extent problematic,[26] data for the other European countries show that new firms typically make a positive contribution to overall productivity growth (see Table 3), although the effect is generally of small magnitude. By contrast, entry in the United States for most industries makes a negative contribution to industry productivity growth. Less surprising, the exit contribution to productivity growth is typically positive across the data for all countries (Table 1), indicating that exiting firms usually have below-average levels of productivity. However, the contribution of exiting firms in the United States is larger than in all other countries. Differences in the role of entry and exit to overall productivity in the United States compared with European countries are probably related and point to a somewhat different nature of firm dynamics in the United States. Indeed, by analysing cohorts of entrants, Foster *et al.* (1998) shows that many weak recent entrants exit the market rapidly in the United States. This tends to boost the estimated contribution of exit to productivity for the U.S. but, at the same time, the presence of such firms also weakens the contribution of entry in the U.S. decomposition.

26. The French data refer to firms with at least 20 employees or with a turnover greater than 0.58m euros.. They are not likely to be representative of the total population. It is also likely that larger firms are over-sampled, lowering the net entry effect and raising the within effect. The Italian data refer to firms with a turnover of at least 5m euros. Sample size is maintained by deleting firms falling below the threshold and adding new firms in. Thus, the Italian data are likely to overstate true entry and exit rates. Furthermore, the sampling rules are likely to over-record exiting firms with falling productivity.

Figure 5. Decomposition of labour productivity growth in manufacturing



Note: Figures in brakets are overall productivity growth rates (annual percentage change).

1. Components may not add up to 100 because of rounding.

2. See main text for details.

Source: OECD.

Table 1. Analysis of productivity components across industries of manufacturing

Proportions of positive contributions to labour productivity growth across manufacturing industries[1]

	Total number of observations (industry * year)	Entry contribution %	Exit contribution %	Between component %
Finland	420	57	93	62
France	126	47	81	40
Italy	348	84	89	85
Netherlands	344	76	77	51
Portugal	211	63	91	49
United Kingdom	392	62	92	45
United States	58	10	98	31

Notes: These calculations are based on all available data with manufacturing and business services. The time periods considered vary considerably across countries.

1. Number of cases in wich the different components made a positive contribution to labour productivity growth (in % of total number of cases)

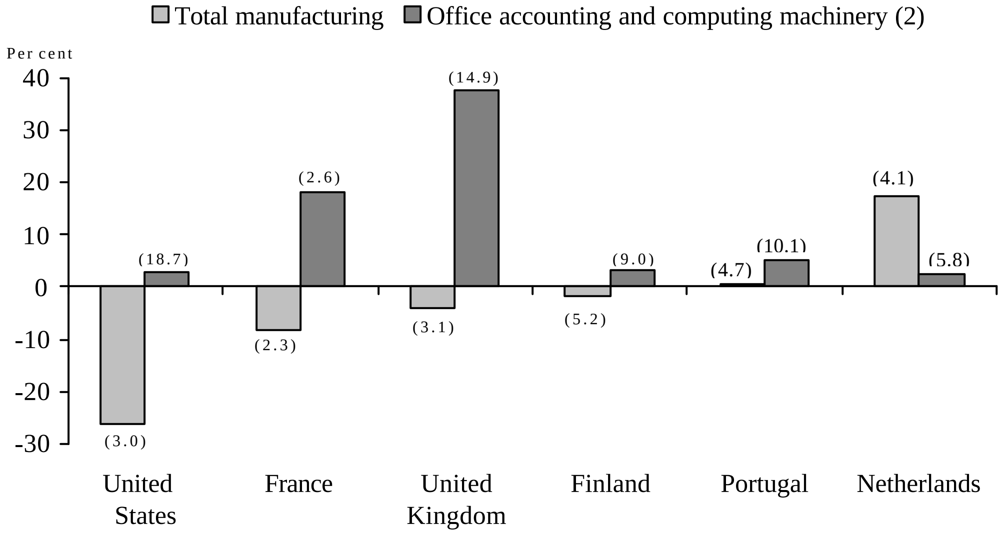
Source: OECD

The contribution made by entry and exit to productivity growth varies considerably across industries. Most notably, in ICT-related manufacturing industries, the entry component makes a stronger than average contribution to labour productivity growth.[27] This is particularly the case in the United States, where the contribution from entrants to total labour productivity is strongly positive, in contrast to the negative effect observed in most of the other manufacturing industries (see Figure 6 for an example of the *office and computing machinery* industry). This suggests an important role for new firms in an area characterised by a strong wave of technological change. The opposite seems to be the case in more mature industries, where a more significant contribution comes from either within-firm growth or the exit of presumably obsolete firms.

27. The industry group is "*electrical and optical equipment*". In the United States, most 3-4 digit industries within this group had a positive contribution to productivity stemming from entry. In the other countries, there are cases where, within this group, the contribution from entry is very high, including the "*office, accounting and computing machinery*" industry in Finland, the United Kingdom and Portugal and "*precision instruments*" in France, Italy and the Netherlands.

Figure 6. Contribution of new entry to labour productivity growth in manufacturing and selected ICT industries

Percentage share of total productivity growth[1]



1. Total productivity growth in parenthesis.

2. Electrical machinery and apparatus n.e.c. for France, Netherlands and Portugal.

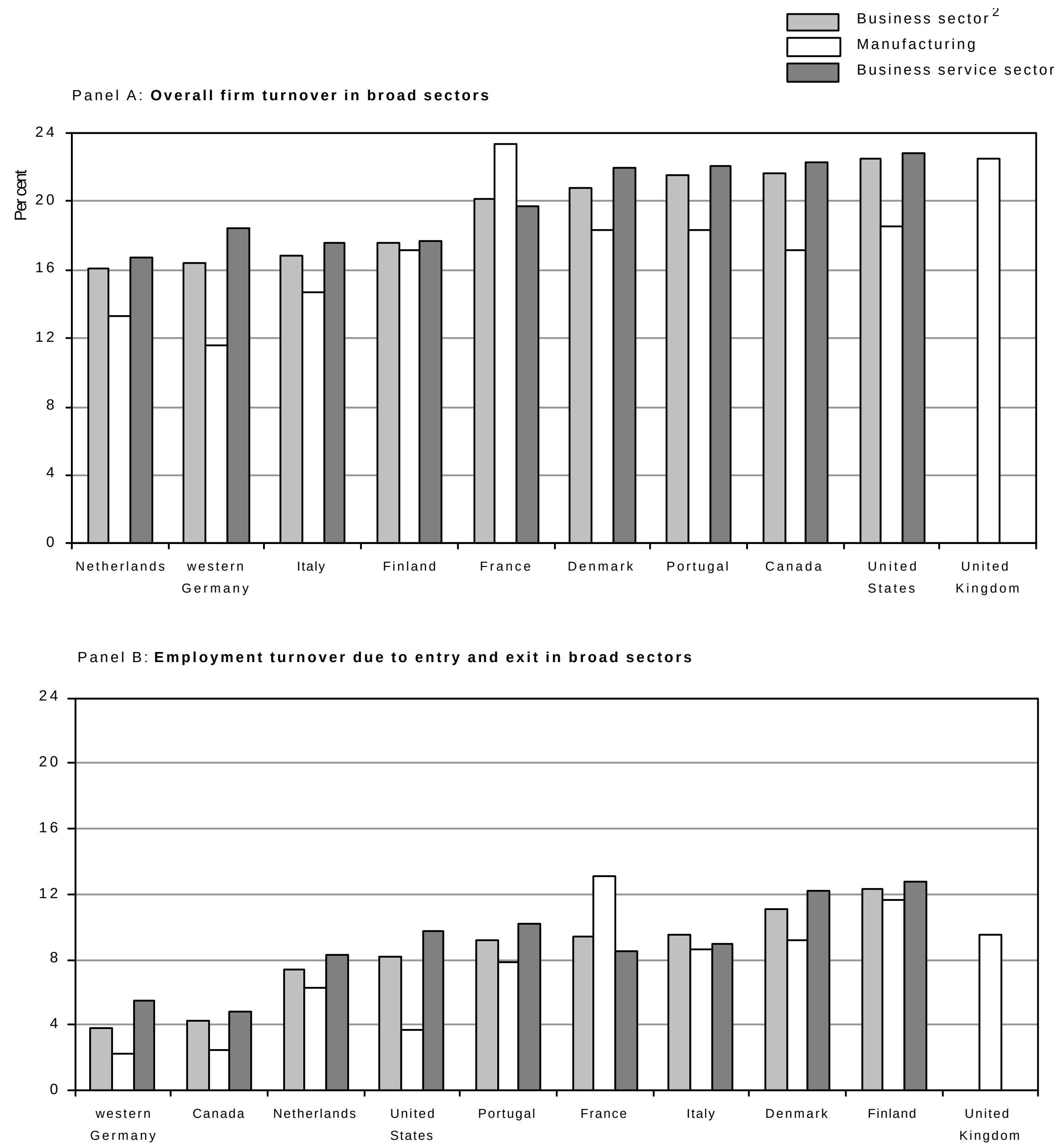
Source : OECD.

Firm dynamics in manufacturing and the ICT industry

The micro literature has recently identified a set of stylised facts about firm dynamics (see Geroski, 1995; Caves 1998) and here we would like to review them on the basis of the OECD firm-level data. Figure 7 seems to confirm a significant churning of firms in all countries (Panel A). Over the first-half of the 1990s, firm turnover rates (entry plus exit rates) was in the range between 15 and more than 20 per cent in the business sector: *i.e.* a fifth of firms are either recent entrants, or will close down within a year. As previously pointed out, the process of entry and exit of firms involves a proportionally low number of workers: i.e. only about 10 per cent of employment is involved in firm turnover, and in Germany and Canada, employment-based turnover rates are around 5per cent (Panel B in Figure 7). The difference between firm turnover rates and employment-based turnover rates arises from the fact that entrants (and exiting firms) are generally smaller than incumbents. For most countries, new firms are only 40 to 60 per cent the average size of incumbents, and in the United States, Germany and Canada their average size is less than 30 per cent of that of incumbents. The relatively small size of entrants in these countries reflects either the large size of incumbents (e.g. the United States) or the small average size of entrants compared with that in most other countries (Germany and Canada). This would suggest that, in these countries, entrant firms are further away from the average size in a given industry (what could be interpreted as the minimum efficient size).

Figure 7. Turnover rates in OECD countries, 1989-94

(entry and exit rates, annual average)[1]

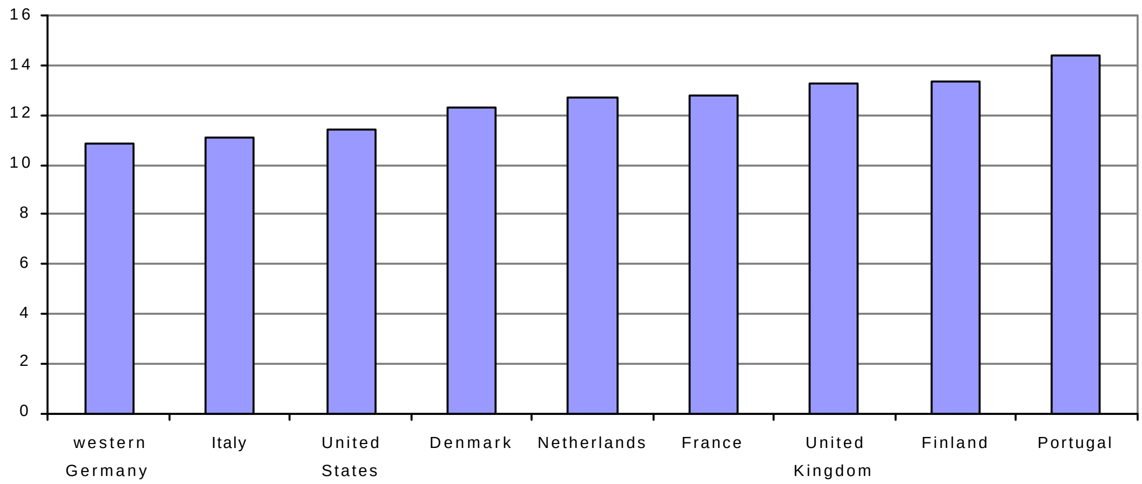


1. The entry rate is the ratio of entering firms to the total population. The exit rate is the ratio of exiting firms to the population of origin. Turnover rates are the sum of entry and exit rates.
2. Total economy minus agriculture and community services.

Source: OECD

The main conclusion from Figure 7 in the context of our international comparison is that there seem to be no significant differences between Europe and North America in terms of firm dynamism. If the latter is taken as a proxy for the ability of industries to innovate and adopt leading technologies -- as the different models in the tradition of the creative destruction hypothesis seem to imply - we can tentatively conclude that such ability may not differ on the two sides of the Atlantic. However, aggregate turnover rates may hide different sectoral behaviours. Figure 8 sheds some light in this respect by presenting the estimated entry rates for each country once differences in the sectoral composition are taken into account by means of fixed effect regressions.[28] In other words, these estimates measure the influence of country-specific factors on firm turnover, over and above those possibly stemming from the sectoral composition of the economy and the different time period covered by the data. The figure suggests that, with the exception of western Germany and Italy, all countries have higher entry rates than the United States. In Portugal, Finland and the manufacturing sector of the United Kingdom, entry rates are between 1.5 and more than 2.5 percentage points higher than in the United States, while in the other countries differences are within one percentage point. Moreover, if the different size structure of firms across countries is taken into account (i.e. not included in the country fixed effects), then the differences are even smaller, and not statistically significant, in the case of Finland and the Netherlands. All in all, it can be concluded that cross-country differences in entry rates are not very large for the countries observed.

Figure 8. Estimated entry rates with control for industry composition[1]



1. Figures reported are the country-fixed effects in an entry equation that controls for industry and time fixed effects.

Fixed effect regressions also allow examination of differences in entry rates across industries, once country and size effects are controlled for (Figure 9). Values in the figure are relative to the overall business sector (un-weighted) average. Notably, high technology manufacturing industries and some

28. The values reported in the figure are the estimated country-specific effects of a panel regression of entry rates on a set of dummy variables accounting for industry, country and time effects. See Bartelsman, Scarpetta and Schivardi (2002) for more details.

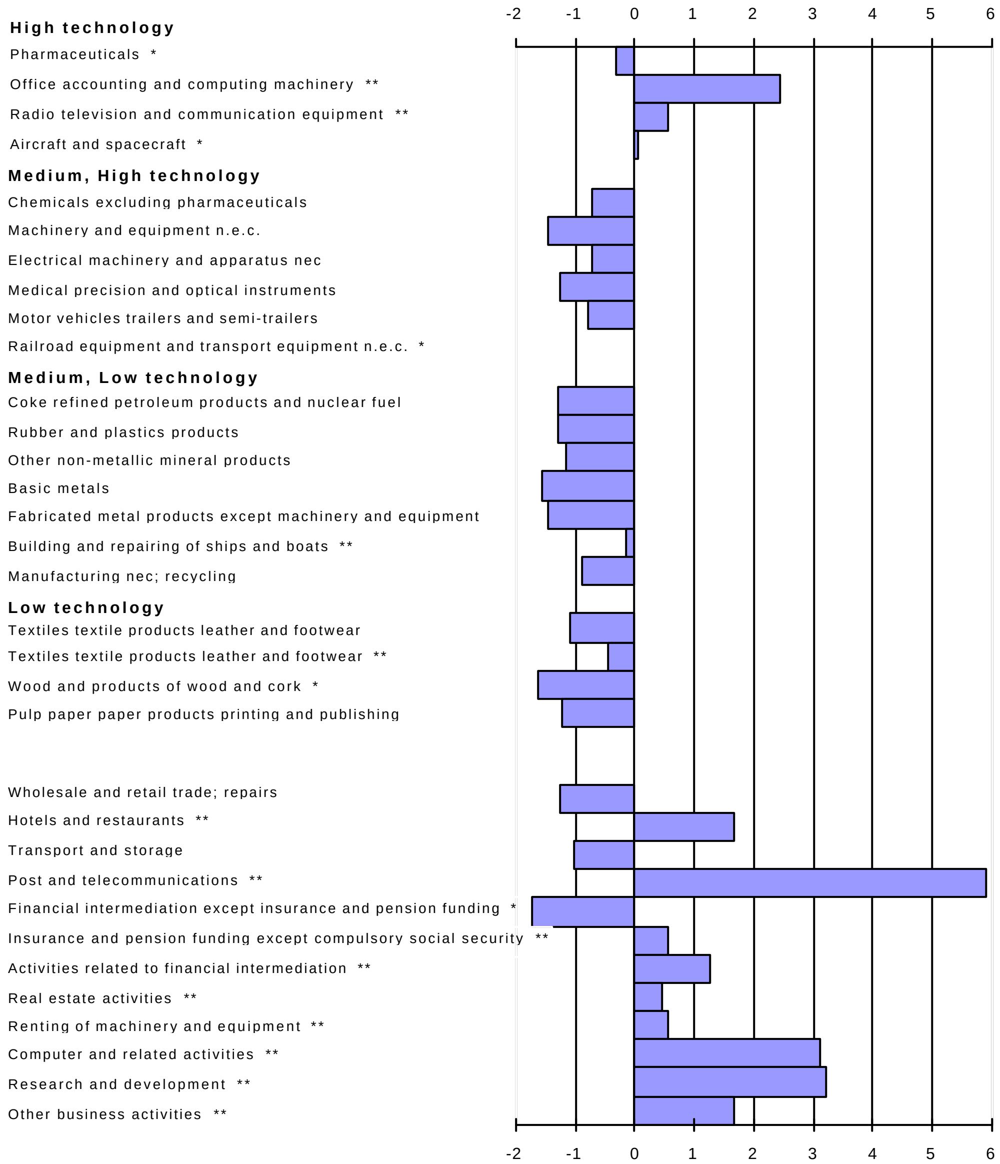
business-service industries, and in particular those related to ICT, have higher entry rates than average.[29] This evidence ties up with earlier discussion about the role of entry in productivity growth in high-tech industries, and lends some support to the vintage models of technological change whereby rapid technological changes are associated with greater firm churning where new innovative units replace outpaced ones.

All in all, there is no evidence in our sample of countries, of a strongly different degree of firm dynamism across countries. At the same time, however, we have seen different contributions of this dynamism to industry-wide productivity performance. The additional piece of the puzzle is the analysis of post-entry performance, another aspect of firm dynamism.

Looking at overall survivor rates, almost 60-70 per cent of entering firms survive the first two years in the countries for which we have data (Figure 10). Having overcome the initial years, the prospects of firms improve further: those that remain in business after the first two years have a 50 to 80 per cent chance of surviving for five more years. Nevertheless, in the countries considered, only about 40 to 50 per cent of firms entering in a given year survive on average beyond the seventh year.

29. The very high positive dummy for post and telecommunication is likely to be due to two factors: i) the privatisation of telecoms in a number of countries that has led to the entry of a number of new private operators; and ii) the rapid increase in the number of firms operating in the communication area, related to the spread of Internet and e-commerce activities.

Figure 9. Estimated industry[1] entry rates relative to the total business sector

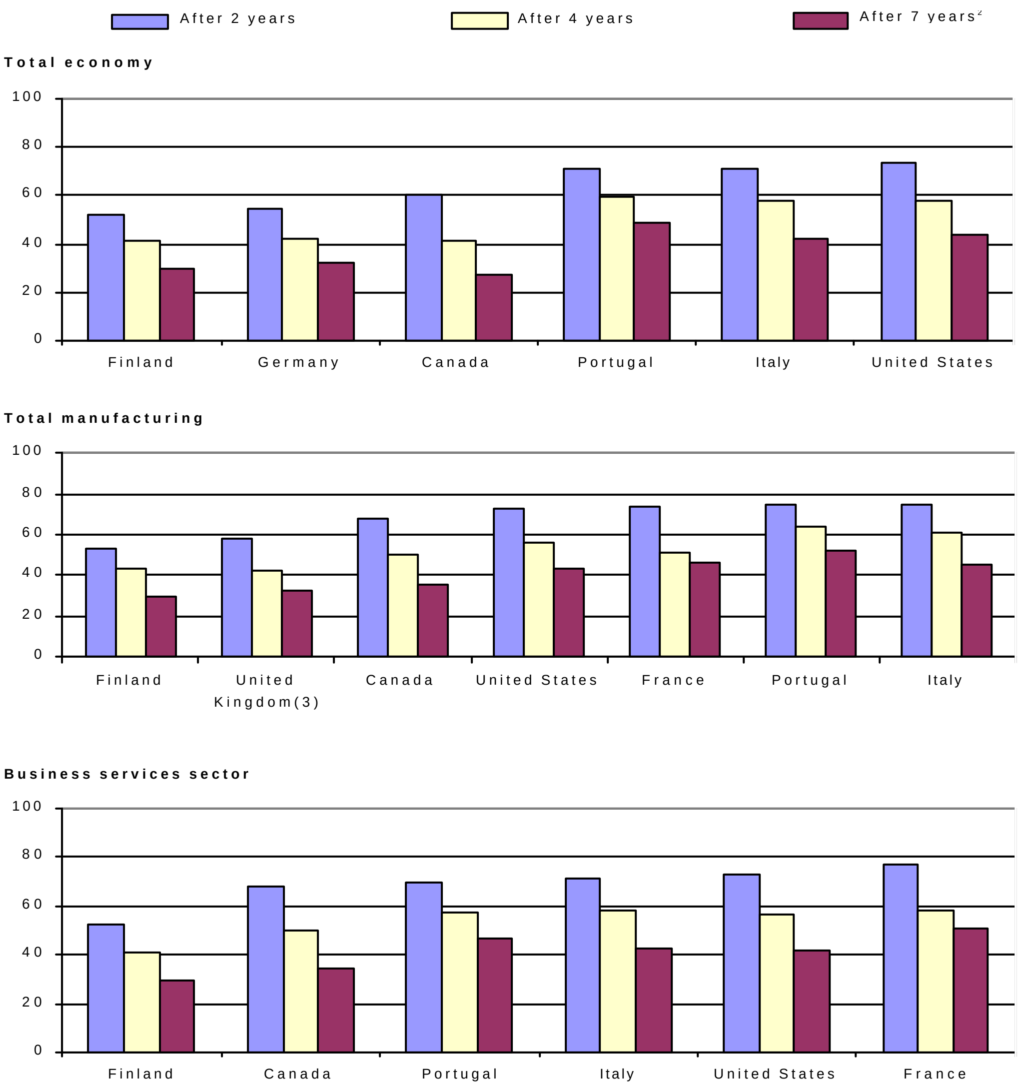


Note: * indicates signifiance at 5%; ** at 1%.

1. Figures reported are the industry fixed-effects in an entry equation that includes country, size and time fixed effects.

Source: OECD

Figure 10. Firm survivor rates at different lifetime[1], 1990s



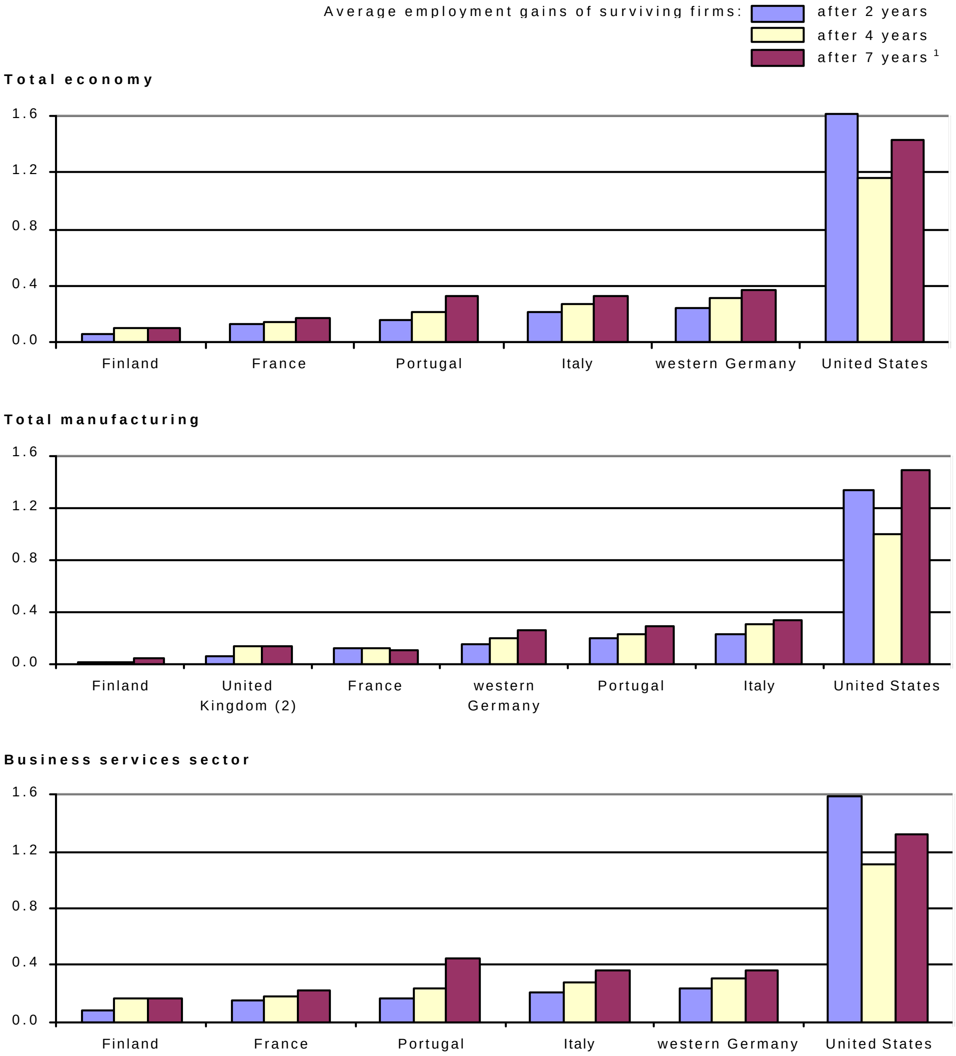
1. The survivor rate at duration (j) is calculated as the probability that a firm from a population of entrants has a lifetime in exess of (j) years. Figures refer to average survival rates estimated for different cohorts of firms that entered the market from the late 1980s to the 1990s.
2. After 6 years for the United Kingdom.
3. Data for the United Kingdom refer to cohorts of firms that entered the market in the 1985-90 period.

Sources: OECD, and Baldwin *et al.* (2000) for Canada.

Failure rates in the early years of activity are highly skewed towards small units, while surviving firms are not only larger, but also tend to grow rapidly. Thus, in most countries the size of exiting firms is broadly similar to that of entering firms. Moreover, the average size of surviving firms increases rapidly to approach that of incumbents in the market in which they operate. On this latter point, there are significant differences across countries (Figure 11): in the United States, surviving firms on average double their employment in the first two years, while employment gains amongst surviving firms in Europe are in the order of 10 to 20 per cent.[30]

Figure 11. Net employment gains among surviving firms at different lifetimes, 1990s

(net gains as a ratio of initial employment)



1. After 6 years for the United Kingdom.
2. Data for the United Kingdom refer to cohorts of firms that entered the market in the 1985-90 period.

Sources: OECD

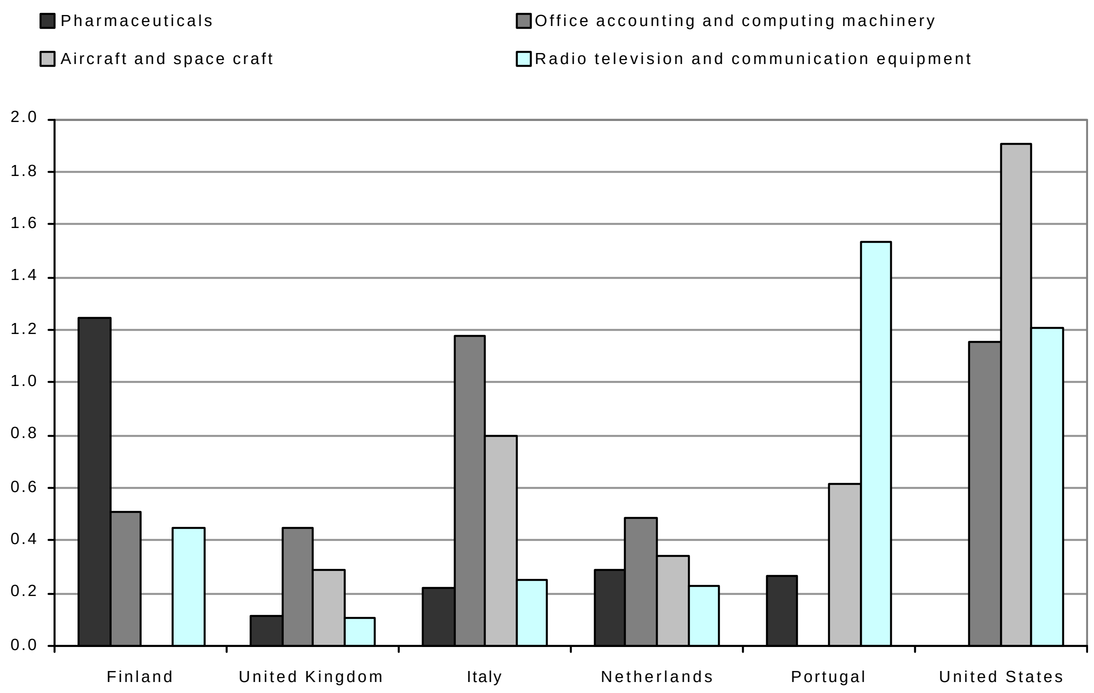
The distinct development of high-technology industries is once again exemplified by the marked employment growth amongst surviving firms (Figure 12). In particular, firms in ICT-related industries

30. The results for the United States are consistent with the evidence in Audretsch (1995*a*,*b*). He found that the four-year employment growth rate amongst surviving firms was about 90 per cent.

(*office accounting and computing machinery* and *radio, TV and communication equipment*) generally experience rapid post entry growth in all countries for which data are available. However, even in these highly dynamic industries, surviving US firms show a stronger employment expansion, compared with those in most of the other countries.

Figure 12. Employment gains among surviving firms in high-tech industries

(net gains as a ratio of initial employment)



Sources: OECD

The marked difference in post-entry behaviour of firms in the United States compared with the European countries is partially due to the larger gap between the size at entry and the average firm size of incumbents, i.e. *there is a greater scope for expansion amongst young ventures in the U.S. markets than in Europe*. In turn, the smaller relative size of entrants can be taken to indicate a greater degree of experimentation, with firms starting small and, if successful, expanding rapidly to approach the minimum efficient scale. These differences in firms' performance can only partly be explained by statistical technicalities or business cycles conditions, and seem to indicate a greater degree of *experimentation* amongst entering firms in the United States. This greater experimentation of small firms in the US market may also contribute to explain the evidence of a lower than average productivity at entry, as discussed above.[31]

31. The other additional factors which could contribute to explain the observed differences in post-entry behaviour include: a) firms with plants spreading into different US states are recorded as single units, while establishments belonging to the same firm, but located in different EU countries are recorded as separate units: available evidence for the United States and Finland reveals only marginal differences in the average number of plants per firm in the two countries (1.2 and 1.1 in total

2.3 Summing up

In this chapter we have further explored recent growth patterns by exploiting industry and firm-level data. The picture that seems to emerge enhances our understanding of the main driver of economic growth and helps to focus our policy-oriented discussion. In particular, we have shown that aggregate productivity patterns are largely the result of within-industry and even within-firm performance in most countries. This should not hide that some industries (both producers and users of ICT) have had stronger than average productivity growth over the past decade and have significantly boosted manufacturing and service overall productivity.

In terms of our international comparison, we have shown that the United States have been notably better than most of its trading partners to acquire comparative advantage in rapidly growing ICT market segments. The U.S. have also experienced a more widespread productivity acceleration of ICT-user industries, while in Europe notable acceleration generally occurred only in the finance sector. So, there seems to be evidence to suggest a different pace of development by both ICT producers and ICT users across the Atlantic.

A number of theoretical studies and some anecdotal evidence suggest that new, innovative, firms may play a key role in the diffusion of a general-purpose technology as the ICT. We have investigated this issue by means of firm-level data. The picture that emerges is one in which, overall, there is a similar degree of firm churning in Europe as in the United States. The distinguishing features of firms' behaviour in the US markets, compared with their EU counterparts can be summarised as follows:

- In the United States, entrant firms are more heterogeneous in terms of both size and productivity than in Europe;
- However, selection effects work quickly so that weak recent entrants exit the market and this is associated with a stronger contribution of exits to total labour productivity in the US compared to Europe;
- Moreover, selection and learning effects imply that successful, surviving entrants expand rapidly, generating stronger post-entry growth. This is consistent with the evidence of a much stronger (employment) expansion of successful entrants in the initial years in the United States compared with Europe.

We have advanced the hypothesis that these differences may indicate a *different degree of market experimentation* in the U.S. as compared with Europe. The more market-based financial system may lead to a lower risk aversion to project financing in the United States, with greater financing possibilities for entrepreneurs with small or innovative projects, often characterised by limited cash flows and lack of collateral. Moreover, low administrative costs of start-ups and not unduly strict regulations on labour adjustments in the United States, are likely to stimulate potential entrepreneurs to start on a small scale, test the market and, if successful with their business plan, expand rapidly to reach the minimum efficient scale. In contrast, higher entry and adjustment costs in Europe may stimulate a pre-market selection of business plans with less market experimentation.

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business sector; b) business-cycle influences could also possibly explain the distinct growth of surviving firms in the United States: estimates of post-entry growth in Italy and Portugal in an expansionary period (the second half of the 1980s) are only marginally higher than those in the early 1990s. See Bartelsman, Scarpetta and Schivardi (2002) for more details.

It is difficult to conclude from our evidence that *greater experimentation* leads to better aggregate performance in all circumstances. However, in a period (like the present) of rapid diffusion of a new technology (ICT), it may allow new ideas and forms of production to emerge more rapidly, thereby leading to a faster process of innovation and technology adoption. This seems to be confirmed by the strong positive contribution made to overall productivity by new firms in ICT-related industries in the sample of OECD countries analysed in this chapter.

3. PRODUCTIVITY, INVESTMENT IN ICT, HUMAN CAPITAL AND CHANGES IN THE ORGANISATION OF WORK: MICRO EVIDENCE FROM GERMANY AND THE U.S.

Introduction

In this chapter, we examine the relationship between the use of advanced technologies such as ICT and related business practices and outcomes such as productivity, employment, the skill mix of the workforce and wages using micro data for the U.S. and Germany. A theme that emerged in the previous chapter is that U.S. businesses engage in more market experimentation than do their European counterparts and that selection and learning effects are more important in the U.S. Relative to those in Europe, the typical entrant in the U.S. is much smaller and less productive than more mature firms. Selection and learning effects yield a substantial contribution from the entry and exit of businesses to growth and productivity. In particular, we see a large contribution from the exit of the least productive businesses in the U.S. and the rapid post-entry growth of surviving entrants in the U.S.

Our objective in this chapter is to analyse the microeconomic underpinnings of the findings outlined in earlier chapters using establishment-level data from the U.S. and one large European economy, Germany. Germany combines European institutions with a large economy, making this comparison both interesting and valid. In particular, we wish to compare the relationships between investments in ICT, market experimentation and productivity growth at the micro level for both countries.

In the course of this analysis, we attempt to explore several questions empirically. We examine the theme of potential differences in experimentation between the U.S. and European economies in two distinctive ways. First, experimentation may be present in the entry and exit process as new businesses adopt new technologies (broadly defined to include the use of advanced technologies but also organisational structure) and concurrently learn whether the technology chosen is suitable and whether the ownership/management team is suitable as well. This form of experimentation is closely linked to the ideas in Jovanovic (1982) where new businesses are uncertain of their type (which can be defined in a variety of ways including managerial ability and/or the appropriate business practices for a specific production unit) and learn about it in the first several periods of operation. Such experimentation suggests that dispersion on a variety of dimensions (productivity, size, wages, skill mix, use of technology) is likely to be especially large for entrants and young businesses. In what follows, we explore this hypothesis by examining the nature of such experimentation across the U.S. and Germany. Again, the working hypothesis from earlier chapters is that the market and institutional environment in the U.S. encourages such experimentation so that we should observe a stronger relationship between establishment age and the dispersion of various outcomes in the U.S.

An alternative but related idea is that each time a business (whether new or mature) adopts a new technology the experimentation process begins anew. This idea, that learning is an "active" ongoing process as businesses adopt new technologies, is based on the model of Pakes and Ericson (1995). Under this view, it is at businesses that are most actively changing their technology where we should observe the greatest dispersion in choices and outcomes reflecting the underlying experimentation. Here again, we are interested in exploring whether the patterns that emerge in the data differ between the U.S. and Germany with the working hypothesis that the U.S. will exhibit more evidence of experimentation.

We focus on cross-sectional micro data for the years 1999 and 2000 in the U.S., and 2000 and 2001 in Germany. While the data are cross sectional, we know the age of the establishments so that we can explore the differences in investment in ITC and outcomes for different cohorts. The micro data permit us to examine the relationship between investment in computers, employee Internet access, the skill mix of the workforce and outcomes such as productivity and wages. While there have been studies conducted at the micro level on these topics for both the U.S. and European countries, our advantage is that we conduct the study for a virtually identical time period using harmonised measurement and methodology. [32]

The chapter proceeds as follows. Section 1 describes the data. Section 2 presents the results of simple regressions relating labour productivity and wages to measures of use of advanced technology in both countries. Section 3 examines the evidence on "experimentation" across countries – first by looking at the results by establishment age and then exploring the active learning model by examining the differences across businesses depending on how actively they are changing their technology. Section 4 concludes with interpretation of the results.

1. Data Description

The firm-level analysis presented in the previous chapter (which draws from the OECD firm-level study, see Bartelsman *et. al.* 2002) is somewhat limited in the number of issues that could be addressed with internationally comparable micro data. There is a trade-off between adding additional countries and still having harmonised data. In this chapter, we are able to examine a richer set of issues by focusing on comparable data from only two countries: Germany and the United States.

Box 3.1 **U.S. Data**

The U.S. data come from two surveys of U.S. manufacturing establishments: the Computer Network Use Supplement (CNUS) to the 1999 Annual Survey of Manufactures (ASM) and the 2000 ASM. We also draw information on establishment age from the Longitudinal Business Database (see Jarmin and Miranda 2002), a research data file maintained by the Center for Economic Studies. Since both surveys are based on the ASM sample frame, we first discuss the general features of the ASM.

Both the 1999 ASM (from which the 1999 CNUS is drawn) and 2000 ASM are part of the 1999-2003 ASM panel. The panel is drawn from the 1997 Economic Census with allowances for new establishment births and replacement for sample deaths. The design for the 1999-2003 panel initially contained approximately 52,000 of the over 380,000 U.S. manufacturing establishments with paid employees. Manufacturing companies with more than $1 Billion in manufacturing shipments are selected into the ASM with certainty. There are just over 500 these certainty enterprises, and all of their over 14,000 establishments are included in the 1999-2003 ASM panel.

Also selected into the ASM with certainty are any remaining establishments that met at least one of the following conditions: have at least 500 paid employees, produce [electronic] computers, or produce in certain "small" industries. This brings the number of certainty cases in the 1999-2003 ASM panel to approximately 16,600. The remaining portion of the sample is chosen randomly, with selection probabilities proportional to size, according to a procedure that minimises sample size while satisfying quality constraints within industry and product strata.

32 For the U.S. studies using micro data include Doms, Dunne, and Troske (1997), Dunne, Foster, Haltiwanger and Troske (2001), Doms, Jarmin and Klimek (2002), and Stolarik (1999a and 1999b). For Germany the only micro study we know of, which analyses the impact of ICT on productivity, is Hempell (2002). This study, however, is based on the German service sector.

For the analysis, we require a number of data items from the ASM and CNUS. Table 1 lists the data items and their source. We also use establishment identifiers and industry codes from the ASM and CNUS files. The CNUS data on e-business processes are available only for reference year 1999. The computer investment data are available for reference years 1992 and 2000. We examine the 2000 cross section only. We match the 1999 CNUS to the 2000 ASM. Since both surveys are drawn from the 1999-2003 ASM panel, differences in the sample are minimal. There will be some difference due to entry and exit. However, the largest difference in the establishment composition of the two files is due to non-response to the 1999 CNUS.[33] The 1999 CNUS contains just fewer than 40,000 establishment observations. After matching the 1999 CNUS, the 2000 ASM and the LBD, we are left with 31,265 establishment observations.

Table 1[34] presents the definitions of the key measures used in this study with U.S. data described in panel 1a and German data in panel 1b. Tables 2 and 3 present summary statistics for the key variables. It is apparent from Table 2 that there are considerable differences across businesses on all measured dimensions in both countries. From Table 3, it is clear that some but far from all of this variation is associated with between industry differences. For example, in the U.S. (Table 3a) computer investment per worker is lowest in the non-metallic minerals industry but highest in the computer and office equipment industry. The gap in computer investment between these two industries is about $1600 per worker, which is substantial. However, this gap is relatively small compared to a one standard deviation difference in computer investment per worker reported in Table 1 (which is $5100 per worker).

Table 1a: Primary U.S. Data Items

Variable	***Source***	***Notes***
Shipments (tvs)	ASM	Total value of shipment. We adjust for changes in inventories to get a concept closer to actual production.
Value Added (va)	ASM	Adjusted shipments minus materials, energy and the costs of resales and contract work.
Employment (te)	ASM	Number of full and part time workers at the plant (production and non-production).
Production Workers (pw)	ASM	Number of full and part time production workers.
Payroll (sw)	ASM	Total salaries and wages paid.
Total machinery and equipment investment (nm)	ASM	Total investment in new equipment and machinery, including vehicles.
Computer investment (nmc)	ASM	Total investment in computers and peripheral equipment (software not included).
% of employees with Internet access (emp_access)	CNUS	% of employees at establishment with access of any kind to the Internet.
STAN industry	Derived	using SIC codes available on ASM
Age	LBD	Categorical age variable taking on values 0 - 10 for plants aged 0-10 and 11 for plants aged 11+.

33. More details on the 1999 CNUS are in U.S. Census Bureau (2001), " *1999 E-business Process Use by Manufacturers: final Report on Selected Processes"*, available at www.census.gov/estats.

34 Note that all the tables in this chapter have two panels labeled "a" and "b" where the "a" panels contain U.S. results and the "b" panels contain German results.

Table 1a: Primary U.S. Data Items

Variable	*Source*	*Notes*
Shipments	IAB	Total value of shipment in the previous business year. No Adjustment for changes in inventories.
Value Added	IAB	Total Shipments minus materials and services received from other plants.
Employment	IAB	Number of (production and non-production) employees (excluding apprentices) at the plant at June, 30th of the current year. Adjusted for part time workers.
Production Workers	IAB	Number of full and part-time workers (as opposed to salaried employees) at June, 30th of the current year.
Payroll	IAB	Total salaries and wages paid in June of the current year (excluding social insurance payments by the employer).
Total machinery and equipment investment	IAB	Total investment in the previous business year (buildings, equipment, machinery, vehicles).
Computer investment	IAB	Total investment in information and communication technology in the previous business year.
% of employees with Internet access	IAB	% of (office) jobs at establishment with access of Internet/Intranet. categorical: 1-all, 2-most, 3 half, 4-a few, 5 none. Information for 2001 only.
STAN industry	IAB	13 categories
Age	IAB	Categorical age variable taking on values 1 - 12 (in 2000: takes the value 11 for plants age 11+, in 2001 takes the value 12 for plants aged 12+).

Box. 3.2 **German Data**

The German data we use are from the IAB Establishment Panel Data Set collected by the Institut für Arbeitsmarkt- und Berufsforschung (IAB), Nuremberg, Germany.[35] This yearly survey has been conducted since 1993 in West Germany and since 1996 in East Germany. Information is obtained by personal questioning carried out by Infratest Sozialforschung, Munich, with voluntary participation by plants managers. Altogether, the (unbalanced) IAB panel comprises 79000 observations and 26000 plants. Detailed descriptions of the IAB Establishment panel can also be found in Kölling (2000).

The sample is drawn from the emp loyment statistics register of the German Federal Office of Labour, which covers all plants with at least one employee (or trainee) subject to social security.[36] All plants included in the population (i.e. all plants included in the employment statistics register---are stratified into 400 cells, which are defined over 10 plant sizes, 20 industries and two regions (West vs. East Germany), from each of which the observations of the establishment panel are drawn randomly. Large plants are over-represented in the IAB panel. In the first wave (1993), for example, the probability of being drawn was on average 91 % for plants employing more than 5,000 employees, but only 3% for plants employing between 100 and 200 employees and as small as 0.1% for plants with less than 5 employees. The over sampling of large plants implies that the survey covers about 0.7% of all plants in Germany, but 10% of all employees.[37]

35. The IAB (in English Institute for employment Research) is the research institute of the Federal Employment Services in Germany.

36. For 1995, the employment statistics cover about 79of all employed persons in Western Germany and about 86% in Eastern Germany, (Bender, Haas and Klose, 2000).

37. Population weights, which are the inverse of the sample selection probabilities, are available for empirical analysis.

Interviewers ask about 80 questions each year on topics including: detailed information on the decomposition of the work-force (gender, skill, blue-collar vs. white-collar, part-time employees, apprentices, civil servants, owners) and its development through time; business activities (total sales, input materials, investment, exports, profit situation, expectations, whether plant does R&D, product and process innovations, organizational changes, technology of machinery, adopted plant policies/strategies); training and further education; wages; lots of information on working time (standard working time, overtime, percentage of employees working overtime, percentages of employees working on Saturdays, working on Sundays, working on shifts, and working with a flexible working time schedule); and general information about the plant (whether plant is subunit of a firm, ownership, birth year, existence of works council, whether plant applies bargaining agreement, whether plant has been merged with or split from another plant in the last year, three-digit industry affiliation, region). While most questions are asked yearly (or on a two-year/ three-year basis), some topics have been surveyed only once.[38]

This study uses observations from the manufacturing sector of the 2000 and 2001 waves of the IAB panel. The regression analysis, however, is only carried out with the latter wave, since we do not observe information on Internet access in 2000. This leaves approximately 7700 observations for the descriptive statistics and 3500 observations for the regression analysis. Altogether, in 1999 there were 336,000 plants (which employed at least one employee subject to social security) in the German manufacturing sector covered.[39] Our sample accounts for approximately 1% of these plants, but for 12% of its workforce and for 11% of its value added.

As indicated in Table 1, the German data permit the measurement of each concept captured by the U.S. data. For the most part, the measurement methodology has been completely harmonised so that the measures are comparable across the countries. A notable exception is employee access to the Internet. Instead of measuring of the percentage of workers that have access to the Internet as in the U.S. data, the German data has a categorical variable on the proportion of workers with Internet access (none, some, half, most, all). Finally, we have converted German measures into dollars using an aggregate PPP measure (OECD, *Main Economic Indicators* 2002).

Confirming the finding of the previous chapter, one difference that is immediately apparent in our comparison here is that the typical U.S. establishment is much larger than its German counterpart (Table 2). We also find that the share of non-production workers (an indirect measure of skill) is larger in Germany relative to the U.S. but this level comparison may not warrant much attention given the potential differences in how production and non-production workers are defined (e.g., in Germany the distinction is based upon hourly wage workers vs. salaried workers while the BLS definition refers more to the type of activity). Productivity and payroll per worker are higher in the U.S. but there is greater dispersion in productivity and payroll per worker in Germany (but see cautions below about simple comparisons of dispersion measures across countries). Total equipment investment per worker is higher in the U.S. but computer investment per worker is higher in Germany. However, here the U.S. exhibits much greater dispersion for both measures of investment relative to Germany. For the most part, the industry rankings on the various measures are similar across the countries although there are some notable exceptions (Table 3).

38. Information on internet access, for example, is only available for 2001.

39. Sourece: IAB-Betriebsdatei, own calculations.

Table 2a: U.S. Descriptive Statistics (weighted by sample weights)				
Statistic:	Mean	Standard Deviation	10th Percentile	90th Percentile
Age (years)	9.45	3.024	4	11 +
Employment	140.1	402.50	15 *(freq=121)*	*288 (freq=19)*
Skill (Proportion of non-production workers)	0.277	0.191	0.071	0.540
Employee Internet Access (percentage)	0.210	0.263	0.000	0.600
Total Equipment Investment per Worker ($1000)	7.927	41.380	0.344	14.938
Total Comp uter Investment per Worker ($1000)	0.455	5.113	0.000	0.925
Log labour Productivity: VA per Worker	4.325	0.758	3.536	5.173
Log Payroll per worker	3.480	0.402	2.972	3.973

Table 2b: German Descriptive Statistics (weighted by sample weights)				
Statistic:	Mean	Standard Deviation	10th Percentile	90th Percentile
Age (years)	9.7	2.99	5	12
Employment	28.95	229.75	2	47
Skill (Proportion of non-production workers)	0.32	0.34	0	1
Employee Internet Access (categorical; 1=all, 5=none)	2.83	1.7	1	5
Total Equipment Investment per Worker ($ 1000)	7.05	23.6	0	14.61
Total Computer Investment per Worker ($ 1000)	0.78	2.71	0	1.97
Log labour Productivity: VA per Worker ($ 1000)	3.63	0.9	2.49	4.59
Log Payroll per Worker ($ 1000)	2.92	0.63	2.05	3.61

Table 3a: U.S. Means by STAN Industry (weighted by sample weights)

Stan Industry	Age	Number of Estabs.	Emp.	Skill	Internet Access	Investment Per worker	Computer Investment. Per worker	Labour Productivity	Log Payroll per Worker
Air & Spacecraft	9.8	242	731.7	0.376	0.378	4.954	0.552	4.576	3.753
Basic Metals	9.4	1282	234.9	0.223	0.183	8.741	0.338	4.395	3.526
Shipbuilding	8.5	119	353.7	0.153	0.137	1.887	0.251	4.004	3.439
Chemicals	9.3	2211	135.3	0.384	0.352	23.362	0.782	4.949	3.694
Petroleum & Oth. Fuels	10.4	163	219.8	0.400	0.450	29.010	0.772	5.570	3.965
Electrical Machinery	9.6	930	201.9	0.359	0.339	5.626	0.821	4.383	3.545
Fabricated Metal	9.7	3547	84.5	0.244	0.156	4.712	0.300	4.256	3.503
Food and Beverages	9.7	2788	192.1	0.292	0.139	9.106	0.289	4.545	3.358
Machinery & Equipment N.E.C.	9.0	3584	113.4	0.303	0.240	5.642	0.722	4.340	3.623
MFG. N.E.C.	9.2	2035	90.3	0.277	0.168	3.992	0.239	4.042	3.341
Medical and optical Instruments	9.3	933	172.8	0.456	0.437	4.505	0.867	4.439	3.605
Motor Vehicles	9.3	973	368.1	0.230	0.172	6.459	0.302	4.373	3.527
Computer and Office Equip	8.2	155	350.7	0.551	0.632	7.154	1.995	4.623	3.750
Non-Metallic Minerals	9.2	2080	73.3	0.228	0.131	16.896	0.236	4.546	3.495
Pulp, Paper, Publishing	9.7	3028	100.9	0.288	0.275	7.276	0.559	4.296	3.538
Radio & Telecommunications Equipment	8.9	655	240.6	0.338	0.362	10.259	0.750	4.371	3.545
Rubber and Plastics	9.3	2251	120.4	0.222	0.163	7.515	0.263	4.218	3.373
Textiles, Leather, Footwear	9.2	1656	148.0	0.206	0.128	3.816	0.263	3.880	3.125
Wood Products	9.2	1539	87.1	0.177	0.089	6.773	0.327	4.054	3.281

Table 3b: German Means by STAN Industry (weighted by sample weights)									
Stan Industry	Age	Number of Estabs.	Emp.	Skill	Internet Access	Investment	Computer Investment Per worker	Labour Productivity	Log Payroll per Worker
Bas Metals	9.6	548	59.7	0.211	2.606	10.072	0.631	3.688	3.044
Coke, Ref Pet Prod, Nuc Fuel, Chemicals, Chem Prod	9.6	497	73.3	0.526	2.319	10.1	1.806	4.288	3.192
Fab Met Prod	10	965	24	0.208	3.116	9.447	0.478	3.742	3.105
Food, Beverage, Tobacco	10.2	858	17.4	0.319	3.061	5.572	0.334	3.281	2.645
Mach & Equip/N.E.C.	8.8	991	42	0.39	2.757	12.389	1.418	3.921	3.155
Manuf Nec/ Receycling	9.5	454	15.3	0.186	2.704	5.885	0.462	3.311	2.669
Med, Prec and Opt Instr	9.6	448	13.5	0.444	2.621	2.993	0.594	3.591	2.95
Mot Veh, Trail and Semis	8.5	362	161.1	0.208	3.099	8.753	0.546	3.725	2.95
Office, Act , Comp Mach; Elec Mach & Appar/Nec; Radio, Tele & Comm Equip	9.1	602	47.1	0.402	2.338	5.174	1.443	3.839	3.135
Other Non-Metallic Min Prod	9.5	453	20.6	0.354	3.101	9.405	0.958	3.635	2.815
Other Transport	10.2	169	46	0.21	2.687	8.067	1.064	3.87	2.957
Pulp, Paper, Printing Pub	9.8	470	26.8	0.49	2.468	7.831	1.86	3.801	3.144
Rubber and Plastics Products	9.8	425	48.7	0.192	2.393	6.784	0.721	3.703	3.069
Textiles, Leather, Footwear	10.2	307	19	0.353	3.56	2.616	0.419	3.504	2.656
Wood Products	9.9	505	12.6	0.146	2.876	4.33	0.262	3.482	2.773

While these summary statistics are useful and the cross-country comparisons of some interest, we base our subsequent analysis on a difference in difference approach (i.e., difference between low and high tech businesses in U.S. vs. difference between low and high tech in Germany). The level comparisons across the countries may be plagued by a variety of measurement problems (e.g., the appropriate price deflator conversion across the countries) and thus we have much greater confidence in the results that rely on differences in differences. In this regard, we especially note that the differences in dispersion across the countries may reflect differences in the degree of measurement error as well as differences in the size distribution or other factors across countries. Thus, we do not put much emphasis on the differences in the levels of dispersion, in say, productivity between the U.S. and Germany reported in Table 2.

In what follows, we seek to relate the use of advanced technology to outcomes like productivity and wages at the micro level. Given limitations of available data, the question is how to characterize advanced technology. In what follows, we rank establishments on the basis of their equipment investment per worker and computer investment per worker. Since both of these measures are not quite what we would like (which instead might be a measure of the stock of high tech capital per worker) and are quite noisy measures in their own right, we use these measures to create a set of technology groups similar to that used in Doms, Jarmin and Klimek (2002). Specifically, for each measure we create 3 groups: (i) zero investment; (ii) low investment (below the 75^{th} percentile); and high investment (above the 75^{th} percentile). We choose to classify high investment establishments as those to the right of the 75^{th} percentile since the investment distributions are so skewed. In turn, we interact these 3 groups to consider six possible combinations. As will become clear, we also use the same technology groups for the German data. In addition, these non-parametric measures are likely to be more comparable across countries.

One point that is worth emphasizing in this context is that the computer investment by itself is likely to be an inadequate measure of the use of advanced technology beyond the obvious problem that we have a flow rather than a stock measure. The computer investment measure only captures the direct spending on computers but does not include the spending on equipment with imbedded advanced technology (e.g., semi-conductors). Prior research using the Survey of Manufacturing Technology (see, e.g., Dunne, 1994) finds that direct spending on computers misses a substantial amount of the investment in high technology equipment. Accordingly, we focus on both total equipment expenditures as well as computer investment expenditures.

With these remarks in mind, it is clear that these measures are imperfect. As a sensitivity check in what follows, we also report results where we use investment in highway vehicles (i.e., cars and trucks - which, like computers, are components of equipment investment) to see whether the results we are finding for so-called advanced technology also apply to for not so advanced technologies such as cars and trucks. This experiment is similar to that performed by DiNardo and Pischke (1997). Obviously, if similar results also hold for vehicle s this would raise substantial questions as to whether our measures of IT investment are capturing advanced technology. Unfortunately, due to data limitations we can do this for the U.S. only.

2. The Relationship between productivity, wages and advanced technology

We begin our micro comparison of the U.S. and Germany by examining the empirical relationship between labour productivity and measures of the choice of technology at businesses including the role of advanced technology and the skill mix of the workforce. In a like manner, we examine the relationship between payroll per worker and these same factors.

Tables 4 and 5 present the results from simple descriptive regressions with labour productivity (log value added) as the dependent variable and measures of the use of technology and the skill mix as right hand side variables. Table 4a presents results for the U.S. while Table 4b presents results for Germany. As discussed in the prior section, we define technology groups in a non-parametric fashion using the equipment investment and computer investment per worker measures. We also include as RHS variables the skill mix (share of non-production workers in the total workforce), a measure of Internet access (as noted in the previous section, these measures are not directly comparable across the countries), and the interaction of the skill mix and the Internet access variable. Also, all regressions include controls for size, age, multi-unit status (a dummy variable indicating whether or not the establishment is owned by a multi-location company), a 2-digit STAN industry code and (for Germany) a dummy indicating that plant is located in East Germany.

In the tables, results are presented on un-weighted, sample weighted, and employment weighted (including sample weighted) basis. Our primary interest is in the employment-weighted specification since these results are the most relevant for the analysis for the other chapters. That is, the weighted results generate aggregate measures of labour productivity comparable to the aggregate industry measures analysed in prior chapters. However, the other specifications are also of interest as it is useful to consider the nature of the relationships when all establishments are treated equally regardless of size. Interestingly, the results are largely the same across these three specifications so our discussion of the employment-weighted results yields a reasonable depiction for all 3 cases.

Table 4a: U.S. Cross Sectional Labour Productivity Regressions

Dependent Variable: Log((TVS-CM)/TE)

Variable		UNWEIGHTED	WEIGHT=SAMPLE WEIGHT	WEIGHT=SAMPLE WEIGHT*TE
		Coefficient Estimate (Std. Error)	Coefficient Estimate (Std. Error)	Coefficient Estimate (Std. Error)
Investment class: Total Equipment / IT	0 / 0	-0.598 (0.125)	-0.636 (0.083)	-0.669 (0.160)
	Low / 0	-0.445 (0.019)	-0.457 (0.021)	-0.461 (0.018)
	High / 0	-0.116 (0.023)	-0.079 (0.025)	-0.157 (0.023)
	Low / Low	-0.497 (0.019)	-0.474 (0.020)	-0.513 (0.017)
	Low / High	-0.369 (0.020)	-0.323 (0.022)	-0.414 (0.019)
	High / Low	-0.108 (0.023)	-0.120 (0.026)	-0.074 (0.021)
	High/ High	Omitted	Omitted	Omitted
% of Employment with Internet Access		0.513 (0.030)	0.376 (0.032)	0.524 (0.028)
% of Non-production Workers (skill)		0.098 (0.036)	0.072 (0.033)	0.154 (0.037)
Interaction		-0.440 (0.076)	-0.090 (0.075)	-0.451 (0.069)
Number of Observations		22,704	22,704	22,704
R^2		0.245	0.218	0.259

Source: Authors calculations from the1999 CNUS and 2000 ASM, Center for Economic Studies.

Notes: All regressions also control for size, age, STAN industry and multi-unit status.

Table 4b: German Cross Sectional Labour Productivity Regressions

Dependent Variable: (Log) Value Added, 3261 obs

Variable		**Unweighted.**		**Weight= Sample Weight**		**Weight=Sample Weight*TE**	
		Coeff.	(Std. Error)	Coeff.	(Std. Error)	Coeff.	(Std. Error)
Investment Class	0/0	-0.296	(0.05)	-0.358	(0.112)	-0.287	(0.068)
(High/High omitted)	Low/0	-0.433	(0.055)	-0.516	(0.117)	-0.434	(0.077)
	High/0	-0.132	(0.062)	-0.09	(0.135)	-0.176	(0.096)
	Low/Low	-0.33	(0.038)	-0.384	(0.101)	-0.393	(0.055)
	Low/High	-0.259	(0.043)	-0.388	(0.115)	-0.31	(0.058)
	High/Low	-0.131	(0.047)	-0.335	(0.131)	-0.172	(0.062)
Internet Access	most	-0.082	(0.071)	-0.023	(0.128)	0.165	(0.098)
(all omitted)	half	-0.137	(0.079)	0.063	(0.159)	-0.053	(0.149)
	a few	0.008	(0.059)	-0.023	(0.12)	0.163	(0.076)
	none	-0.062	(0.065)	-0.086	(0.121)	0.09	(0.104)
% of non-production workers		0.64	(0.092)	0.534	(0.169)	0.978	(0.133)
Interaction	most	0.163	(0.185)	0.288	(0.279)	-0.333	(0.229)
% of non-production /Internet	half	0.294	(0.194)	-0.39	(0.373)	0.029	(0.322)
Access	a few	-0.103	(0.161)	-0.016	(0.265)	-0.585	(0.201)
	none	-0.573	(0.19)	-0.419	(0.302)	-0.828	(0.257)
R^2		0.245		0.182		0.315	

Source: Authors calculations from the 2001 wave of the IAB Establishment Panel.
Notes: All regressions also control for size, age, STAN industry, multi-unit status and East Germany.

Table 5a: U.S. Cross Sectional Average Payroll Regressions

Dependent Variable: Log(Payroll/TE)

Variable		**Un-weighted** Coefficient Estimate (Std. Error)	**Weight=Sample Weight** Coefficient Estimate (Std. Error)	**Weight=Sample weight*TE** Coefficient Estimate (Std. Error)
Investment class: Total Equipment / IT	0 / 0	-0.273 (0.059)	-0.293 (0.043)	-0.288 (0.077)
	Low / 0	-0.204 (0.009)	-0.233 (0.010)	-0.240 (0.008)
	High / 0	-0.070 (0.010)	-0.095 (0.013)	-0.045 (0.011)
	Low / Low	-0.228 (0.009)	-0.238 (0.010)	-0.261 (0.008)
	Low / High	-0.127 (0.010)	-0.148 (0.011)	-0.165 (0.009)
	High / Low	-0.068 (0.011)	-0.077 (0.013)	-0.067 (0.010)
	High/ High	Omitted	Omitted	Omitted
% of Employment with Internet Access		0.215 (0.014)	0.192 (0.016)	0.219 (0.014)
% of Non-production Workers (skill)		0.340 (0.017)	0.235 (0.017)	0.349 (0.018)
Interaction		-0.001 (0.036)	0.198 (0.038)	-0.006 (0.033)
Number of Observations		22,947	22,947	22,947
R^2		0.283	0.257	0 408

Source: Authors calculations from the1999 CNUS and 2000 ASM, Center for Economic Studies.

Notes: All regressions also control for size, age, STAN industry and multi-unit status.

Table 5b: German Cross Sectional Average Payroll Regressions

Dependent Variable: (Log) Payroll per Worker, 3134 obs

Variable		**Un-weighted**		**Weight= Sample Weight**		**Weight=Sample Weight*TE**	
		Coeff.	(Std. Error)	Coeff.	(Std. Error)	Coeff.	(Std. Error)
Investment Class	0/0	-.117	(.025)	-.102	(.081)	-.111	(.036)
(High/High omitted)	Low/0	-.081	(.024)	-.050	(.080)	-.104	(.035)
	High/0	.012	(.032)	.102	(.098)	.018	(.042)
	Low/Low	-.079	(.017)	-.096	(.073)	-.141	(.031)
	Low/High	-.044	(.022)	-.197	(.099)	-.032	(.024)
	High/Low	-.021	(.020)	.080	(.088)	-.030	(.027)
Internet Access	most	.026	(.029)	.163	(.082)	.124	(.056)
(all omitted)	half	.071	(.043)	.346	(.103)	.068	(.115)
	a few	.060	(.028)	.072	(.099)	.107	(.061)
	none	.031	(.035)	.044	(.084)	.055	(.069)
% of non-production workers		.358	(.053)	.220	(.121)	.582	(.103)
Interaction	most	.092	(.074)	.192	(.173)	-.17	(.122)
% of non-production /Internet	half	-.124	(.106)	-.382	(.210)	-.173	(.231)
Access	a few	-.037	(.084)	.091	(.230)	-.183	(.140)
	none	-.615	(.134)	-.624	(.228)	-.713	(.170)
R^2		0.353		0.301		0.342	

Source: Authors calculations from the 2001 wave of the IAB Establishment Panel.

Notes: All regressions also control for size, age, STAN industry, multi-unit status and East Germany.

In both countries, use of advanced technology (defined using the technology groups described in section II with appropriate caveats) and the use of more skilled workers are associated with higher labour productivity. Also, in the U.S., the interaction of Internet access and the skill mix is (somewhat surprisingly) negative while the interaction effects in Germany are more difficult to decipher, as the effects are not monotonic and often statistically insignificant.[40] Still, at first glance, it is striking that the overall patterns are so similar across the two countries.

While the patterns across the countries are broadly similar, the quantitative effects are different in some interesting ways. In particular, our reading of the results is that the use of advanced technology yields a greater increase in labour productivity in the U.S. compared to Germany. We base this inference on the difference between the labour productivity of the highest technology group (High/High) and the lowest technology group (0/0). In the U.S., the productivity premium for being "High/High" is 67 log points in the U.S. and 29 log points in Germany. In a like manner, the productivity premium for being "High/High" relative to "Low/Low" is 51 log points in the U.S. and 39 points in Germany.

Some of the intermediate comparisons are less clear-cut. For example, conditional of the level of total equipment investment there is an additional productivity premium for U.S. establishments with high computer investment per worker of approximately 7 to 10 log points. These effects are estimated less precisely for Germany. According to the point estimates, a business with high computer investment per worker has, conditional on the level of total equipment investment, a productivity premium of between 8 to 17 log points. Alternatively, conditional on computer investment, there is a bigger productivity premium from an increase in total equipment per worker in the U.S. relative to Germany. That is, conditional on computer investment per worker, the productivity premium in going from low to high equipment investment is between 41 and 44 log points in the U.S. and 14 and 31 log points in Germany. We think these intermediate/conditional comparisons are interesting but place more emphasis on the comparisons based upon using the combined impact of total equipment and computer investment spending (e.g., High/High vs. 0/0) given the limitations of the measures.

Internet access has a slightly larger quantitative effect in the U.S. than Germany. While the differences in the measurement of the variables make this a bit difficult to compare, consider that in the U.S. going from the 10^{th} percentile plant to the 90^{th} percentile plant (see Table 2a) yields an increase in Internet access from 0 percent to 60 percent of the workforce. Using the coefficients from Table 4a suggests this is associated with an increase in productivity of approximately 24 log points (this calculation takes into account the negative interaction effect). In Germany, an increase from none to half or most (which is roughly equivalent in going from 0 to 60 percent) yields according to Table 4b coefficients an increase in productivity of between 13 to 23 log points.[41]

In terms of other effects of interest, in both countries an increase in the skill mix is associated with an increase in productivity and in this case the quantitative effect is much larger in Germany.[42] Also, as noted the interaction between Internet access and the skill mix is negative[43] in the U.S. while the effect is

40 The surprising negative interaction effect may in part be related to the fact that the non-production worker mix is a poor proxy for the skill mix. For example, the non-production worker mix includes clerical workers. Put differently, the interaction effect may be picking up composition effects within the two broad categories of workers that we measure.

41 The interaction effects for Germany are imprecisely estimated so appropriate caution required about this comparison. However, we have estimated these specifications without the interaction effects and the quantitative estimated impact is still approximately the same.

42 This measure of skill is quite crude but the only one we have available readily for both countries. For Germany, there are alternative measures of skill and somewhat surprisingly we find that when we include these alternative measures of skill instead of this measure that we find less of an impact of a change in skill on productivity.

43 Interestingly, the negative interaction term for the U.S. implies that the marginal impact of increased skill, as measured by the share of non-production workers, on productivity is negative for a significant number of establishments with high levels of

not monotonic in Germany. Going from "none" to "all" Internet access does yield a positive interaction effect in Germany.

Tables 5a and 5b present analogous results based on payroll per worker for the two countries. Interestingly, the findings suggest that productivity differences are also reflected in wage differences along the same dimensions (i.e. the RHS variables in the regressions) especially in U.S. As is typically the case in these types of regressions, appropriate caution needs to be given to the interpretation. It is likely the case that U.S. high tech firms are especially high skill firms and the production/non-production distinction only captures part of the skill differences across firms. Existing studies (e.g., Doms, Dunne and Troske, 1997); and Abowd, Haltiwanger, Lane and Sandusky, 2001) suggest that this pattern holds in the U.S. Alternatively, it may be that there is some rent sharing of "success" from adopting advanced technology. In looking at the quantitative patterns, the wage gaps tend to be smaller than productivity gap. For example, the wage gap between 0/0 gap and High/High group is 0.288 for U.S. and only 0.111 for Germany. One possible explanation for the apparent greater compression of wages relative to observables in Germany is that this is due to the wage setting institutions in Germany (and Europe more generally) that reduces the flexibility of relative wages and thus reduces experimentation in Europe.

As we have noted, appropriate caution needs to be exercised in interpreting these results since measuring advanced technology *via* equipment investment and computer investment per worker groups is imperfect. For some sensitivity analysis, for the U.S., we also considered the analysis defining the six groups using investment in trucks as opposed to the investment in computers. We estimate the same productivity and payroll per worker regressions as in Tables 4a and 5a using the investment category groups defined using investment in "low-tech" equipment – highway vehicles (cars and trucks). While the results (not reported here) for total equipment investment were more or less unchanged (as expected) we find no productivity of wage premium at establishment with high investment in highway vehicles. As such, this gives us more confidence that there is information content in the computer investment data we are exploiting in this analysis. Unfortunately, the data do not support a similar exercise for Germany.

In sum, there are striking similarities in overall patterns but some notable differences in the quantitative effects in examining the relationship between outcomes like productivity and payroll per worker and measures of the use of advanced technology via equipment expenditures, computer expenditures and internet access. In both the U.S. and Germany, the high productivity workplaces are the high skill and high tech workplaces. In the U.S., the differences in technology use account for more variation across businesses in productivity and payroll per worker. In what follows, we treat these results as a backdrop to investigate the focus of this chapter – do we observe a greater degree of experimentation in the U.S. relative to Germany?

3. Experimentation? Differences across Germany and the U.S.

The Role of Establishment Age

As discussed in the introduction of this chapter and in earlier chapters, a key theme/hypothesis is that the U.S. exhibits greater market experimentation, which might help explain its stronger growth performance in a period of rapid diffusion of the a new general purpose technology (ICT). One way to explore this idea is to examine the nature of experimentation for entrants and young businesses. New businesses are inherently experimenting as they are beginning to produce goods or services at a new location. However,

Internet access. Our prior hypothesis was that Internet access and skill would interact positively. This may yet be the case and our finding may be due to imperfections in our measures – especially for skill as noted above. An alternative and somewhat whimsical interpretation is that the web-surfing by the non-production workers is decreasing productivity.

the incentives for experimentation may vary across institutional environments. In environments that especially encourage experimentation, we would expect to see greater dispersion in both choices and outcomes for young and new businesses.

Tables 6 and 7 present means and standard deviations of the key measures by establishment age. Results in Table 6 suggest that means do not vary systematically with age with a few notable exceptions. For the U.S., we see the result obtained in earlier chapters that new businesses are small relative to their mature counterparts. This finding does not hold for Germany. In addition, it does appear that high-tech investment spikes for young businesses and then exhibits mild u-shaped behaviour.

Table 7 show that productivity dispersion falls systematically with age in U.S. but that this pattern does not hold for Germany.[44] The magnitude of the change in dispersion is substantial in U.S. For the U.S., the decrease in dispersion measured by the standard deviation from the youngest to the most mature businesses is about 0.22. A reduction in 22 log points is substantial but small relative to the overall dispersion in productivity. For the U.S., we also see similar patterns for dispersion in payroll per worker. That is, more mature businesses have less between plant dispersion in payroll per worker in U.S. Again, Table 7(b) shows no systematic pattern in dispersion of payroll per worker in Germany.

While we observe greater dispersion in productivity and payroll per worker for young businesses in the U.S., we do not observe striking differences in the dispersion of technology investment and skill mix patterns by establishment age in the U.S. There is evidence that equipment investment per worker is more dispersed for young businesses relative to mature businesses but there is less of a systematic pattern for computer investment.

44 In unreported results, we have calculated the statistics in Table 7 (and Table 6) using industry controls. That is, before calculating the statistics, we deviate each measure from the relevant industry-specific (2-digit STAN mean). We find the same basic patterns in the results. In particular, even controlling for industry, we find that productivity dispersion falls systematically with age in the U.S. but it does not fall in Germany. For example, for the U.S. the standard deviation of log productivity decreases from 0.92 for the youngest plants to 0.67 for the most mature plants while the equivalent statistics for Germany are 0.54 (youngest) and 0.59 (most mature). The patterns for other variables are similar as well. We also repeated the exercise using the employment weighted distribution and found similar patterns.

Table 6a:U.S. Means by Establishment Age (weighted by sample weights)												
Age (years)	0	1	2	3	4	5	6	7	8	9	10	11
Number of Establishments	843	1297	751	588	561	547	518	520	629	620	634	23694
Employment	86.9	80.6	80.5	84.4	89.8	88.3	113.5	99.2	88.8	111.5	102.6	157.2
Skill (Proportion of non-production workers)	0.24	0.27	0.26	0.26	0.28	0.25	0.24	0.30	0.28	0.28	0.27	0.28
Employee Internet Access (percentage)	NA	0.26	0.21	0.19	0.22	0.21	0.23	0.26	0.24	0.22	0.23	0.21
Total Equipment Investment ($1000)	1162.3	845.3	1242.8	890.2	948.0	846.2	952.2	647.2	641.7	819.7	910.0	1400.6
Total Computer Investment ($1000)	55.4	44.6	48.2	62.9	47.0	63.3	52.9	55.2	45.9	68.5	64.9	85.8
Total Equipment Investment per Worker ($1000)	36.47	15.38	17.12	11.60	7.19	7.78	9.07	9.70	9.43	6.40	7.03	6.52
Total Computer Investment per Worker ($1000)	0.85	0.61	0.64	1.02	0.37	0.48	0.41	0.44	0.41	0.38	0.58	0.42
Log labour Productivity: VA per Worker	4.34	4.29	4.37	4.33	4.35	4.26	4.12	4.27	4.17	4.25	4.30	4.35
Log Payroll per Worker	3.38	3.32	3.34	3.37	3.38	3.35	3.37	3.45	3.42	3.37	3.38	3.52

Source: Authors calculations from 1999 CNUS and 2000 ASM, Center for Economic Studies.

Table 6b: German Means by Establishment Age												
Age (years)	1	2	3	4	5	6	7	8	9	10	11	12
Number of Establishments	92	197	250	231	250	292	337	447	581	621	2465	2256
Employment	20.34	22.5	18.35	18.79	15.27	18.45	15.65	15.91	22.02	21.64	32.78	35.65
Skill (Proportion of non-production workers)	0.23	0.32	0.26	0.38	0.25	0.31	0.38	0.34	0.31	0.34	0.32	0.33
Employee Internet Access (1-5 categories)	2.96	2.85	2.43	2.32	3.16	2.55	2.73	2.54	2.46	2.91	3.12	2.88
Total Equipment Investment ($1000)	694.18	350.38	394.06	293.31	117.16	309.89	148.39	159.64	190.73	225.97	283.23	375.33
Total Computer Investment ($1000)	32.23	28.02	93.06	69.79	14.4	20.56	15.96	16.81	17.46	17.94	37.63	35.82
Total Equipment Investment per Worker ($1000)	17.09	8.23	15.01	6.93	7.07	5.45	10.47	7.27	5.52	13.53	6.21	5.78
Total Computer Investment per Worker ($1000)	1.09	0.65	0.56	0.89	0.46	1.21	1.43	1.27	0.51	0.67	0.84	0.59
Log labour Productivity: VA per Worker ($ 1000)	3.3	3.36	3.42	3.47	3.77	3.55	3.77	3.77	3.58	3.48	3.66	3.65
Log Payroll per Worker ($ 1000)	2.82	2.72	2.66	2.62	2.82	2.83	2.95	2.92	2.87	2.74	2.92	3.03

Source: Authors calculations from the 2000 and 2001 waves of the IAB establishment Panel.

Table 7a: U.S. Standard Deviations by Establishment Age (weighted by sample weights)												
Age (years)	0	1	2	3	4	5	6	7	8	9	10	11
Number of Establishments	843	1297	751	588	561	547	518	520	629	620	634	23694
Employment	277.7	140.4	176.0	140.3	203.7	172.0	400.4	624.8	366.3	304.6	199.7	432.5
Skill (Proportion of non-production workers)	0.20	0.21	0.20	0.20	0.22	0.18	0.19	0.24	0.22	0.20	0.20	0.18
Employee Internet Access (percentage)	NA	0.29	0.29	0.26	0.27	0.26	0.28	0.33	0.29	0.27	0.28	0.26
Total Equipment Investment ($1000)	5588.0	4732.8	9679.5	6101.5	9335.6	3961.5	5615.5	3437.5	3129.8	3783.8	4213.9	11588.7
Total Computer Investment ($1000)	469.8	269.2	327.3	448.4	284.5	416.4	346.3	686.7	484.5	656.2	442.2	1054.7
Total Equipment Investment per Worker ($1000)	151.8	72.80	85.28	26.77	31.89	18.38	49.29	88.11	80.50	15.81	18.70	27.16
Total Computer Investment per Worker ($1000)	4.16	3.18	4.40	3.67	1.31	1.47	2.66	1.16	2.10	1.76	1.97	5.75
Log labour Productivity: VA per Worker	0.94	0.89	0.84	0.88	0.85	0.73	1.18	0.78	0.80	0.79	0.72	0.72
Log Payroll per Worker	0.50	0.51	0.48	0.46	0.46	0.37	0.44	0.47	0.38	0.39	0.41	0.38

Source: Authors calculations from 1999 CNUS and 2000 ASM, Center for Economic Studies.

Table 7b: German Standard Deviations by Establishment Age												
Age (years)	1	2	3	4	5	6	7	8	9	10	11	12
Number of Establishments	92	197	250	231	250	292	337	447	581	621	2465	2256
Employment	99.73	148.08	117.03	178.06	71.54	100.07	49.46	46.71	59.25	67.83	237.12	309.48
Skill (Proportion of non-production workers)	0.25	0.36	0.33	0.40	0.34	0.36	0.41	0.39	0.34	0.38	0.32	0.34
Employee Internet Access (1-5 categories)	1.83	1.81	1.68	1.65	1.70	1.66	1.64	1.53	1.65	1.63	1.71	1.70
Total Equipment Investment ($1000)	21635.97	3438.17	6559.35	8679.07	764.23	13690.35	1024.23	954.70	1600.43	2047.34	3231.78	21851.71
Total Computer Investment ($1000)	321.10	314.09	5481.75	3320.81	130.09	203.26	129.86	78.15	166.20	144.88	785.03	1017.27
Total Equipment Investment per Worker ($1000)	33.64	25.94	48.15	14.70	18.72	11.57	34.03	17.65	13.11	54.68	18.64	19.37
Total Computer Investment per Worker ($1000)	3.19	1.39	5.24	3.86	1.75	3.10	4.46	2.57	1.40	1.60	3.05	1.60
Log labour Productivity: VA per Worker ($ 1000)	0.67	0.83	0.83	1.03	0.98	0.76	0.83	0.97	0.83	0.82	0.91	0.90
Log Payroll per Worker ($ 1000)	0.53	0.78	0.70	0.74	0.67	0.65	0.58	0.62	0.57	0.56	0.62	0.59

Source: Authors calculations from the 2000 and 2001 waves of the IAB establishment Panel.

The Role of Active Learning – Differentiating between businesses actively changing their technology and others

Businesses that are actively changing their technology are also inherently experimenting. There is uncertainty about the best way to implement a new technology and/or whether the business in question is capable of implementing the new technology in a successful manner. However, again the market and institutional environment may provide different incentives for experimentation. If adjustment costs from institutional factors limit flexibility then businesses may choose a lower mean, lower risk strategy of implementation.

For this analysis, we use the technology groups that we used in the simple regression analysis in the previous section. For example, businesses that are most actively engaged in changing their technologies are the "High/High" group – those businesses that are above the median in both equipment investment per worker and computer investment per worker.

Tables 8 and 9 present differences in means and standard deviations for choices and outcomes by these technology groups for the U.S. and Germany. In terms of means, businesses that are more actively changing their technology in both countries have higher productivity, higher payroll per worker, a higher skill mix, and have more workers with access to the Internet (an alternative technology measure in its own right). The differences in the means are more pronounced in the U.S.

The striking differences between the U.S. and Germany are seen in Table 9. In the U.S., the businesses most actively changing their technology have greater dispersion in productivity, payroll per worker, the skill mix of workers, computer and equipment investment per worker, and the internet access relative to those businesses less actively changing their technology (e.g., the "0/0" group or the "Low/Low" group). The differences in dispersion are large in magnitude. For example, for productivity the increase in dispersion from the "0/0" technology group to the "High/High" technology group is almost 40 log points. Strikingly, these patterns do not hold for Germany where there is no systematic relationship between the nature of changes in technology and the patterns of dispersion.

To explore these findings further, we use the results from section III that relate the characteristics of the business to the productivity differences. In particular, we use the regression results in Table 4 to examine how much of the changes in productivity dispersion across technology groups can be accounted for by changes in the dispersion of characteristics across businesses (e.g., skill mix, internet access, computer investment and equipment investment per worker) and how much is accounted for by unobservable factors. Table 10 presents the results of this exercise. Interestingly, both observable and unobservable factors help account for the increasing dispersion with pace of technology change in the U.S. These results are consistent with the view that experimentation occurs over both observable and unobservable dimensions. That is, the contribution of observables may reflect the role of experimentation as businesses try different ways of conducting business. Alternatively, the role of the unobservables might be interpreted as suggesting that those businesses most actively changing their technology face considerable uncertainty about how best to change the technology and whether they have the "ability" to change the technology successfully. Apparently, both observable and unobservable factors are important in the U.S. For Germany, given that there is not a systematic relationship between the pace of technology changes and dispersion, it is harder to interpret the results. However, we do see some modest role for differences due to dispersion in observables but no impact of dispersion in un-observables.

Table 8a: U.S. Means by IT and Total Equipment Investment Categories (weighted by sample weights)

(High Category defined as investment exceeding the 75th Percentile)

Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Number of Establishments	40	9047	2872	10163	4401	2284	2395
Age	9.54	9.41	8.84	9.71	9.53	9.51	8.78
Employment	34.4	101.0	136.7	148.7	149.9	209.1	228.0
Skill: (Proportion of non-production workers)	0.20	0.25	0.24	0.27	0.37	0.25	0.33
Employee Internet Access (Fraction)	0.07	0.16	0.21	0.19	0.34	0.22	0.34
Total Equipment Investment ($1000)	0	282.6	4332.6	396.1	604.5	4322.6	6586.7
Total Computer Investment ($1000)	0	0	0	22.29	195.17	38.81	668.30
Total Equipment Investment per Worker ($1000)	0	2.47	33.32	2.23	3.44	22.34	36.58
Total Computer Investment per Worker ($1000)	0	0	0	0.16	1.44	0.20	3.04
Log labour Productivity: VA per Worker	3.94	4.19	4.73	4.19	4.42	4.65	4.83
Log Payroll per Worker	3.33	3.39	3.56	3.43	3.62	3.60	3.73

Source: Authors calculations from 1999 CNUS and 2000 ASM, Center for Economic Studies.

Table 8b: German Means by IT and Total Equipment Investment Categories

(High Category defined as investment exceeding the 75th Percentile)

Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Number of Establishments	1579	793	450	1727	1057	524	1543
Employment	9.15	14.45	16.54	44.43	34.05	76.33	58.5
Skill: (Proportion of non-production workers)	0.34	0.25	0.24	0.25	0.4	0.26	0.39
Employee Internet Access (Fraction)	3.23	2.94	3.03	2.71	2.2	2.2	2.44
Total Equipment Investment ($1000)	0	36.16	420.16	112.54	119.43	962.77	1467.63
Total Computer Investment ($1000)	0	0	0	12.27	47.35	25.59	209.36
Total Equipment Investment per Worker ($1000)	0	2.69	32.91	2.11	3.1	13.05	25.45
Total Computer Investment per Worker ($1000)	0	0	0	0.29	1.66	0.35	4.15
Establishment Age	9.94	9.53	8.49	9.96	9.85	10.23	9.25
Log labour Productivity: VA per Worker ($1000)	3.45	3.46	3.73	3.57	3.81	3.75	4.03
Log Payroll per Worker ($ 1000)	2.77	2.74	2.93	3.05	3.09	3.13	3.13

Source: Authors calculations from the 2000 and 2001 waves of the IAB establishment Panel.

Table 9a: U.S. Standard Deviations by IT and Total Equipment Investment Categories (weighted by sample weights) ***(High Category defined as investment exceeding the 75th Percentile)***							
Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Number of Establishments	40	9047	2872	10163	4401	2284	2395
Establishment Age	2.935	3.023	3.522	2.781	2.933	2.978	3.561
Employment	33.66	291.45	422.19	396.27	457.50	422.18	669.98
Skill: (Proportion of non-production workers)	0.109	0.179	0.190	0.178	0.213	0.159	0.213
Employee Internet Access (Fraction)	0.153	0.223	0.281	0.235	0.313	0.264	0.321
Total Equipment Investment per Worker ($1000)	0	2.181	103.60	2.065	2.143	64.612	96.252
Total Computer Investment per Worker ($1000)	0	0	0	0.117	12.679	0.125	6.656
Log labour Productivity: VA per Worker	0.572	0.744	0.922	0.606	0.652	0.891	0.944
Log Payroll per Worker	0.239	0.405	0.441	0.356	0.380	0.361	0.414

Source: Authors calculations from 1999 CNUS and 2000 ASM, Center for Economic Studies.

Table 9b: German Standard Deviations by IT and Total Equipment Investment Categories ***(High Category defined as investment exceeding the 75th Percentile)***							
Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Number of Establishments	1579	793	450	1727	1057	524	1543
Employment	28.07	39.56	81.64	169.32	118.44	313.96	409.87
Skill: (Proportion of non-production workers)	0.38	0.31	0.33	0.25	0.34	0.28	0.34
Employee Internet Access (Fraction)	1.81	1.72	1.7	1.54	1.44	1.34	1.54
Total Equipment Investment ($1000)	0	141.99	1963.85	588.83	573.66	4841.08	34957.82
Total Computer Investment ($1000)	0	0	0	45.41	278.73	101.55	3735.69
Total Equipment Investment per Worker ($1000)	0	1.7	60.61	1.67	1.6	9.94	37.35
Total Computer Investment per Worker ($1000)	0	0	0	0.17	1.1	0.14	6.46
Establishment Age	2.77	3.04	3.71	2.9	2.79	2.7	3.27
Log labour Productivity: VA per Worker ($1000)	0.93	0.8	0.85	0.84	0.8	0.66	0.94
Log Payroll per Worker ($ 1000)	0.64	0.66	0.55	0.52	0.65	0.49	0.56

Source: Authors calculations from the 2000 and 2001 waves of the IAB establishment Panel.

Table 10a:U.S. Means and Standard Deviations of Predicted Values and Residuals by IT and Total Equipment Investment Categories (Based on regression in middle column of table 8a)

(High Category defined as investment exceeding the 75th Percentile)

Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Mean of Predicted Values	3.967	4.196	4.720	4.194	4.419	4.669	4.854
Standard Deviation of Predicted values	0.210	0.267	0.321	0.250	0.253	0.298	0.325
Standard Deviation of Residuals	0.448	0.682	0.783	0.555	0.607	0.780	0.750

Source: Authors calculations from 1999 CNUS and 2000 ASM, Center for Economic Studies.

Table 10b: Means and Standard Deviations of Predicted Values and Residuals by IT and Total Equipment Investment Categories (Based on regression in middle column of table 8a)

(High Category defined as investment exceeding the 75th Percentile)

Investment class: Equip / IT	0 / 0	Low / 0	High / 0	Low / Low	Low / High	High / Low	High / High
Mean of Predicted Values	3.553	3.33	3.81	3.603	3.682	3.703	4.104
Standard Deviation of Predicted Values	0.285	0.277	0.309	0.325	0.351	0.293	0.341
Standard Deviation of Residuals	0.856	0.751	0.641	0.804	0.704	0.651	0.818

Source: Authors calculations from the 2001 wave of the IAB establishment Panel.

4. Summary and interpretation

The evidence presented in this chapter suggests U.S. businesses engage in experimentation in a variety of ways in a manner that is not matched by their German counterparts. There is greater experimentation amongst young businesses and there is greater experimentation among businesses actively changing their technology. This experimentation is evidenced in dispersion in productivity and in related dispersion in key choices like skill mix and the role of Internet access. The evidence in this chapter also shows the mean impact of adopting new technology greater in U.S. than in Germany. Putting the pieces together suggests that U.S. businesses choose a higher mean, higher variance strategy in adopting new technology.

There are many caveats and cautions that must be noted for interpreting the results in this fashion. Our measures of technology as well as our measures of outcomes like productivity and wages at the micro level are imperfect and likely subject to both classical and non-classical measurement error. Moreover, the comparison is only for the manufacturing sectors in the U.S. and Germany and largely reflects within country cross-sectional differences across businesses in each country for the year 2000. Whether these results would hold up in a larger cross-country sample or for other years is an open question. In a related matter, the causal link between use of advanced technology and productivity is difficult to determine without longitudinal data and as such our results on the relationship between technology and productivity (and wages) should be interpreted as characterising correlations between the variables of interest. Having noted these cautions, it is striking to us that systematic differences across the countries in the micro data are readily apparent. The covariance structure between productivity and measures of changing technology differ systematically at the micro level across the U.S. and Germany in a manner that is clearly suggestive of the U.S. exhibiting a greater degree of experimentation in the adoption of new technologies.

4. ICT AND GROWTH: THE ROLE OF FACTOR AND PRODUCT MARKETS

Introduction

The economic theory needed to understand the role of ICT is not unified and different mechanisms are needed to explain how growth occurs through different channels (namely, through capital deepening and technology shifts, or through growth in the ICT producing sector). Neoclassical investment theory and more modern versions incorporating uncertainty are needed to understand capital deepening. The nature of demand and tastes for innovation are useful in understanding some of the problems associated with MFP growth. Theories of endogenous growth may shed some light on growth within firms in the ICT producing sector. Further, strategic IO theory can help explain how firms use innovation as a competitive weapon, and how resources move between competing firms and sectors of the economy. Finally, growth models with an evolutionary flavour emphasise that firms grope for the proper configuration of inputs, outputs, and technology in an attempt to profitably serve the market.

While shedding light on the mechanisms underlying the effects of ICT on growth, the models also need to be consistent with the stylised facts displayed in the previous chapters. These include the findings that the US had higher ICT investment intensity than the EU on average during the 1990s. Further, the EU did not enjoy the productivity boom in the late 1990s. At the micro level, entrants are relatively smaller in the US but grow much faster, conditional on survival. Also, the dispersion in a range of indicators among firms with high ICT intensity is larger in US than in the German manufacturing sector. However, in the manufacturing sector, the ICT intensity of US and German firms does not differ much on average. A full model that explains all the features cannot be pulled off the shelf, although the different models described below in turn, exhibit features that can help explain some of the emerging facts.

In the following, the notion that economic advances accrue in some automatic fashion to those that purchase the advanced ICT, is tossed aside resolutely. As stressed by Baily (2002), the adoption of ICT requires explicit innovative actions. Firms producing ICT goods, or making use of ICT both must experiment with their production processes and the characteristics of goods and services produced in order to find a combination that is successful in the market place. Productivity and profitability differences driven by differential efficiencies, costs and customer preferences yield a selection mechanism that sorts out the good from the bad implementations of ICT in the 'research laboratory' that is the market.

Table 1 below shows the channels through which growth is expected to occur, along with the theory needed to understand the mechanisms, and the institutional or policy environment that impinges on the mechanism. In what follows, we first discuss alternative perspectives on the role of ICT – in particular as an investment good and as an innovative activity. Using this discussion, we then describe each of the growth channels in turn. Finally, we discuss the role that market institutions might be playing in impacting these channels of growth.

Table 1. **Growth Channel, theory, and policy**

Channel	Driving force/Theoretical	Area of possible policy
Capital deepening	Investment; growth accounting	Factor markets
MFP		
Innovative adoption of ICT		
Within firms		
Process/product	R&D; strategic IO	Product markets
Internal organisation,	Experimentation; labour	Factor markets
Resource reallocation	General Equilibrium; Strategic	Factor and product markets
Knowledge creation	R&D; Endogenous Growth	Science and Tech. Policy
ICT producers		
Within firm	R&D; endogenous growth,	Factor and product markets
Resource reallocation	General Equilibrium; Strategic	Factor and product markets

1. ICT as an investment good

In Table 4.1, only one channel, that of capital deepening, makes use of investment theory to explain the driving forces behind the effects of ICT. The importance of this channel for the total expected growth effect of ICT is mostly an empirical issue. Growth accounting quantifies the effect by treating ICT investment analogously to other asset purchases and the hiring of other productive inputs. As seen in Chapter 2, the contribution of ICT to growth is much smaller in EU countries than in the US. Most of the difference derives from a lower stock of ICT assets, and thus a lower expenditure share on this input into production, although growth rates of ICT capital services continue to lag somewhat in the EU as well.

The variables that determine the contribution of ICT capital services to growth in the accounting framework include tax rates, asset depreciation, and asset prices, as well as the rate of return on investment. The allocation of resources between ICT capital services and other factors of production also depends on asset prices for other investment types, as well as the wage rate. For this reason, the conditions in the factor markets are important for investment in ICT. In papers by Caballero and Hammour (1998) and Blanchard (2001), bargaining power of workers, or stringent labour market (LM) regulations may push firms away from labour and towards more capital-intensive technologies. There is enough evidence that LM regulations tend to be stricter in most EU countries than in the U.S but there is much less information on how regulations affect the relative share of ICT in total capital input. From the micro-level manufacturing data we do see that investment per worker in individual industries is higher in Germany, but that the ratio of ICT investment to total equipment investment is about the same.

Another variable that plays a role in investment is the uncertainty surrounding returns. With small modifications to the investment function, the option value of waiting before committing to sunk investment can be incorporated into the investment function. In general investment will be lower in a more volatile environment (Dixit and Pindyck, 1994). The effect of this type of uncertainty on the relative investments in ICT and other equipment is not clear. On the one hand, the general-purpose nature of ICT provides exactly the kind of flexibility in future production that options theory calls for. On the other hand, the technological uncertainty of ICT-related investment projects likely is higher than tried-and-true equipment, which would point towards the value of waiting. Although it is proper to consider technological uncertainty as a cause of slow diffusion, this path is not able to explain the differences in ICT intensity across countries, nor the differences in firm-level heterogeneity seen in the micro-level manufacturing data.

2. ICT adoption as an innovative activity

Describing ICT investment through use of neoclassical investment theory does not appear to be able to fully account for the differences across countries, sectors or firms, and does not explain fully how ICT use may affect growth. Seeing ICT adoption by a firm as an innately innovative activity, is an alternative perspective that can potentially help in this regard. How do these views of ICT adoption differ, and why does business spending on innovative activities, for example R&D, require such different theory from investment in buildings or traditional equipment?

Both types of expenditures have costs and benefits associated with them, with associated factor prices, and marginal revenue products. Both types of expenditures are characterised by benefits that occur over time and by timing differences in the flow of benefits and costs, thus requiring some method of expectations formation and of discounting to determine optimal current expenditures. However, the effects of uncertainty may differ between the two types of expenditures. The chance of a successful outcome is related to the effort spent on innovation. Further, with innovative activities, the outcome of the search for a better mousetrap may be uncertain, but once a successful discovery is made, the result may be used elsewhere by the firm at relatively little extra cost. These characteristics are consistent with viewing ICT as a general purpose technology (see Bresnahan and Trajtenberg, 1995). Also, they underlie the predictions emerging from endogenous growth models.

ICT may be used by firms in many different ways and for many different purposes, but it is unknown a priori how best to implement the technology. Unfortunately, the search for improvements through adoption of ICT is not yet formalized in the manner that R&D laboratories are. In an R&D lab, trial and error takes place in a controlled environment, at an experimental scale. No such laboratory exists in implementing ICT to improve business processes or products. Instead, the laboratory for figuring out and developing good implementations of ICT must be the market itself.

The search for a successful implementation of ICT is not restricted to finding ways to substitute away from labour or other productive inputs. As will be discussed below, ICT changes transactions costs in many interactions between actors within firms, and between firms and their customers and suppliers. As such, areas for improvement will involve search over strategies to increase ‘organisational capital’, by experimentation with various schemes such as performance pay, flexible job requirements, and workforce training (e.g. Bresnahan, Brynjolfsson and Hitt, 2002, Black and Lynch, 2001, 2002). Also firms will experiment with strategies within the supply chain, such as make-or-buy decisions, strategic alliances and customer relation management (examples from management literature, e.g. Hax and Wilde, 1999, or Duysters and Hagedoorn, 2000). In addition, firms may experiment with product characteristics using the ‘mass customisation’ (increased product variety without increased marginal cost) that is made possible through use of ICT. According to most theoretical accounts of innovation, the chance of success depends positively on the amount of experimentation. Quite often, firms can replicate a successful ICT implementation for not much more than the direct capital and labour input cost and, therefore their profitability also increases with scale. Moreover, in a rapidly evolving environment, firm profitability increases if the firm can adjust its scale up or down, depending on the apparent success in the market of its particular implementation strategy.[46]

Firms fail because they are unable to match up their system of coordination and control with the available technological opportunities, according to Pavitt (1998), rather than because they are unable to understand

46 This effect is well known in the card game of black jack, where a player can make positive profits despite unfair odds overall, if he can change the size of the bet as the probability of having a winning hand changes over the course of the game.

the technology. By broadening ones view of ‘technology’ to include the implementation through internal organization and management of supply chain as well as the physical ICT assets, the problem of within firm innovation may be analysed through more neoclassical models. For example, in models of learning, the amount of experimentation increases the learning rate and boosts the present value of profit flows (Wieland, 2000). While some of the models attempt to characterize the optimal amount of experimentation (e.g. Moscarini and Smith, 2001), they do not explicitly state how the experimentation is to take place. In the management literature, advice is given on how to infuse a firm with the desire to experiment and innovate (e.g. Hamel, 1999), but the exact methodology for experimentation is left to specialized literature.

In considering the experimentation process, the learning and selection effects emphasized by Jovanovic (1982) and Ericson and Pakes (1995) (and discussed briefly in earlier chapters 2 and 3) are relevant. Each cohort of new entrants will face uncertainty about many facets of the way to do business but in the recent era especially how best to adopt and implement ICT. Existing businesses will also face uncertainty as they restructure and retool their production and organization as they implement ICT. Failure to adopt the new technology implies falling behind but failing to adopt the new technology successfully may be just as bad. Those entrants and those adopting businesses that have implemented poorly will have lower profits and productivity and as such will contract and exit. Those businesses that implement successfully (and/or through learning by doing learn how to implement successfully) will have profitability and productivity advantages and expand. The market selection and learning effects this perspective suggests have obvious policy implications that we discuss below.

Beyond the trial and error aspects of experimentation, another important set of factors are those that imply a possible wedge between social and private returns to innovative activities. Endogenous growth theory (eg Jones and Williams 1999), describes the effect at the macro level of the market failures associated with R&D. Incomplete appropriability of the benefits leads to under-investment in a decentralised equilibrium. On the other hand, ‘stepping on toes’ or a congestion externality occurring between firms competing for a prize leads to over-investment, as does the neglect of socials losses owing to ‘business stealing’ away from the incumbents using a previous generation of technology.

It does not seem likely that business firms that purchase existing ICT technology and then experimentally arrive at a successful implementation have the same problem in appropriating the benefits as they would have, had they acquired truly non-rival knowledge. However, externalities associated with additional users in a communications network may hamper adoption at early stages of such networks. Likewise, the ‘stepping on toes’ externalities may describe problems associated with first-mover advantages inside ICT producing sectors, but less in ICT-using sectors. On the other hand, the ‘business stealing’ externality may be particularly relevant for ICT adopters, where the quality and variety of products or services made possible by successful implementation of ICT may rapidly erode the incumbents’ market share. Differences across countries in the facility with which resources (both in factor and product markets) are reallocated among competing suppliers may therefore provide a possible cause for differences in ICT adoption.

It is important to note that the implications of the externalities for welfare are not unambiguous. There is always the possibility of excessive dynamics (Reiss 1982 AER; Berry & Waldfogel 1999 Rand; Jones and Williams 1998 QJE). Negative externalities of ‘stepping on toes’ and business stealing may outweigh the positive externality of knowledge spillovers and create excessive investment in innovative activities. Although hard empirical proof is lacking, Jones and Williams gather circumstantial evidence that overall R&D investment is sub-optimal in a decentralised economy.

3. The growth channels

With the above views of ICT adoption as an asset investment or as a decision to innovate highlighted, we now turn to the channels through which ICT adoption lead to growth. First, labour productivity and output grow as a result of capital deepening. Growth accounting in Chapter 1 shows how investment in ICT that increases the real flow of services attributable to the stock of ICT assets contributes to output growth. This direct channel of ICT adoption to output is well understood, theoretically and empirically. More interesting are the possibilities that adoption of ICT provides efficiency gains over and above the contribution of capital deepening. Even when quality improvements in ICT assets are controlled for (see Chapter 2), the measured multifactor (MFP) residual still shows rates of "technical change" that varies across countries. An open question is whether ICT is contributing to this residual "technological" growth. The following sketches out how ICT adoption may end up increasing MFP or MFP growth.

MFP growth

ICT potentially contributes by increasing the efficiency of communication and information processing throughout parts of the economy where many actors successfully have implemented the technology. The improvements in communication and information processing have direct consequences for (at least) two aspects of economic processes: (i) transaction cost will go down and (ii) the productivity of knowledge workers will increase.[47] In a related manner, ICT implementation is associated with changes in the organizational capital of firms (as emphasized for example by Bresnahan, Brynjolffson, and Hitt (2002)).

Economic transactions, whether they take place among human beings, between firms and customers, or between firms are accompanied by transaction costs. These include transport costs and search costs, but also the costs incurred to check whether contracts are carried out properly (see Milgrom and Roberts [1994] for a detailed discussion). The distorting effects of these costs are well known: they place a wedge in the match-up of demand and supply. It is indeed possible that economically desirable transactions do not occur because of excessive transaction costs.

The use of ICT could yield more efficient communication between economic parties. For instance, to better match demand and supply in the labour market, but also to aid in the logistics of production processes, with the purchase of final consumer products (e-commerce) or with the transaction between firms (business-to-business commerce). Indeed, examples abound of internet-based markets, such as the market for real estate or for automotive parts. Unfortunately, factual estimates of the magnitude of the reduction in transactions costs due to ICT are scarce.

Less clear are the quantitative economic consequences of the emergence of new markets and/or the growth of existing markets as a result of decreasing transaction costs. In the former situation an entirely new market comes into existence with concomitant surplus. In the latter case existing producers' and consumers' surplus can increase. An example of such a situation is the market for second-hand commodities. On-line auctions make it possible that buyers and sellers don't have to be at the same physical place. Millions of transactions can be handled real-time. Indeed, this market has experienced a spectacular growth in recent years, leading to a more efficient allocation of the stock of existing goods.

Another possible implication of the penetration of ICT is that ICT intensity and competition in a market are positively correlated. If markets become more transparent firms have to resort to enhancements of their

47 A third effect is that the supply and demand curves can change through increased ICT uptake; supply curves tilt since marginal costs fall relative to fixed costs because of the non-rival nature of knowledge as a production factor, while demand curves tilt due to the increased frequency and force of (network) externalities (see Shapiro and Varian, 1998). For the story we develop here these consequences are of less importance.

products and processes in order not to loose market share. Put differently, ICT investments by firms react to market structure, and in turn affect market structure. What this means is that the penetration of ICT into economic processes is ruled, to some extent, by a snowball effect, where the incentive to adopt ICT increases with the penetration rate.

The second consequence of ICT use throughout the economy is its possible impact on the efficiency of knowledge creation and innovation. Knowledge workers conduct Research & Development (R&D) in order to come up with new products (product innovations) or enhance the efficiency of existing production processes (process innovations). Due to the use of ICT in research it is quite possible that the number of successful product and/or process innovations increases for the same R&D efforts. Besides the use of ICT to provide useful scientific and technical information for knowledge workers, the effectiveness of R&D may increase because ICT allows more rapid feedback on customer desires.

All of these changes are associated with potential changes in the organizational structure of firms. The manner in which firms interact with each other (through changes in the supply-chain structure and management) and the manner in which firms organize and locate their production facilities, capital and workforce inputs are all potentially impacted by the implementation of ICT. The work of Bresnahan, Brynjolffson and Hitt (2002), for example, suggests that those businesses that also changed their organizational capital exhibited the largest productivity gains from ICT. Thus, it may be that the contributions of ICT to the measured residual technology growth are also (or even mostly) associated with the accompanying changes in organizational capital.

ICT Production

Improvements in the efficiency and quality of ICT production can also contribute directly to growth. One of the contributing factors here is that one of the largest users of ICT is the ICT producer sector itself. The role of experimentation is presumably important in the ICT producing sector as well as in the ICT using sector. Moreover, the organisational capital of ICT producers has been impacted as well as in the ICT using sector. Thus, much of the discussion above is relevant for ICT producers. In addition, the structure of product and factor markets likely plays an important role for both ICT producers and users. We turn to this issue now.

4. Market Institutions: The role of product and factor markets

It is beyond the scope of this effort to provide a comprehensive survey the literature on the role of market institutions and policies for promoting growth via the channels discussed above. Instead, we discuss some of the key points that have emerged in the literature that will help guide the empirical analysis of the role of policy in Chapter 5. In many ways, the core hypothesis explored in Chapter 5 is non-controversial. That is, that policy barriers to resources being allocated to their highest valued use may have an adverse impact on economic performance in general and productivity growth in particular. While this core view is not controversial, it is an open question as to what specific policies act as such barriers and, of course, it may be that market imperfections or externalities call for active policy intervention. In turn, some of the policies designed to combat market imperfections or address externalities may also have adverse impacts in terms of barriers to efficient resource allocation.

Most of our discussion in what follows focuses on the role of product market competition and the product and factor market environment necessary to provide the incentives for development, adoption and experimentation of new technologies. While related, in some ways our discussion neglects the role of stable macro policies that create a healthy market environment for capital accumulation and thus the policies needed to promote the traditional capital deepening channel of ICT. This neglect is not to suggest this aspect of policy is unimportant but rather that such a perspective is already reasonably well understood and agreed upon. In that regard, it does not seem that the case for U.S. versus European differences in the contribution of ICT to growth lies in the differences in macro policies across these countries.

Product and factor markets and within firm growth

Starting with the role of product market competition, the theoretical literature has yielded ambiguous results about the sign and the magnitude of the impact of competition on innovation. The standard Schumpeterian argument is that the relationship between competition and innovation is negative, due to the hypothesised negative impact of competition on the appropriability of innovation profits. Post-innovation perfect competition makes firms indifferent *vis-à-vis* the choice of whether to innovate or not. Conversely, the expectation of some degree of post-innovation market power pushes firms to engage in innovative effort and undertake the required resource investment. In general, the statement that post-innovation rents should be high enough to cover the cost of innovation is relatively uncontroversial (see *e.g.* Kamien and Schwartz, 1982). The policy implication is that some protection of intellectual property rights is needed (IPRs hereafter).

By contrast, pre-innovation monopoly power may be a requisite for innovation. Nelson and Winter (1982), among others, point to the role of retained profits in financing innovation in a world of imperfect capital markets. Levin (1978) emphasises the role of pre-innovation barriers to enforce post-innovation monopoly power. Others argue that, in certain industries, to the extent that future innovations complement past ones, incumbents may have higher returns from innovation than entrants (e.g. Reinganum, 1983).

In contrast to these views, textbook microeconomic theory suggests that competition brings about allocative efficiency gains by forcing price to converge to marginal costs. The role of competition in raising efficiency may not, however, be limited to such static gains; additional potential gains -- much larger in magnitude -- arise from "dynamic efficiency". Dynamic efficiency is likely to bring about additional gains with respect to those related to static efficiency because firms will continue to improve their performance in ways they would not have were competitive pressures weak (Winston, 1993). Moreover, taking a dynamic perspective on competition allows to understand better new forms of competition observed in "dynamically" competitive industries (Evans and Schmalensee, 2001).

Models focussing on dynamic efficiency need a premise as to why monopolistic firms do not minimize costs or the present value of costs. Much of the literature takes recourse to information asymmetry and the associated agency problems. In these models, monopoly rents are captured by managers (and workers) in the form of managerial 'slack' or reduced work effort, and product market competition disciplines firms into efficient operation. At least three different channels can be identified (Nickell *et al.*, 1997). First, competition creates greater opportunities for comparing performance, making it easier for the owners or the market to monitor managers (Lazear and Rosen, 1981; Nalebuff and Stiglitz,1983). Next, since more competition is likely to raise the likelihood of bankruptcy at any given level of managerial effort, managers may work harder to avoid this outcome (Schmidt, 1997; Aghion and Howitt, 1998). Also, if product market rents are partly shared with workers in the form of higher wages or reduced effort, then competition probably influences workers' behaviour too (Haskel and Sanchis, 1995).

It should be stressed that theoretical predictions of the effects of greater competition on managers' incentives are often "subtle and ambiguous" (Vickers, 1995). For example, models using *explicit* incentives under information asymmetry do not lead to clear-cut implications (see *e.g.* Holmström, 1982), while intertemporal models using *implicit* (*i.e.* market-based) rewards suggest a positive link between competition and managerial effort if productivity shocks are more correlated across competitors than managerial abilities (Meyer and Vickers, 1997). But, competition could also lead to more slack if managers are highly responsive to monetary incentives (Scharfstein, 1988).

Turning to factor markets, factor market regulation and the specific employment contracts resulting from the labour bargaining setting, may restrict the domain over which firms may experiment. If changing the size of the overall labour force is difficult, firms may not want to experiment too much in make-or-buy decisions. If pay scales and job description are written in stone, firms may not be able to play with incentive schemes that induce employees to undertake new initiatives. Overall, with a restricted domain of configurations to choose from, theory would predict less within firm productivity growth from the channel of organisation and supply chain management.

Factor and product markets and resource reallocation

Factor and product market policies also play an important role in determining innovative activity and growth though the channel of resource reallocation from less to more productive firms (including reallocation through firm entry and exit.)[48] The arguments here are different in nature from those that rely on asymmetric information. If competitive pressure is lacking, not only are managers able to avoid extra effort for the reasons given earlier, but the overall rewards to the firm from innovative effort may be lower as well, because the market does not respond by shifting demand to firms with better price or quality. In a more competitive market, buyers will more rapidly shift their expenditures to a firm that has made a successful product or process innovation. If factor markets are flexible, firms will be able to adjust factor inputs to match the demand for their products and the most efficient producers will expand while the less efficient producers will contract and potentially exit.

The overall effect of competition on incentives to innovate through the resource reallocation channel is not unambiguous. Although demand may shift more rapidly to the better firms, overall mark-ups and profit margins may decline with heightened competition. Yet, what is important to a firm is the difference between expected profit following innovation, versus profit if it falls behind technologically. Further complications in the link between competition and incentives to innovate relate to relative technological positions of firms in the market. A firm that is far ahead in its technology may sit back while innovative efforts by competitors do not lead to large movements in market share. Overall, recent theoretical work find a hump-shaped relationship between competition and innovation, while recent empirical work show a positive relationship.

Modelling the effect of product market competition on resource reallocation is not straightforward. First, endogenous growth models with entry, exit, and reallocation of resources between firms are only recently being developed (Klette and Kortum, 2002). Next, the literature is still groping towards a generally accepted indicator of the degree of product market competition (Boone, 2000). Finally, only recently are the various pieces being put together (Aghion, Bloom, Blundell, Griffith and Howitt 2002, Bartelsman and Hinloopen 2002). Although a full model has not been developed to explain the role of factor and product markets in reallocation, we will give a description of the requirements for such a model, by pulling together pieces from the existing literature.

The Klette and Kortum model provides a framework for studying endogenous growth in a setting with heterogeneous firms. The model is able to account for many of the stylised facts emerging from firm-level empirical studies and yields results at the aggregate level that coincide with quality ladder models

48 It should be noted that the channel called resource reallocation here includes more than what is captured in the 'between' term in productivity decompositions. This channel also includes the incentive effect that resource reallocation has on inducing firms to increase their own productivity, which is captured in the 'within' term in decompositions.

(Grossman and Helpman 1991). In the model, the heterogeneity of innovation intensity across firms is imposed by assuming that firm profitability varies across firms.[49] Further, the model assumes monopolistic competition across differentiation products, but assumes the innovator takes all in the quality ladder for each particular differentiated product. Extensions of this model could allow multiple suppliers of each product, with the degree indicator of competitiveness determining how the profit shares move with technological state of the supplier. A reasonable indicator of the degree of competitiveness of an industry has the property that it moves monotonically with the profit share of the efficient firms, as argued by Boone (2001).

Models that capture both the heterogeneity among firms, entry, exit, and reallocation of resources between incumbents, innovative activity, and the degree of competition, must take into consideration some of the following effects. First, when considering the incentive to innovate, the expenses of the innovative activity should not be balanced against the expected profit flows, but against the difference in expected profit flows between this case, and the case in which no innovative activities where undertaken. With stronger competition, mark-ups may be lower, but the loss of market share and rents for non-innovating firms may be larger than under weak competition. Next, the effect of heightened competition on the incentive to innovate may depend on how close the competing firms are technologically. Aghion *et al.* (2001*a*) argue that, for any given level of protection of IPRs, fierce competition between firms with similar technological competencies (neck-and-neck competition) may force them to innovate in order to escape competitive pressure. Boone 2000 shows how incentives vary depending on state of efficiency relative to competitors, and distinguishes the effects of competition on product and process innovation. Based on results in Aghion et al. (2002), it is generally thought that the relationship between competition and innovative activity is hump-shaped. The intuition is that the expected profit from a risky investment increases with more competition, up to a point, because the gains from a higher market share for successful innovator are not outweighed by the reductions from the decline in mark-up.

The above discussion deals primarily with product market competition. Because the costs of resource reallocation increase with less flexible factor markets, the incentive for innovation should increase monotonically with more flexibility. Further, the ease of reallocation boosts growth through the direct arithmetic channel of increasing the share of more productive firms, but also through the incentives it creates firms to innovate and boost their own productivity level. In an environment where innovation and experimentation are closely linked, barriers to reallocating capital and labor inputs can have a very adverse impact on productivity and growth.

5. Summary

In this chapter, we sketched the main links between factor and product market policies, innovation, and growth. In particular,

- We outlined three possible channels through which ICT can affect growth: (i) the 'traditional' process of capital deepening; (ii) ICT as an instrument for innovative activity; (iii) the contribution of the ICT-producing sector to growth. Since we consider ICT as a general-purpose technology, we have placed considerable emphasis on the role of experimentation in the development of new ICT products as well as in the implementation of ICT. For the latter, we stressed that ICT has changed the manner in which businesses organise themselves internally and interact externally with other businesses and consumers.

49 Further research will be needed to extend the model such that experimentation by firms causes heterogeneity in profits and innovation intensity.

- The importance of experimentation raises a variety of questions regarding the appropriate market institutions for promoting growth via ICT. Incentives for the development of an ICT-production industry seems to be impacted by market structure and externalities in complex ways raising difficult questions about the appropriate market policy interventions (if any). In terms of adoption, experimentation suggests that market selection and learning effects are likely to be important. As such, product and factor market barriers to the reallocation of capital and labour inputs can adversely influence the successful adoption and diffusion of innovative technologies like ICT.

5. DO POLICY AND REGULATORY SETTINGS HELP TO EXPLAIN INDUSTRY DIFFERENCES IN PRODUCTIVITY AND INNOVATION ACTIVITIES ACROSS OECD COUNTRIES?

Introduction

In the first three chapters, we described the impact of ICT on productivity and growth, both at the aggregate and micro levels, highlighting differences between OECD countries. One is naturally led to conjecture as to what generates these differences, especially given that the capabilities and costs of ICT are more or less the same across countries. In Chapter 4, drawing from different theoretical models, we then advanced the hypothesis that these differences may be related to the institutional and policy settings characterising the OECD countries. Theory, however, does not give clear indications as to the magnitude of the effects, or to the specific aspects of the institutional and policy settings that are of foremost importance for performance. This final chapter provides some empirical evidence on this issue by relating industry-level performance in different countries with a set of OECD indicators of product and labour market policy and institutions.

Ideally, we would like to trace the link between market institutions, the investment in and adoption of ICT, and differences in productivity dynamics and innovation activity across countries. However, data limitations make this analysis rather difficult, at least on a cross-country basis (i.e. the relevant dimension to study policy and institutions). Instead, we take an indirect approach and look at the broader links between policy, productivity and innovation, after controlling for a set of other possible influences. The implications of the empirical results for our ICT discussion are, however, straightforward. First, we explore the links between policy and industry performance during the past two decades, when the IC technology shock offered many new opportunities to boost internal efficiency and innovation. In this respect, we are looking at a 'natural experiment' in which differences in policy and institutional settings may have been particularly important in influencing firms' decisions. Second, the focus on individual industries in manufacturing allows taking into account possible differences in their patterns of innovation and adoption of new technologies. This enables us to identify ICT-producing industries and industries that are heavy users of ICT equipment and check for any difference in performance with respect to other industries.

The chapter is organised as follows. We first review the empirical literature linking policy and institutions with innovation and productivity. Second, we conduct our own empirical exploration along two separate dimensions. First we explore the role of policy and institutions on productivity, while controlling for technological catch up across countries and innovation efforts (proxied by R&D). Second, we look at whether policy and institutions also affect innovation itself and, via this channel, further contribute to shape productivity performance. If one sees the investment and adoption of ICT as a form of innovative activity, then these results may provide a direct explanation for the observed differences in the spread of ICT across countries.

5.1 Existing empirical evidence

Product market competition, innovation and productivity

The empirical evidence on the links between product market competition and productivity growth is limited and not always conclusive. Some studies focus on trade liberalisation with estimated positive effects on both the level and growth rates of productivity (*e.g.* MacDonald, 1994; Van Wijnbergen and Venables, 1993). There have also been attempts to link *technical efficiency* to competition. For example, Caves and Barton (1990), Caves *et al.* (1982) and Green and Mayes (1991) suggest that, above a certain threshold, market concentration leads to a reduction in technical efficiency. Other studies look at specific industries across different countries and assess the role of domestic and global competition (*e.g*. Porter, 1990; McKinsey Global Institute, 1997; Baily and Gerbach, 1995; and several articles in *OECD Economic Studies* No. 32, 2001). These studies tend to conclude that domestic competition is key for productivity and for gaining world market shares, although Baily and Gerbach (1995) also point to the importance of 'global competition' -- that is, exposure to the best producers wherever they are located -- for productivity growth. Finally, there are a number of firm-level studies that report a positive impact of competition (proxied by concentration rates, size of rents etc.) on productivity in the United Kingdom (Nickell, 1996; Blanchflower and Machin, 1996; Nickell *et al.*, 1997; Disney *et al.*, 2000). In contrast with the empirical studies mentioned above, Nickell (1996) uses simultaneously different measures of competition (Lerner index, 5-firm concentration ratio, and a measure of the number of competitors). Less competition is found to be associated with less MFP growth for all variables except the dummy on the number of competitors, which is found to have a negative and significant effect only when the Lerner index is not included in the equation.

Evidence on the links between product market competition and innovation is even more scant, although in recent years a number of empirical studies have found a positive association using sector- and firm-level data for the United Kingdom (see e.g. Geroski, 1990; and Blundell *et al.*, 1995, 1999).[50] These studies suggest that incumbents are pushed to innovate in order to pre-empt rivals. Conversely, Aghion et al. (2001*b*) find a hump shaped relationship between patents and competition, the latter measured by price-cost mark-up in a panel of British firms. Still, for a large portion of the range of variation of the mark-up, they find an upward sloped relationship, which becomes downward sloped only in the neighbourhood of perfect competition. They also find evidence supporting the hypothesis that *ceteris paribus* neck-and-neck competition, as measured in each industry by the distance between average productivity and the international technological frontier, is associated with greater innovation performance and a more negative relationship between patents and the industry's mark up.

Cross-country evidence on competition and innovation or productivity growth is limited and often confined to bivariate correlations (*e.g*. Koedijk and Kremers, 1996), case studies (*e.g.*Havrylyshin, 1990), or the inclusion of a tariff rate or import restriction variable in cross-country growth regressions (*e.g.* Lee, 1993). Some authors also provide indirect evidence on the association of import penetration with innovation and growth, although import penetration may also proxy international technological spillovers and not only the level of competitive pressure (*e.g.* Coe and Helpman, 1995).

There are a number of reasons why cross-country evidence is scarce. Commonly used indicators of competition (such as mark-ups or concentration indexes) are typically endogenous to innovation and, as typical in empirical studies of growth, it is often difficult to find suitable instruments. Analysis based on panel data with a long time dimension can somewhat alleviate this problem by exploiting the lag structure. However long time series are often not available on a cross-country basis. An additional problem, which

50. See also Cohen (1995) for a survey of earlier studies.

concerns also studies conducted on panel data, is that measures such as concentration indexes (*e.g.* *n*-firm concentration ratios and the Herfindahl index) or the Lerner index are likely not to be monotone with respect to common notions of competition (see Boone 2000a, 2001). Finally, these indexes fail to provide a direct link to policy or regulation.

Given that the degree of product market competition cannot be easily gauged from direct observation, an alternative route consists into focusing into its policy determinants. In particular, we will use a set of cross-country quantitative indicators of product market regulation and regulatory reform developed by the OECD.[51] These indicators measure the pro-competitive stance of regulation on the basis of a large set of regulatory provisions in OECD countries.[52] Letting aside political-economy considerations (see *e.g.* Duso and Röller, 2001), indicators of regulatory stance can be considered exogenous with respect to performance variables. Moreover, their relationship with common notions of competition is, in principle, less ambiguous. Nevertheless, given that these indicators take into account only legal regulatory provisions, they might fall short of capturing all relevant factors determining actual competitive pressure.

Before presenting the econometric analysis, it is instructive to have a graphical look at the cross-country aggregate evidence concerning the links between MFP growth, indicators of innovation performance and product market regulation. We start with a quick glance at the empirical relationship between innovative activity and growth. The evidence is generally supportive of a positive and strong relationship between innovation performance and output or productivity growth, especially when the analysis is conducted at the sectoral or firm levels.[53] In aggregate cross-country regressions, it is somewhat more difficult to establish a clear link between an indicator of R&D effort and productivity growth, unless control for other factors influencing MFP is included.[54] A simple way to control for these other factors is to work with first-difference series instead of level series as in Figure 1. It shows a significant correlation between *changes* in business enterprise expenditure in R&D (BERD) intensity and acceleration in MFP growth between 1990s and 1980s.

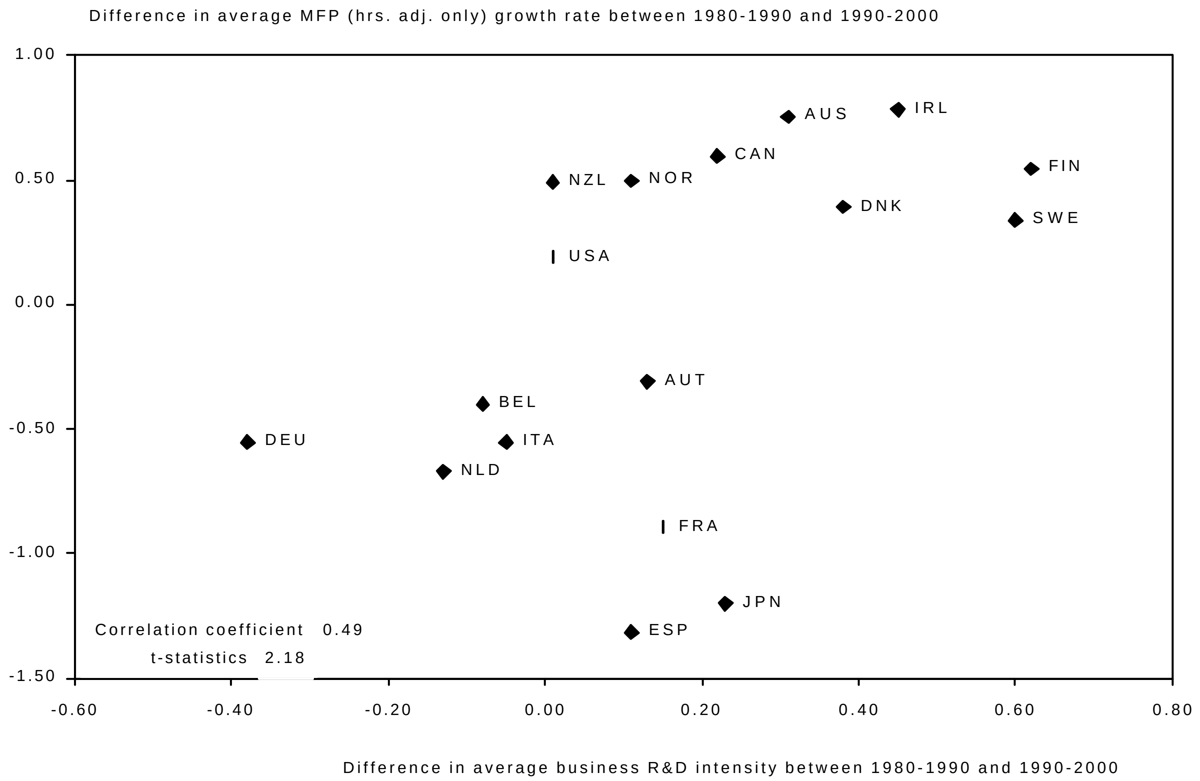
51 . We use different indicators of the stringency of regulations in the product and labour markets. The overall index of the stringency of *product market regulation* (PMR) is a static indicator (referring to conditions in 1998), composed of three elements: i) direct *state control* of economic activities, through state shareholdings or other types of intervention in the decisions of business sector enterprises and the use of command and control regulations; ii) *barriers to private entrepreneurial activity*, through legal limitations on access to markets, or administrative burdens and opacities hampering the creation of businesses; and iii) regulatory *barriers to international trade and investment*, through explicit legal and tariff provisions or regulatory and administrative obstacles. In order to further characterise the regulatory settings in the R&D equation, this overall indicator is further split into *outward-oriented* regulations (e.g. tariff and non-tariff barriers) and *inward-oriented* regulations. The latter have also been split into *economic* regulations (state control, legal barriers to entry etc.) and *administrative* regulations (administrative burdens on start-ups, features of the licensing and permit system etc.). The indicators *of employment protection legislation* (EPL) focus on both regular and temporary contracts. They are available for two periods (late 1980s and 1998) and in the econometric analysis the shift in regime has been defined on the basis of information about the timing of major EPL reforms (concerning both temporary and regular workers) in OECD countries. See Nicoletti, Scarpetta and Boylaud (1999) for more details.

52 . The aim of the OECD indicators is to measure to what extent competition and firm choices are restricted in industries and areas where there is no *a priori* reason to expect the government to interfere or where regulatory goals could be achieved by less coercive means. They have no ambition to measure the quality and the effectiveness of existing regulatory environments (See Nicoletti *et al.*, 1999).

53. As summarised by Nadiri (1993), the output elasticities of R&D at the firm level tend to be around 0.1 to 0.3 and the rates of return around 20 per cent to 30 per cent.

54 See among others Cameron, 1998, Frantzen, 2000, Scarpetta and Tressel, 2002

Figure 1. Changes in R&D intensity and MFP acceleration

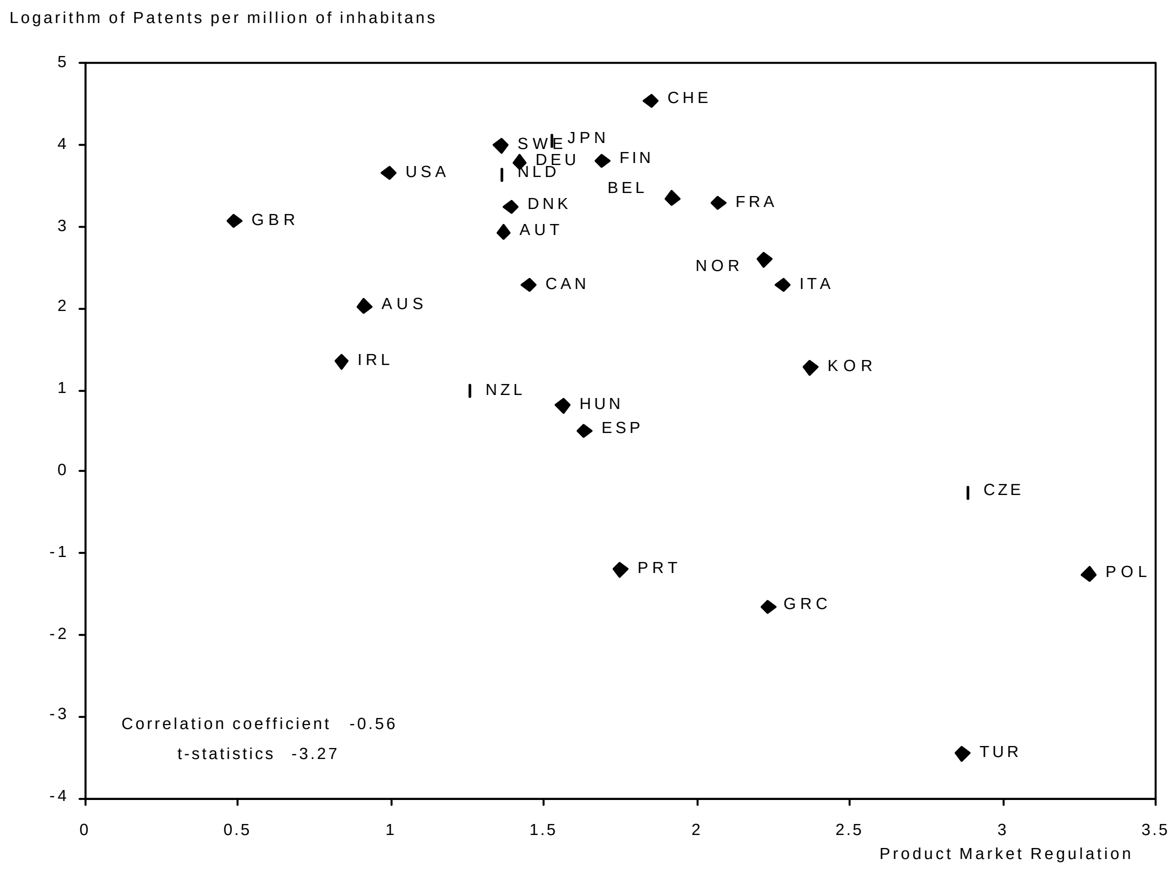


Source: Authors' calculations.

Furthermore, Figure 2 presents evidence of a negative bivariate correlation between patent performance (another possible proxy for innovation)[55] and the OECD summary indicator of product market regulation that includes aspects of inward- and outward- economic and administrative regulation (see Nicoletti *et al.*, 1999). The correlation is robust to the elimination of single outliers (such as Turkey), although its significance depends considerably on a small group of countries with significantly lower patent performance (Portugal, Greece, the Czech Republic, Poland and Turkey), whose elimination makes the correlation coefficient insignificant at standard statistical level. Similar correlations are found with R&D intensity, another proxy for innovation activity.

55. We thank Dominique Guellec for the help provided as regard to these data.

Figure 2. Patents per capita and product market regulation



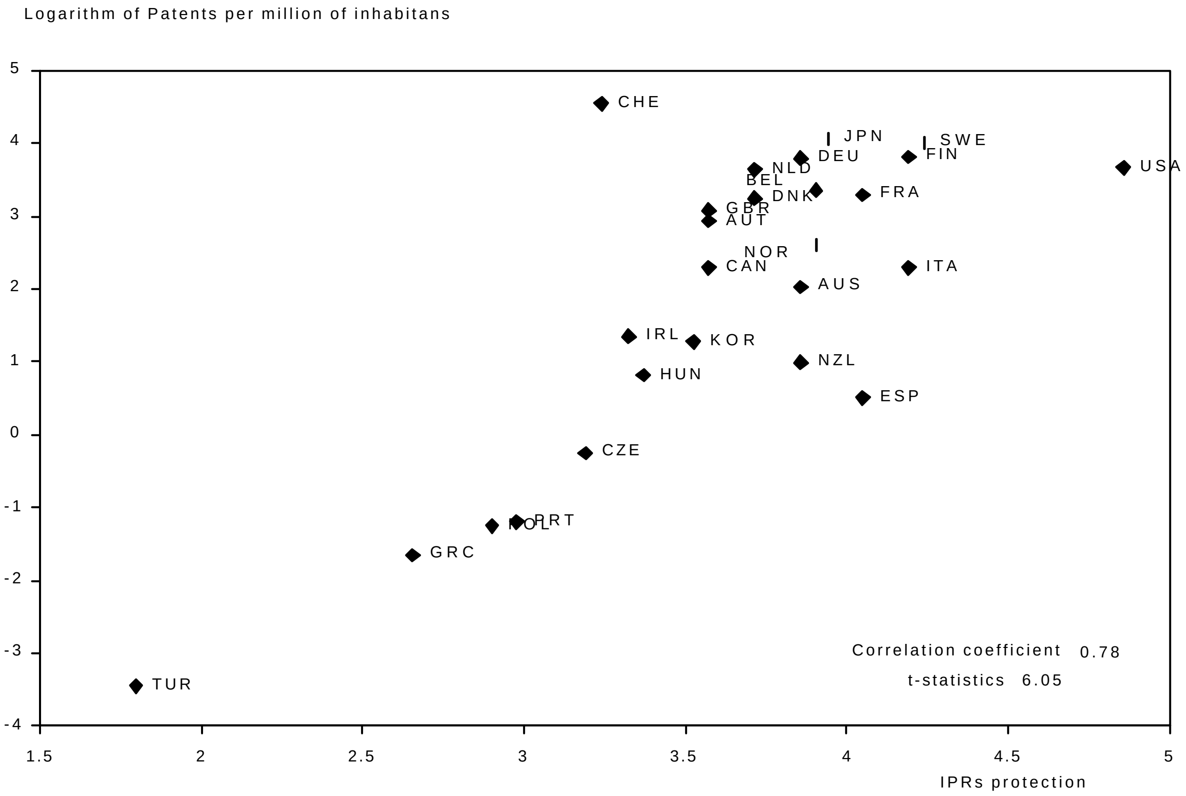
1. The OECD summary index of product market regulation is from Nicoletti *et al.* (1999). Patents are defined as consolidated family of patent at EPO, USPTO and JPO by country of invention and priority year 1993.

Source: Authors' calculations.

Regulation on Intellectual Property Rights (IPRs hereafter) is excluded from Figure 3. As stressed above, the fact that some degree of protection of IPRs is likely to have positive impact on innovation is relatively uncontroversial in the literature, while the policy debate focuses now on the optimal degree of protection (see *e.g.* Scotchmer, 1991, and David, 2001). Figure 2 shows indeed a robust positive correlation between innovation performance and an indicator of protection of IPRs developed by Ginarte and Park (1997).[56]

56. Nonetheless, although indicators based on legal provisions usually have the advantage of being relatively exogenous with respect to variables of innovation performance, this does not seem to be the case with the indicator of protection of IPRs that is found to be endogenous to R&D expenditure (Ginarte and Park, 1997). Thus, care must be taken in evaluating the impact of IPR protection in this type of correlation as well as in the following regression analysis.

Figure 3. Patents per capita and product market regulation



1. The summary index of IPR protection is from Park (2001). Patents are defined as consolidated family of patent at EPO, USPTO and JPO by country of invention and priority year 1993.

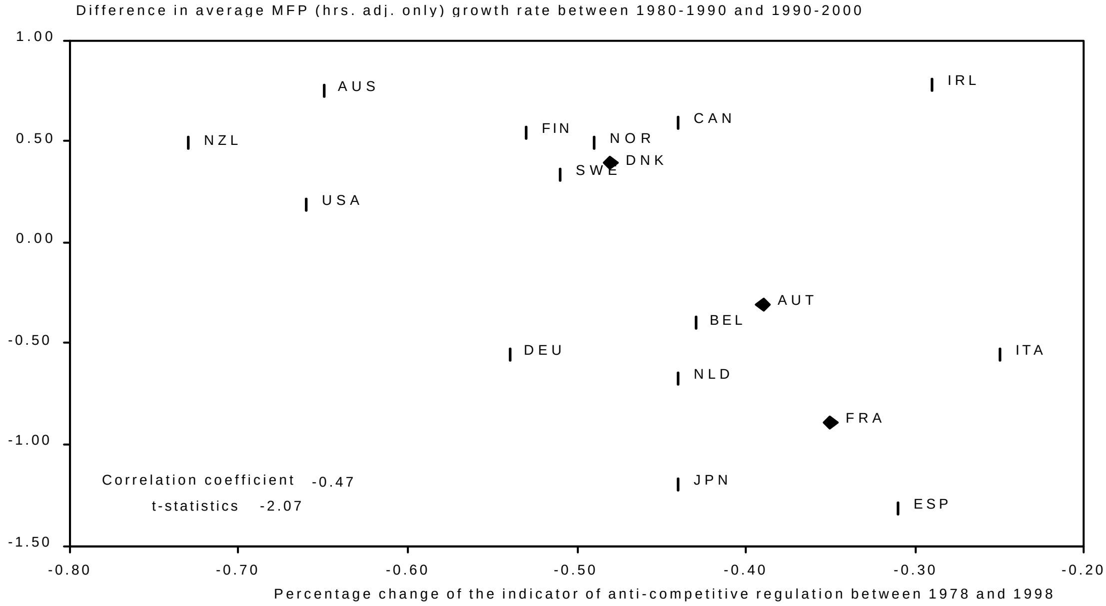
Source: Authors' calculations.

Figure 4 shows a negative correlation between the acceleration of MFP, the change in anti-competitive product market regulation (Panel A) and the change in regulation concerning IPRs (Panel B) between the 1980s and the 1990s. Correlations are in both cases significant at the 10% level. Furthermore, in Panel A Ireland appears to be a clear outlier, whose elimination from the sample makes the correlation become significant at the 1% level. The same occurs upon elimination of Spain in Panel B.

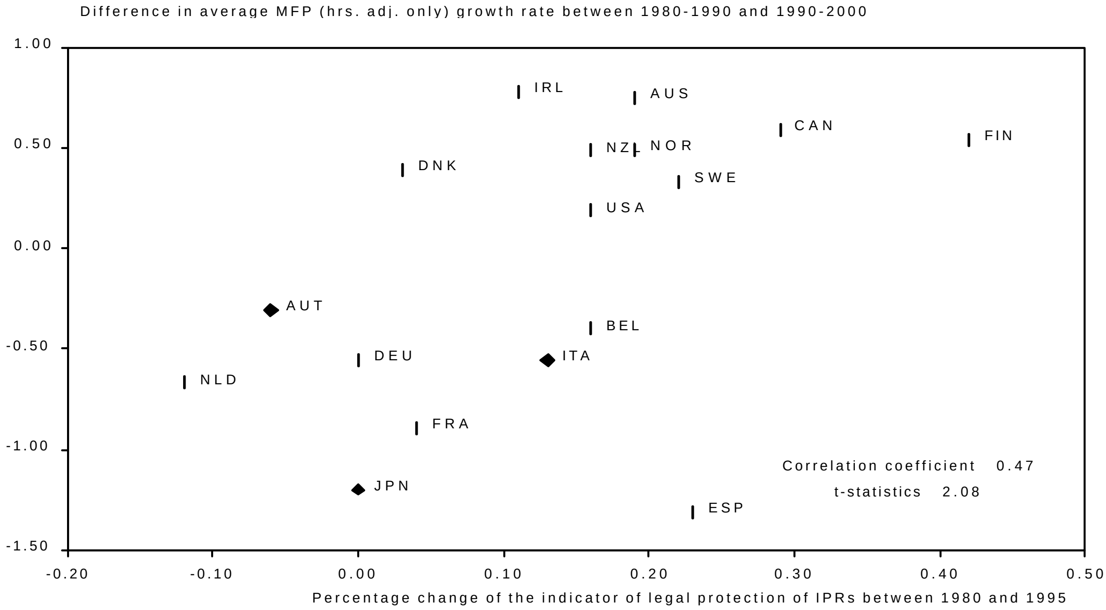
Pooling together these simple relationships in a simple regression we find that changes in anti-competitive product market regulation and IPRs protection explain 37% of the variance of the acceleration of MFP growth. As suggested by Figure 5 that plots the acceleration of MFP growth against the predicted values from this simple regression, the relatively poor performance of these indicators is again due to Ireland (and to a lesser extent Spain) being an outlier. Indeed without Ireland the two regulatory variables becomes significant at the 5% level and explain more 55% of total variance (that climbs up to 60% with elimination of Spain).

Figure 4. Acceleration of MFP, change in PMR and change in protection of IPRs

Panel A. **Product market regulation and MFP growth** [1]



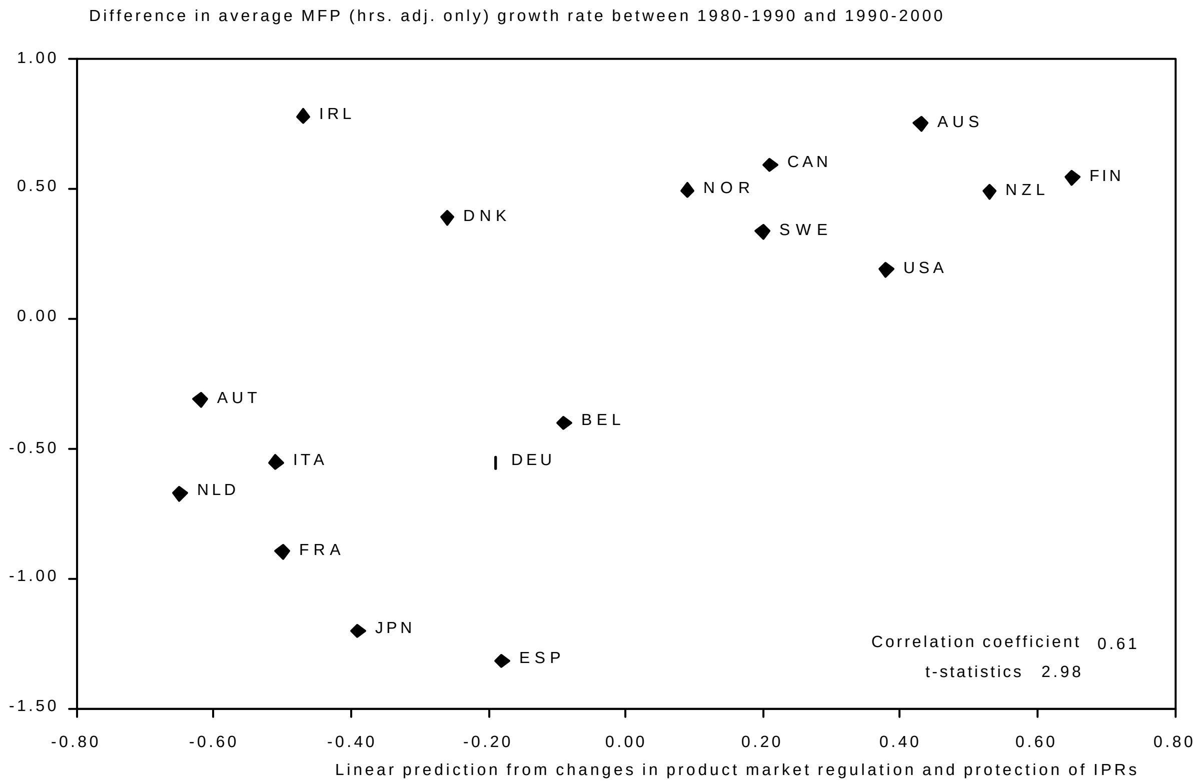
Panel B. **Regulation on IPRs and MFP growth** [2]



1. The indicator of anti-competitive product market regulation used in this figure is based on historical data on the regulatory stance in 7 non-manufacturing industries (gas, electricity, post, telecommunications, passenger air transport, railways and road freight). Depending on the industry, the following dimensions have been considered : barriers to entry, public ownership, market structure, vertical integration and price controls (see Nicoletti et al. 2001 for a complete description).
2. The indicator of legal protection of IPRs used in this figure is based on the following dimensions: range of patentable items (coverage), membership in international agreements, risk of loss of protection, enforcement provisions, duration of protection (see Ginarte and Park, 1997 for a complete description).

Source: Authors' calculations.

Figure 5. Regulatory changes as predictors of the acceleration of MFP growth



Source: Authors' calculations.

Labour market institutions, innovation and adoption

It can be argued that labour market policies and institutions affect both the size of innovation and technology adoption rents, through their impact on the cost of pursuing innovation and adoption, and the scope for the firm to appropriate these rents rather than sharing them with workers or other firms (see notably Boyer, 1988, and Hall and Soskice, 2001). This occurs in spite of the fact that policy-makers usually do no set labour market policies to accomplish the goal of enhancing innovation or fostering adoption. Three main aspects of policy and institutional settings seem to be more closely related to innovation and adoption, although the links are complex (see Box 5.1 for more details): *i*) the system of industrial relations; *ii*) the costs of hiring and firing (proxied by the stringency of Employment Protection Legislation, EPL); and *iii*) the possible interactions between industry-specific characteristics of the technology and EPL which lead to different human resource strategies.

The industrial relation regime prevailing in a country is likely to influence the human resource strategy of an innovating firm. Broadly speaking, in countries where wage negotiations are decentralised and where there is little co-ordination amongst employers, firms tend to adjust their workforce while innovating by hiring adequately skilled workers on the labour market. Conversely, in centralised or sectoral wage bargaining systems, wages are more compressed and firms, despite finding more difficult to attract high skilled workers on the external market, gain from training their own workers (as there is a greater wedge between productivity and wages at high skill levels). In addition, countries that have centralised or sectoral wage bargaining systems also tend to have comparatively high hiring and firing costs. The combination of wage compression and high labour adjustment costs tend to favour a process of competence accumulation based on firm-supported training and on-the-job learning. Wage compression may not, however, be a sufficient condition for firms to rely on the internal labour market to adapt its work force and, ultimately, for the decision to innovate and/or adopt a new technology. Another feature of industrial relation system plays a crucial role: the degree of co-ordination amongst employers. Co-ordination is implicit in highly centralised wage setting systems but also exists in some countries with predominantly sectoral bargaining systems (e.g. Germany). In co-ordinated countries, there is only a limited variability of wage offers across firms, thereby reducing the scope for poaching. Likewise, co-ordination often leads to close inter-firm practices where poaching is considered as unfair behaviour.

The potential effects of bargaining regimes and EPL on the incentives to innovate and adopt new technologies may also depend on the technological characteristics of the sector in which firms operate. While in low-tech industries strict EPL is always likely to lead to higher adjustment cots with possible negative effects on innovation and adoption, in high-tech industries the effects of EPL may depend on the technological trajectory of the sector. When technological progress is cumulative (i.e. further innovations along the same trajectory), then investing in the internal labour force may be effective, and firms in these industries are likely to have a better innovation performance when labour market institutions enhance a thorough exploitation of the internal labour market. This is less so if technological progress leads to frequent shifts in the type of physical and human capital required in the production process. In this latter case firms have to rely on the external labour market which may be costly when EPL is very strict. Empirical evidence indeed suggests countries with co-ordinated industrial relations systems and relatively stringent employment protection (e.g. Germany, Austria) have stronger technological comparative advantage in industries characterised by cumulative technological progress than countries with decentralised wage bargaining, no co-ordination and low EPL (e.g. United States, but also United Kingdom and New Zealand more recently) (see Bassanini and Ernst, 2002a).

Box 5.1 Labour market institutions, regulations and performance[57]

Labour market institutions can affect firms' performance by influencing innovation rents associated with innovation and adoption of new technologies. In decentralised wage-bargaining systems workers can appropriate a large part of the rents generated by successful innovations, thereby reducing incentives to innovate in the first place. The risk of hold-up can be partly mitigated when bargaining occurs at the national level (or at the industry level but with economy-wide co-ordination) and pins down a general frame for the wage schedule. In such a case, the reservation wage is fixed for all lower-level bargaining units and is adjusted mainly in response to aggregate shocks. As a consequence, the firm’s incentive to undertake innovative investment no longer depends on the bargaining power of its own workers (Teulings and Hartog, 1998).

The industrial relations systems play also a prominent role on the accumulation of competencies and human capital required for developing and implementing innovations. In centralised/co-ordinated industrial relations systems wages are typically compressed over the skill dimension.[58] Furthermore, in these systems the possibility for the most efficient firms to attract more skilled people by offering higher wages is limited.[59] Hence it could be argued that co-ordinated industrial relations systems, by leading to lower expected earnings for the upper range of skills (with respect to unskilled labour), may reduce workers’ willingness to pay for the accumulation of generic human capital,

57. This box draws heavily on joint work of one of us with Ekkehard Ernst (Bassanini and Ernst, 2002a). We are most grateful to him for letting us use part of that material here.

58. An industrial relations system can be said to be co-ordinated when: i) the wage-bargain occurs in a centralised way or co-ordination among employers and/or trade unions sets a uniform band of wages; ii) employers and trade unions co-operate as regard to decision-making inside the firm; and iii) business associations have an active role in solving free-riding problems across firms (Carlin and Soskice, 1990).

59. Indeed, there is empirical evidence that there are no wage gains to switching jobs in Germany (Zimmermann, 1998) but these gains are substantial in the United States (McCue, 1996).

thereby leading to lower innovation performance because of lower supply of skilled labour. Nevertheless, firms too invest in general training (see Booth and Snower, 1996, and Acemoglu and Pischke, 1999*a,b*, for recent surveys), and have greater incentive to pay for training the larger the compression of wages over the skill dimension, because they can reap the greater difference between the marginal productivity of skilled workers and their earnings.

Wage compression is not, however, a sufficient condition to induce a firm to pay for the accumulation of generic competencies when there is no economic mechanism at work to prevent other firms from poaching on its pool of skilled workers. Co-ordinated industrial relations systems provide at least two such institutional arrangements: i) centralised and co-ordinated wage-bargaining settings may extend contracts to cover almost all firms and workers and allow only limited variability of wage offers across firms, thereby dampening poaching since workers have no incentive to change job if no better wage offer can be made by the poaching firm (Teulings and Hartog, 1998; Acemoglu and Pischke, 1999*a*); and ii) customary inter-firm practices, typical of co-ordinated industrial relations regimes, may enforce an equilibrium wherein poaching is considered as unfair behaviour.[60] Furthermore, the cost of training is often shared among employers when business associations have a prominent role (Soskice, 1997, Casper *et al*., 1999). As a consequence the only unambiguous effect of the wage compression associated with industrial relations regimes is to partially swap the roles of agents as regard to paying for training. Indeed, Lynch (1994), Blinder and Krueger (1996), Acemoglu and Pischke (1999) and OECD (1993 and 2000) report scattered evidence of more firm-sponsored training in more coordinated countries.

Hiring and firing restrictions may raise the cost of labour adjustment, which is often needed after innovations have been introduced (see *e.g.* Cappelli, 2000). The effects of these restrictions on productivity and innovation are, however, likely to be mediated by industrial relation regimes. In co-ordinated countries, firms are less sensitive to the adjustment costs imposed by firing restrictions, because they tend to reallocate labour internally. Likewise, in these countries, statutory or contractual employment protection may also help solving the moral hazard problem that arise when the process of accumulation of firm-specific competencies (as well as the associated worker's effort) cannot be not fully monitored, as is often the case when competencies are acquired on the job. Co-ordination between employers and trade unions may favour the achievement of a co-operative equilibrium through the establishment of an environment of mutual trust and loyalty. In this case, employment protection complements these arrangements by introducing a commitment mechanism that enforces an otherwise time-inconsistent implicit contract, since the incentive to increase one's own generic human capital (at the expense of firm-specific one) is smaller the greater the credibility of the career prospects within the same firm.

Industry-specific characteristics of technological change and associated competence requirements are also likely to influence innovation and adoption and their effect may depend on industrial relation regimes. In mature and low-tech industries, firms undertake little in-house R&D activity and mostly adopt technology developed elsewhere. The scope for expanding production is often limited and innovation frequently leads to downsizing. In these contexts, strict EPL may have significant repercussions on productivity and adoption of new technologies, especially if competencies required to implement innovations are not available inside the firm.[61] In high tech industries, two regimes can be distinguished on the basis of their innovation patterns: *Schumpeter Mark I* and *Schumpeter Mark II* (Kamien and Schwarz, 1982, Nelson and Winter, 1982, Malerba and Orsenigo, 1995, Breschi *et al.*, 2000). In *Schumpeter Mark I* industries (*e.g.* precision instruments, standardised software, household appliances), firms often undertake sequences of short-lived projects on the basis of the same general knowledge but different specific realisations (e.g. as a consequence of short life-cycles of products and rapid capital depreciation). In this process, they rely on a one-shot match of human and physical capital requiring (or at least not being impaired by) a quick turnover of workers (or even firms themselves). Conversely, in *Schumpeter Mark II* industries (*e.g.* electronic components, aircrafts and spacecrafts), firms undertake incremental innovations along an existing technological trajectory and competencies for this type of innovations are often found inside the firm. This also implies that the loss of few staff members may involve significant costs for firms operating in these industries.

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60. For instance, Blinder and Krueger (1996) report that inter-firm job mobility is virtually non-existent in Japan due to firms' customary practices of refusing to employ people already working for other firms. Similarly Casper et al. (1999) report about legal provisions in Germany that reduce workers' mobility after training.

61. For a discussion about the role of strict regulation on the patterns of technological specialisation of countries, see Saint-Paul (2002).

4.2 The empirical evidence on the links between policy, institutions and performance

Our empirical analysis focuses on the determinants of productivity and innovation (proxied by R&D) in OECD manufacturing, on the basis of country/industry and time-series data. This sectoral analysis allows to consider a set of specific regulatory aspects and to seek possible interactions between them and institutional, policy and technological factors characterising each manufacturing industry. At the same time, however, given our results in Chapter 2 (i.e. the fact that most of productivity growth in manufacturing is explained by within-industry performance) this sectoral analysis may also offer economy-wide indications as to the role of policy and institutions for performance. Our empirical approach starts with the productivity equation and, insofar as R&D is a driving force of productivity, then moves to analyse the determinants of industry R&D intensity. This allows assessment of the direct effect of policy and regulations on productivity and the indirect effects *via* their impact on innovation activity.

Policy and institutions and productivity

The multifactor productivity equation is derived from a production function in which technological progress is a function of country/industry specific factors, as well as a catch-up term that measures the distance from the technological frontier in each industry (see Scarpetta and Tressel, 2002 for more details). The cross-country, cross-industry analysis of productivity is centred on a catch-up specification of productivity, whereby, within each industry, the production possibility set is influenced by technological and organisational transfer from the technology-frontier country to other countries. In this context, multi-factor productivity (MFP) for a given industry j of country i (MFP_{ijt}) can be modelled as an autoregressive distributed lag ADL(1,1) process in which the level of MFP is co-integrated with the level of MFP of the technological frontier country F: Formally,

$$\ln MFP_{ijt} = b_1 \ln MFP_{ijt-1} + b_2 \ln MFP_{Fjt} + b_3 \ln MFP_{Fjt-1} + \sum_k g_k V_{kijt-1} + f_i + g_j + d_t + e_{ijt} \quad [1]$$

where (V_{ijt}) is a vector of covariates (*e.g.* product and market labour regulations, human capital, or R&D) affecting the level of MFP; f_i , g_j, and d_t are respectively country, industry and year fixed effects. e is an *iid* shock.

Under the assumption of long-run homogeneity ($1-\beta_1=\beta_2+\beta_3$) and rearranging equation [1] yields the convergence equation:

$$\Delta \ln MFP_{ijt} = b_2 \Delta \ln MFP_{Fjt} - (1-b_1) RMFP_{ijt-1} + \sum_k g_k V_{kijt-1} + f_i + g_j + d_t + e_{ijt} \quad [2]$$

where $RMFP_{ijt}=ln(MFP_{ijt})-ln(MFP_{Fjt})$ is the technological gap between country i and the leading country F. Multi-factor productivity, MFP_{ijt}, is measured as the Hicks neutral productivity parameter, according to a standard neo-classical production technology under constant returns to scale.

The following (multifactor productivity) index is used as a measure of the MFP level:

$$MFP_{ijt} = \frac{Y_{ijt}}{\overline{Y}_{jt}} \cdot \left(\frac{\overline{L}_{jt}}{L_{ijt}}\right)^{a_{ijt}} \cdot \left(\frac{\overline{K}_{jt}}{K_{ijt}}\right)^{1-a_{ijt}} \quad [3]$$

where a *bar* denotes a geometric average over all the countries for a given industry j and year t. The index has the desirable properties of superlativeness and transitiveness which makes it possible to compare national productivity levels (see Caves, Christensen and Diewert, 1982). We used sectoral PPPs to convert underlying data into common currency, while also taking into account differences in purchasing powers across countries (as in Griffith *et al.*, 2000). However, as shown by Scarpetta and Tressel (2002), the main results are robust to the use of PPPs for total GDP (as in Dollar and Wolff, 1994; and Bernard and Jones, 1996*a*). The empirical analysis covers 17 manufacturing industries in 18 OECD countries over the period 1984-1998 (see Box 5.2 for details on the data).[62]

Box 5.2 Data used in the productivity and R&D regressions[63]

The main data source is the 2001 OECD STAN database, which provides information on value added, capital stock, employment and labour compensation. Data on R&D intensity (R&D expenditure divided by industry value added) is from the OECD ANBERD dataset. It measures both public and privately-funded R&D performed by businesses. Data on sectoral occupational skills have been assembled from various sources. The classification of countries as regard to the degree of centralisation and co-ordination co-ordination of their industrial relations system is based on the OECD indicator of the level of co-ordination of the wage-bargaining (see Elmeskov *et al.*, 1998), which classifies countries into three groups (low, intermediate, and high co-ordination). In the regression productivity and R&D equations, we take countries with an intermediate level of centralisation or co-ordination as a benchmark, and include dummies for low and high coordination countries. Indicators of product and labour market regulations are from Nicoletti *et al.*, (1999) and those on labour market institutions are from Elmeskov *et al.* (1998).

Import penetration is defined as the ratio of total imports to apparent demand. Data on imports are from OECD Foreign Trade Statistics. Consistent with the computation of R&D intensity, the data on output used in the computation of apparent demand are the result of the harmonisation of different sources (OECD STAN Database -- edition 2000, OECD Annual National Accounts Database, OECD Industrial Structure Statistics-ISIS).

Data on firm size are from the OECD SME Database. The measure used in the R&D regressions is the ratio of total employment of firms with 50 or more employees to total employment of all firms in the sample (excluding those with fewer than 10 employees).

Data on trade barriers are from the OECD Indicators of Tariff & Non-tariff Trade Barriers and refer to 1996. Tariffs are defined as the simple average of *ad valorem* tariff rates applied to the most favoured nation. The indicator of non-tariff barriers is a frequency ratio: it corresponds to the proportion of tariff lines to which anti-competitive non-tariff barriers apply. To avoid tariff measures being non-representative, observations in which the frequency ratio of non-*ad valorem* tariffs is greater than 20 per cent (Coke, refined petroleum and nuclear fuel -- ISIC 23 -- in Japan; Other non-metallic mineral products -- ISIC 26 -- and Telecommunication equipment -- ISIC 32 -- in Norway) are dropped from the sample.

The indicator of protection of IPRs has been developed by Ginarte and Park (1997). It varies between 0 and 5 from least to most stringent. The data used in this paper refer to 1995 and have been kindly supplied by Walter Park. All other regulatory indicators (administrative regulation, anti-competitive inward-oriented economic regulation) are from Nicoletti *et al.* (1999). They vary between 0 and 6 from least to most restrictive and refer to 1998.

Two alternative indicators of human capital are used in the R&D regressions: the share of the working-age population that completed at least upper-secondary education (from the OECD *Education at a Glance* database) and the average years of education (from Bassanini and Scarpetta, 2002).

Table 1 presents a set of policy and institutional-augmented MFP regressions.[64] We start (column 1) with the simplest specification in which MFP growth is only a function of the growth in the country leader

62. The countries are: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, (western) Germany, Greece, Italy, Japan, Korea, Netherlands, Norway, Portugal, Sweden, United Kingdom and United States.

63. This box draws heavily on joint work of one of us with Ekkehard Ernst (Bassanini and Ernst, 2002a). We are most grateful to him for letting us use part of that material here.

(MFP_{leader}) and the technology gap (RTFP). We then include R&D to the RHS (column 2) and test whether its effect also works through the technology gap (column. 3, R&D*RTFP). This would be consistent with the idea that R&D is also important for technology transfer and plays a role in developing the 'absorptive capacity (see Griffith *et al.* 2000). In the columns 4-6, we explore whether the estimated impacts vary depending on the technological regime characterising each industry. For simplicity we distinguish between low-tech industries (LT) and high-tech industries (HT). Moreover, we further split the high-tech group (column 10 in the Table) into two components: high-tech industries with different technology trajectories (*Mark I* type industries); and high-tech industries with cumulative technologies (Mark II type industries). Equations 7-9 includes our overall indicator of product market regulation (PMR) -- which is assumed to have a direct effect on productivity as well as an indirect effect via the adoption process -- and the indicator of employment protection legislation (EPL) indicator -- whose coefficient is allowed to vary depending on the bargaining regime prevailing in each country.

The results clearly point to a differentiated effect of the technology gap on productivity depending on the technology regime and market characteristics. Technological convergence seems to take place predominantly in low-tech industries, which the coefficient on the technology gap is not significant in high-tech industries. These results are consistent with the idea that industries operating in low-tech industries tend to share the same technology and thus spillover effects may be significant. In contrast, such spillovers are likely to be less marked when technological trajectories stimulate product or process diversification and lead to market power, as it is the case in high-tech industries.

The results on R&D also raise some interesting issues. While there is evidence of a significant positive *direct* effect of R&D on productivity (as would be expected), there is no evidence of R&D also boosting productivity *indirectly* by improving the ability of firms to learn about advances at the leading edge ("absorptive capacity").[65]. It has also been argued that the nature of R&D and its impact on productivity may vary depending on market conditions under which firms operate. This hypothesis is tested empirically in Table 1 by differentiating the estimated coefficient of R&D by the technology regimes in which firms operate. The estimated effect is insignificant in high-tech industries, while it is significant in low-tech industries. Moreover, the indirect effect of R&D on productivity *via* the interaction term is positively signed and significant in some specifications, suggesting that technological leaders may actually enjoy high productivity returns by investing in R&D than followers.

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64 . These are the preferred specifications obtained by a model selection process that is discussed in Scarpetta and Tressel (2002). All equations control for the presence of outlier observations in the original sample and for heteroskedasticity. Moreover, specifications including product and labour market regulations correct for cluster effects do to the fact that indicators of regulations do not vary across industries but only across countries.

65 . This latter effect is shown by the interaction variable between R&D and the technology catch-up variable, which is not statistically significant. Cheung and Garcia Pascual (2001) also found a non-significant effect of R&D expenditure in the diffusion of technology. However, the present results are in contrast with those of Griffith *et al.* (2000). See Scarpetta and Tressel (2002) for a discussion of these different results.

Table 1. Productivity regressions: the role of R&D, market structure and regulatory settings - Manufacturing

Dependant variable: ΔTFP_{ijt}	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Constant	**-0.030** **	**0.018**	**0.029** *	**-0.014**	**0.035** ***	**0.004**	**0.002**	**0.016**	**0.004**	**0.047**
	(0.013)	*(0.015)*	*(0.016)*	*(0.011)*		*(0.018)*	*(0.013)*	*(0.015)*	*(0.020)*	*(0.031)*
$\Delta TFP_{Leader\ j\ t}$	**-0.007**	**-0.007**	**-0.007**	**-0.006**	**0.001**	**-0.005**	**-0.005**	**-0.005**	**-0.005**	
	(0.008)	*(0.009)*	*(0.009)*	*0.008*	*(0.009)*	*0.009*	*(0.009)*	*(0.008)*	*(0.008)*	
$\Delta TFP_{Leader\ j\ t}$ (Mark I)										**0.096**
										(0.062)
$\Delta TFP_{Leader\ j\ t}$ (Mark II)										**-0.014**
										(0.011)
$RTFP_{i\ j\ t-1}$	**-0.029** ***	**-0.029** ***	**-0.019** **							
	(0.004)	*(0.005)*	*(0.009)*							
$RTFP_{i\ j\ t-1}$ (LT)				**-0.039** ***	**-0.020** ***	**-0.050** ***	**-0.060** ***	**-0.036** ***	**-0.053** ***	
				(0.006)	*(0.004)*	*(0.016)*	*(0.011)*	*(0.006)*	*(0.012)*	
$RTFP_{i\ j\ t-1}$ (HT)				**-0.021** ***	**-0.006**	**0.007**	**-0.023**	**-0.005**	**-0.019**	
				(0.005)	*(0.004)*	*(0.015)*	*(0.018)*	*(0.014)*	*(0.017)*	
$RTFP_{i\ j\ t-1}$ (Mark I)										**-0.053**
										(0.056)
$RTFP_{i\ j\ t-1}$ (Mark II)										**0.052** ***
										(0.015)
$R\&D_{i\ j\ t-1}$		**0.006** ***	**0.009** ***							
		(0.002)	*(0.003)*							
$R\&D_{i\ j\ t-1}$ (LT)					**0.004** ***	**0.004**	**0.004** ***	**0.004** **	**0.004** **	
					(0.001)	*(0.003)*	*(0.002)*	*(0.002)*	*(0.002)*	
$R\&D_{i\ j\ t-1}$ (HT)					**0.004** *	**0.014** **	**0.007**	**0.007**	**0.007**	
					(0.002)	*(0.006)*	*(0.007)*	*(0.006)*	*(0.006)*	
$R\&D_{i\ j\ t-1}$ (Mark I)										**0.00004**
										(0.017)
$R\&D_{i\ j\ t-1}$ (Mark II)										**0.025** ***
										(0.009)
$(R\&D * RTFP)_{i\ j\ t-1}$			**0.003**							
			(0.003)							
$(R\&D * RTFP)_{i\ j\ t-1}$(LT)						**-0.002**				
						(0.003)				
$(R\&D * RTFP)_{i\ j\ t-1}$(HT)						**0.012** *	**0.007**	**0.005**	**0.006**	
						(0.006)	*(0.007)*	*(0.006)*	*(0.006)*	
$(R\&D * RTFP)_{i\ j\ t-1}$(Mark I)										**-0.011**
										(0.024)
$(R\&D * RTFP)_{i\ j\ t-1}$(Mark II)										**0.021** ***
										(0.007)
PM regulations (PMR)							**0.007** *		**0.007**	
							(0.004)		*(0.006)*	
$PMR * RTFP_{i\ j\ t-1}$							**0.016** **		**0.011** *	
							(0.007)		*(0.007)*	
High corporatism								**-0.005**	**-0.004**	
								(0.004)	*(0.004)*	
Low corporatism								**-0.003**	**-0.002**	
								(0.005)	*(0.005)*	
EPL (medium corporatism)								**-0.010** ***	**-0.009** ***	
								(0.003)	*(0.003)*	
EPL (low corporatism)								**0.0004**	**0.0002**	
								(0.002)	*(0.003)*	
EPL (high corporatism)								**0.007**	**0.006**	
								(0.005)	*(0.005)*	
Industry dummies	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RESET[1]	0.79	1.57	2.34 *	1.64	0.77	1.74	2.87 **	3.73 **	3.21 **	12.75 ***
Observations	2569	2063	2063	2570	2063	2063	2063	2063	2063	932

[1] Ramsey's omitted-variable test: F-test on the joint significance of the additional terms in a model augmented by including the second, third and fourth powers of the predicted values of the original model.

All equations include a constant. *, **, *** denote significance at the 10%, 5%, 1% level, respectively. Standard errors adjusted for heteroskedasticity of unknown form and cluster effects on countries in parentheses. The sample is adjusted by excluding influential observations identified by the DFITS cut-off combined with the COVRATIO cut-off.

The absence of any marked effect of R&D in high-tech industries is somewhat puzzling and not very comforting in our review of the possible sources of disparities in innovation and adoption and ultimately productivity growth. However, on the basis of the discussion above (see Box 5.1), we split the high-tech group into a Mark I and a Mark II group, depending on their technological trajectory. To do this, we use a more disaggregated classification of high-tech industries (note that both country and time coverage are reduced). In Mark I industries, returns on R&D may not be long lasting and are likely to be driven by the need to engage in (perceived) product differentiation to maintain/acquire market shares. By contrast, Mark II industries are generally characterised by 'creative accumulation', with the prevalence of large, established firms and the presence of barriers for new innovators. Returns to R&D in these industries are likely to be larger than in Mark I industries, possibly leading to persistent technological leadership. Our results broadly adhere to these theoretical considerations. R&D has a strong positive effect in Mark II industries but not in Mark I industries. Moreover, there are greater returns from R&D of leading firms compared with followers in Mark II industries but not in Mark I industries. Indeed, in these industries there are high appropriability conditions and knowledge and technological progress is strongly cumulative, which gives the technological leader an advantage in the introduction of innovations.

Moving to policy and institutions, our results point to a weak direct effect of product market regulation on productivity, but a strong indirect effect via the process of adoption of existing technologies (column 7). In other words, the further an industry/country is from the frontier, the stronger the cumulative negative effect of strict regulations on productivity. These regulations discourage innovation, but also slow down the adoption of existing technologies, possibly by creating artificial barriers to the entry (or expansion) of 'imitating' firms and/or by reducing the scope for international spillovers. We also find inconclusive results as to the possible impact of industrial relations regimes on productivity, proxied by the dummies on the degree of corporatism (the sum of co-ordination and centralisation in wage bargaining).[66] However, differences in these regimes seem to affect significantly the estimated impact of EPL on multifactor productivity. If allowed to vary across the different industrial relations regimes, the negative impact of strict EPL on productivity is stronger and statistically significant only in countries with an intermediate degree of centralisation/co-ordination -- *i.e.* where sectoral wage bargaining is predominant without co-ordination. As discussed above, innovation and adoption require a continuous process of technological change, and the latter is often associated with skill upgrading of the workforce. In this context, strict EPL raises the costs of adjusting the workforce, and this may have a particularly detrimental effect on innovation and technology adoption if, in addition, the lack of co-ordination does not offer a firm the required institutional device to guarantee a high return on internal training, because other firms can poach on its skilled workforce by offering higher wages.

Policy, institutions and innovation

The above results clearly point to a significant role of R&D activity on productivity, even if the effect varies significantly depending on the technological regime in which firms operate. Thus, we explore whether policy and institutions also have an impact on R&D activity and, via R&D, on productivity. Following a large theoretical and empirical literature,[67] the simplest possible model of the determinants of innovative effort relates the latter to expected profit differential - that is the expected difference between profits that the firm can earn once it has successfully innovated and profits that would be earned otherwise. In turn, the expected profit differential depends on the degree of competition (and regulation) in the product market and other factors. Taking the ratio of business-performed R&D expenditure to sales (R&D intensity hereafter) as the indicator of innovative activity, we can write the following reduced form equation (see Bassanini and Ernst, 2002a, for details):

$$R\&D = f(\mathbf{PMR}, \mathbf{OTHER}) \quad [4]$$

66 . The Table reports the coefficients of intermediate and highly centralised countries, with decentralised countries are the reference group.

67. See *e.g.* Aghion *et al.* (2001*a*); Boone (2000*b*); Geroski (1990); Aghion *et al.* (2001*b*).

where *R&D* stands for R&D intensity, **PMR** for a vector of indicators of product market regulation, and **OTHER** for a vector of other controls.

In the following, equation [4] is implemented empirically on a cross-section of 18 manufacturing industries and 18 OECD countries. The choice of a cross-section -- rather than a panel data, as in the case of productivity equation -- is justified by the need to include a set of control variables for which time dimension is lacking, including detailed aspects of product market regulations. As indicators of product market regulation we use measures of inward-oriented economic regulation (state control, legal barriers to entry, price controls, etc…), administrative regulation (administrative barriers on start-ups, feature of the licensing and permit system, etc…), indicators of tariffs and non-tariffs barriers, plus an indicator of global protection of IPRs. Furthermore, we use import penetration as a proxy for competitive pressures not captured by the regulatory indicators. Finally, most of the other factors can be controlled for either by industry dummies (technological opportunity, returns to scale, dynamics of the industry's world demand etc…) or by country dummies (aggregate demand, supply of human capital etc…). However, other factors (such as capital intensity and the dynamics of the industry's domestic demand), being co-determined in equilibrium, are not included in the reduced form, since, in a cross-section, it is impossible to find valid instruments for these variables. A control for the average size of firms represents an exception. In fact, this control captures the bias in R&D intensity across industries and countries due to different accounting practices between large and small firms and has been proved to play an important role in the literature (see *e.g.* Griliches, 1990, Geroski, 1990).

Choosing a log-linear form for convenience, equation [4] can be therefore re-written as:

$$\log R\,\&\,D_{ij} = a + \sum_h g_h PMR_{ij}^h + f IMP_{ij} + d SIZE_{ij} + m_i + c_j + e_{ij} \qquad [5]$$

where *IMP* and *SIZE* denote import penetration and average size, m stands for the country dummy, c stands for the industry dummy, e is the standard error term, while h, i and j index product market regulatory indicators, countries and industries, respectively.

With the exception of indicators of tariffs and non-tariff barriers and inward-oriented economic regulation, all other regulatory indicators refer to economy-wide regulation and institutions that are by definition identical across industries in each country and therefore cannot be identified in the presence of country dummies. Moreover, the same applies to the indicator of inward-oriented economic regulation for which no sector breakdown is available for manufacturing industries, leading us to proxy it with an economy-wide indicator. Therefore, to gather some evidence on the absolute impact of economy-wide product market regulations on R&D intensity we need to complement equation [5] with a specification of the determinants of the country fixed effect, that is:

$$m_i = a + \sum_h c_h PMR_i^h + \sum_m d_m CNTRL_i^m \qquad [6]$$

where *CNTRL* stands for a number of other economy-wide control variables that are indexed by m. By plugging equation [6] into equation [5] we obtain the general specification of our R&D equation.[68] The sample used for the R&D equation includes 2-digits manufacturing industries.[69] If not differently specified,

68 . As in the case of the productivity equations, we control for the presence of outliers in the sample and correct standard errors fo r the presence of cluster effects.

69 . The industry *manufacturing not elsewhere classified* (ISIC 36 and 37), being a residual sector, is excluded, while *food, beverages and tobacco* (ISIC 15 and 16) and *textiles* leader and clothing (ISIC 17, 18 and 19) have been aggregated due to lack of data availability. Countries considered are Austria, Belgium, Canada, Germany, Denmark, Finland, France, Greece, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States.

all variables have been averaged across 1993-1997, excluding years in which observations were missing for most of the industries. Data on R&D intensity are the same as those described in Box 2, i.e. the ratio of the industry's Business Expenditure in Research and Development (BERD) to the industry's total output. In a sensitivity analysis we also use the ratio of government-financed BERD to total output.[70] As we do not always have data on the ratio of government-financed BERD to total BERD for the same years for which we have data for R&D intensity, we construct an estimate of government-financed BERD to total output as the product of the average ratio of government-financed BERD to total BERD[71] by the average ratio of BERD to output. We make here an implicit assumption that these two ratios do not vary over time. This assumption can be justified on the basis of the limited variation over time (with respect to variation cross-country and cross-industry) of both ratios. Data on the ratio of government-financed BERD to total BERD are from the OECD R&D database.

The first specification in Table 2 only includes basic controls for R&D intensity, including country specific effects.[72] The other specifications try to account for these country-specific effects by including different aspects of the regulatory and institutional environment, although in a limited number to avoid problems of multicollinearity. In particular, we consider the degree of co-ordination of industrial relations systems, in order to distinguish between fully decentralised and un-co-ordinated regimes, co-ordinated regimes and mixed ones, and the overall level of human capital. Columns 2-5 consider the indicators of inward-oriented administrative and economic regulation separately, while a simple average of these indicators is included in columns 6-7. In both these two groups of specifications non-significant variables are sequentially eliminated.[73] The share of the population that completed at least upper-secondary education seems less significant than average years of education (compare column 2 with column 3); therefore the latter is retained in all the other specifications (columns 4-7).

70. The advantage of using R&D intensity data is that they are available for many countries on a comparative basis. Nevertheless, these data suffer from important limitations (for a general discussion, see Griliches, 1990). R&D intensity is an indicator of input in the innovative process rather than output. Consequently improvements in the efficiency of the innovation process (greater output with less input) can be mistakenly interpreted as a reduction of the innovative effort. Moreover, R&D intensity conveys only information about formal innovation expenditure. In many industries informal innovation is a sizeable component of overall innovation activity. Also, reported data tend to overestimate R&D intensity of large incumbents relative to small firms and new entrants.

71. As in the case of other variables, the ratio of government-financed BERD to total BERD is an average across 1993-1997, excluding years in which observations were missing for most of the industries. In the case of the United Kingdom, however, the ratio of government-financed BERD to total BERD refers to 1989 (last available year).

72. One of the purposes of presenting results from a specification including country dummies (column 1) is that it allows assessment of the quality of the estimates obtained with the other specifications. Indeed, if the estimates of those variables that are included in all the specifications changed significantly upon substitution of proxies of the country fixed effects, this may indicate a serious omitted variable problem. It is reassuring that, across all specifications, the point estimate of the coefficients of industry-varying variables fall into the boundaries of the 5 per cent confidence intervals and that the RESET test statistics are always insignificant at standard statistical levels. Moreover, a sensitivity analysis performed on our preferred specification (corresponding to column 5 of Table 2) by eliminating one country at a time suggests that coefficient estimates are relatively robust to variation of country coverage.

73. Estimates from specifications not including tariff barriers are not shown for brevity. In any case, the exclusion of tariff barriers do not change estimated coefficients of other variables.

Table 2. The R&D equation: main results

Dependent variable: logarithm of R&D intensity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Independent variables							
Employment share of large firms	0.019 ***	0.027 **	0.023 **	0.022 *	0.022 *	0.022 *	0.023 *
	(0.006)	*(0.010)*	*(0.011)*	*(0.011)*	*(0.012)*	*(0.012)*	*(0.013)*
Import penetration	0.004 *	0.005 **	0.004 *	0.004 **	0.004 *	0.004 *	0.004 **
	(0.002)	*(0.002)*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.002)*
Non-tariff barriers	-0.014 ***	-0.018 ***	-0.023 ***	-0.023 ***	-0.023 ***	-0.023 ***	-0.023 ***
	(0.005)	*(0.004)*	*(0.005)*	*(0.005)*	*(0.005)*	*(0.004)*	*(0.004)*
Tariff barriers	0.025	0.002	-0.003	-0.005	-0.007	-0.012	-0.010
	(0.019)	*(0.062)*	*(0.025)*	*(0.025)*	*(0.027)*	*(0.031)*	*(0.031)*
Administrative regulation		0.148	0.134	0.125			
		(0.131)	*(0.147)*	*(0.130)*			
Inward-oriented economic regulation		-0.438 ***	-0.446 **	-0.435 ***	-0.393 ***		
		(0.135)	*(0.162)*	*(0.134)*	*(0.122)*		
Overall inward-oriented regulation						-0.430 **	-0.435 **
						(0.176)	*(0.181)*
Protection of IPRs		0.708 ***	0.674 ***	0.660 ***	0.758 ***	0.824 ***	0.856 ***
		(0.166)	*(0.176)*	*(0.163)*	*(0.152)*	*(0.217)*	*(0.166)*
Low coordination dummy		-0.599 ***	-0.559 ***	-0.596 ***	-0.730 ***	-0.913 ***	-0.863 ***
		(0.262)	*(0.181)*	*(0.169)*	*(0.198)*	*(0.230)*	*(0.243)*
High coordination dummy		0.216	0.058			-0.093	
		(0.176)	*(0.203)*			*(0.188)*	
Upper-secondary education share		0.020 *					
		(0.011)					
Average years of education			0.061 **	0.067 **	0.066 **	0.086 ***	0.076 ***
			(0.024)	*(0.027)*	*(0.026)*	*(0.026)*	*(0.026)*
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	No	No	No	No	No	No
RESET[1]	2.45 *	0.77	1.87	1.92	1.94	2.28 *	2.00 *
R-squared	0.88	0.85	0.85	0.85	0.84	0.84	0.84
Observations	254	254	254	254	254	254	254

[1] Ramsey's omitted-variable test: F-test on the joint significance of the additional terms in a model augmented by including the second, third and fourth powers of the predicted values of the original model.

All equations include a constant. *, **, *** denote significance at the 10%, 5%, 1% level, respectively. Standard errors adjusted for heteroskedasticity of unknown form and cluster effects on countries in parentheses. The sample is adjusted by excluding influential observations identified by the DFITS cut-off combined with the COVRATIO cut-off. Excluded observations are: Food, beverages and tobacco (ISIC 15-16) in Norway, Computers (ISIC 30), Telecommunication equipment (ISIC 32) and Wood (ISIC 20) in Ireland, Other transport (ISIC 35) in Greece, Coke, petroleum and nuclear fuel (ISIC 23) in the United Kingdom, Printing and publishing (ISIC 22) and Motor vehicles (ISIC 34) in Belgium, Printing and publishing (ISIC 22) in France, Other transport (ISIC 35) in Italy and Electrical Machinery (ISIC 31) in the Netherlands.

The insignificant coefficient estimate for tariffs might be due to controlling for import penetration (which captures some aspects of competitive pressure) and the lack of variability of the indicator resulting from the fact that trade barriers are the same across all EU countries (although this statement is true also for non-tariff barriers). Nonetheless, as discussed in Chapter 4, there might be good theoretical reasons for a less negative impact of tariffs (rather than of non-tariff barriers) on innovation. Under Cournot competition in partial equilibrium, conditional to the level of knowledge spillovers, tariffs have a positive impact on profits (because they add to foreign competitors' costs) without changing the incentive to reduce own costs via innovation. However, in general equilibrium, tariffs interact negatively with imports and might then have a negative overall impact due to their indirect effect on knowledge spillovers. This effect is stronger for non-tariff barriers that have a greater impact on the diffusion of products and, eventually, the possibility of imitation and reverse engineering by domestic firms. Moreover high non-tariff barriers can be thought to affect directly the elasticity of substitution between imported and domestically produced products, thereby inducing low incentives to innovate when domestic and foreign firms have similar levels of competitiveness (the case of "neck and neck" competition).

The degree of protection of IPRs appears to be positively and significantly associated with R&D intensity in all specifications.[74] The same applies to inward-oriented economic regulation, while the estimated coefficient for administrative regulation is not significantly different from zero. In other words, restrictions to competition enforced through administrative barriers to entry do not seem to have a negative effect on innovation performance. This might be due to the fact that administrative regulation, by discouraging entry, may contribute to increasing *ex post* innovation rents and improving appropriability conditions, reinforcing the effect of IPRs protection. Obviously, this positive effect is stronger for incumbents, and is likely to be overestimated in equations using R&D data (see the discussion on R&D data in the previous section). Nevertheless, several other explanations are possible: i) by reducing competitive pressures, high administrative barriers may also reduce competitive selection and, hence, overall industry efficiency (Vickers, 1995; Nickell, 1996), including efficiency in turning R&D into innovation (in this case R&D is less productive and the recorded R&D intensity higher, without implying that firms are innovating more); ii) tight administrative regulation may generate rents and wage premia, pushing towards more capital-intensive and higher-technology production processes (see e.g. Chennels and van Reenen, 1998, and Acemoglu and Shimer, 2000); and iii) the stringency of administrative regulation may proxy for size, compensating for possible errors in the measurement of this variable. The bottom line is that these regression results do not authorise us to conclude that the level of administrative regulation is irrelevant for innovation. As a partial confirmation of this no-conclusion, the estimated coefficient of overall inward-oriented regulation in columns 6-7 is strongly significant and virtually identical to that of economic regulation in columns 2-5.

Among the possible covariates for which we could not control for in Table 2 due to the limitation of our dataset, public expenditure in R&D is perhaps the most critical for two reasons: i) public expenditure is likely to respond to different incentives than private expenditure; and ii) public expenditure in R&D may either crowd-out or stimulate private expenditure. Indeed, the literature has found that private expenditure in R&D is not neutral with respect to public expenditure (and particularly government-financed expenditure in R&D)[75]. Table 3 presents a sensitivity analysis where our preferred specifications (corresponding to columns 4, 5 and 7 of Table 2) have been re-estimated by including the ratio of government-funded business-performed R&D to total output. To do so, 66 further observations (including three complete countries[76]) have been excluded in the unadjusted sample due to missing data.[77]

74. Results concerning protection of IPRs must be taken with care as the coefficient of this variable is likely to be overestimated due to the endogeneity of the indicator to the level of R&D expenditure (see Ginarte and Park, 1997).

75. For instance, Lichtenberg (1988) finds that non-competitive R&D procurement tends to crowd out private R&D investment, while competitive procurement stimulates private R&D investment. By contrast, Guellec and Van Pottelsberghe (1997) support the complementarity hypothesis. See David *et al.* (1999) for a survey.

76. Excluded countries are Belgium, Greece and the Netherlands.

77. This group of specifications however performs much better from the point of view of outlier control. After adjusting for influential observations the difference between this sample and the sample of Table 2 amounts to 59 observations.

Table 3. The R&D equation: sensitivity analysis: controlling for public expenditure in R&D

Dependent variable: logarithm of R&D intensity	(1)	(2)	(3)
Independent variables			
Employment share of large firms	0.015	0.014	0.015
	(0.010)	*(0.011)*	*(0.013)*
Import penetration	0.010 **	0.010 **	0.010 **
	(0.004)	*(0.004)*	*(0.004)*
Non-tariff barriers	-0.031 ***	-0.031 ***	-0.031 ***
	(0.005)	*(0.005)*	*(0.006)*
Tariff barriers	0.000	-0.001	-0.005
	(0.003)	*(0.003)*	*(0.004)*
Government-financed R&D intensity [1]	0.216 ***	0.217 ***	0.208 ***
	(0.048)	*(0.048)*	*(0.055)*
Administrative regulation	0.040		
	(0.140)		
Inward-oriented economic regulation	-0.499 ***	-0.498 ***	
	(0.149)	*(0.146)*	
Overall inward-oriented regulation			-0.649 **
			(0.222)
Protection of IPRs	0.733 ***	0.766 ***	0.916 ***
	(0.175)	*(0.145)*	*(0.180)*
Low coordination dummy	-0.899 ***	-0.950 ***	-1.111 ***
	(0.208)	*(0.248)*	*(0.298)*
Average years of education	0.052 **	0.052 **	0.071 **
	(0.025)	*(0.024)*	*(0.026)*
Industry dummies	Yes	Yes	Yes
Country dummies	No	No	No
RESET [2]	2.98 **	2.99 **	2.45 *
R-squared	0.89	0.89	0.88
F-test on industry dummies	203.43 ***	371.21 ***	126.80 ***
Observations	195	195	195
Industries	18	18	18
Countries	15	15	15

[1] Logarithm of the ratio of government-financed BERD to output.

[2] Ramsey's omitted-variable test: F-test on the joint significance of the additional terms in a model augmented by including the second, third and fourth powers of the predicted values of the original model.

All equations include a constant. *, **, *** denote significance at the 10%, 5%, 1% level, respectively. Standard errors adjusted for heteroskedasticity of unknown form and cluster effects on countries in parentheses. The sample is adjusted by excluding influential observations identified by the DFITS cut-off combined with the COVRATIO cut-off. Excluded observations are: Computers (ISIC 30), Telecommunication equipment (ISIC 32) and Wood (ISIC 20) in Ireland, and Other transport (ISIC 35) in Japan.

Not surprisingly, the elasticity of R&D intensity with respect to government-financed R&D intensity appears to be significantly greater than zero (with a point estimate of about 21 per cent). However, the effect of this variable on the other coefficient estimates is relatively modest, with most regulatory indicators having a stronger and more significant estimated impact except in the case of administrative regulation whose t-statistic drops enormously. In brief, this sensitivity analysis qualitatively confirms the main results.

Bassanini and Ernst (2002b) go beyond this point by considering simultaneously the role of product and labour market regulations. As regard to the estimates of product market regulation this is important since there is a strong correlation between indicators of product and labour market regulation (see Nicoletti *et al.*, 1999), therefore equations presented in Table 2 and 3 might suffer from an omitted variable problem. Table 4 shows the estimated effects of this extended specification (corresponding to column 2 in Table 3): consistent with the productivity equation, the coefficient of EPL is allowed to vary between countries with high and low/intermediate levels of co-ordination. While the estimated coefficients for product market regulatory variables in these extended specifications are virtually identical to those shown in Table 3, complex patterns emerge as regard to the effect of the stringency of labour market regulation.

Table 4. Estimated effect of employment protection on R&D intensity

Dependent variable: logarithm of R&D intensity		Type of industrial relations system: Low / intermediate coordination	Type of industrial relations system: High coordination
Industry type	Low-tech industries	-0.16	-0.46 **
		(0.20)	(0.19)
	Mark I indusries	-0.38 *	-0.11
		(0.21)	(0.26)
	Mark II industries	-0.37 *	0.69 **
		(0.21)	(0.30)

*, **, *** denote significance at the 10%, 5%, 1% level, respectively. Standard errors are in parentheses. The coefficients follows from the estimation of the specification corresponding to column 2 of Table 2 augmented by labour market regulation (source: Bassanini and Ernst, 2002b).

In particular, the effect of employment protection adds to the negative effect of product market regulation in unco-ordinated countries,[78] with a degree of magnitude equivalent to that of inward-oriented economic regulation.[79] Conversely, in co-ordinated countries the stringency of employment protection seems to be negatively associated with R&D intensity in low technology industries, but positively associated in Mark II industries.[80] These results are consistent with the theoretical discussion of the role of the interplay between labour market institutions and industry characteristics in shaping incentives for different human resource strategies and thereby innovation patterns.[81] Indeed, these results seem to reflect the fact that hiring and firing restrictions depress the incentive to innovate the greater the need of downsizing and/or reshuffling one's own workforce after having successfully innovated. These negative effects are however smaller the larger the scope for internal labour markets. In the context of a cumulative and specific knowledge base, stringent employment protection and co-ordinated systems of industrial relations, by aligning workers' and firms' objectives, enhancing the accumulation of firm-specific competencies and encouraging firm-sponsored training, may allow firms to fully exploit the potential of the internal labour market.

5.3 Concluding remarks

The empirical evidence reported in this Chapter seems to suggests that stringent regulatory settings in the product and labour markets may contribute to explain cross-country difference in innovation activity and adoption of leading technologies, thus providing an interpretation for the growth patterns discussed in the previous Chapters of this study.

It also appears that the impact on performance of regulations and institutions depends on certain market and technology conditions, as well as on specific firm characteristics. In particular, the burden of strict product market regulations on productivity seems to be greater the further a given country/industry is from

78. The estimated coefficient of EPL in low-tech industries is not significantly different from zero. However, these industries account on average for only 20 per cent of total R&D expenditure in manufacturing.

79. The standard deviation of the indicator of employment protection is similar to that of the indicator of inward-oriented economic regulation in our sample.

80. The estimated coefficient for Mark I industries is approximately equal to zero.

81. See, for example, Saint-Paul (2002).

the technology frontier. That is, strict regulation hinders the adoption of existing technologies, possibly because it reduces competitive pressures or technology spillovers, and restricts the entry of new high-tech firms. In addition, strict product market regulations have a negative impact on the process of innovation itself. Thus, given the strong impact of R&D on productivity, there is also an indirect channel whereby strict product market regulations may reduce the scope for productivity enhancement.

We have also provided some evidence that high hiring and firing costs weaken productivity performance, but this occurs almost exclusively when wages and/or internal training do not offset these higher costs, thereby inducing sub-optimal adjustments of the workforce to technology changes. The link between EPL and innovation activity is also complex. Our analysis suggests that different joint configurations of EPL and bargaining regimes may lead to high innovative activity, though in different sectors of the economy. In particular, strict EPL adds to the negative effects on innovation of strict product market regulations in un-co-ordinated countries. Conversely, in co-ordinated countries strict EPL tilts the pattern of specialisation of innovative activities towards stable and cumulative technological paradigms and away from activities characterise by large turnover of technologies. To the extent to which important domains of the ICT industry are dominated by the frequent changes in the leading technology (e.g. in software industry), these results may help to explain why continental European countries, while enjoying leading positions in more industries with cumulative technologies (e.g. motor vehicles) are slow in moving into the ICT industry. On the one hand, our results suggests that the combination of strict EPL and intermediate bargaining regimes (i.e. lacking co-ordination), as in many continental European countries, is likely to lead to lower innovation activity and less incentives to adopt leading technologies. On the other hand, countries with a co-ordinated bargaining system but a high level of anti-competitive product market regulation (*in primis* Italy but to some extent also Japan and Germany among G7 countries), while being able to keep up with innovations in cumulative industries, have weak incentives in adopting and innovating in ICT technologies. Indeed, product market reforms are perhaps the most important item in an ideal policy agenda in these countries.

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