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# Productivity and Convergence in a Panel of OECD Industries: Do Regulations and Institutions Matter?

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## *ABSTRACT/RESUMÉ*


**Productivity and Convergence in a Panel of OECD Industries: Do Regulations and Institutions Matter?**

We analyse the impact of innovation activity and product and labour market institutions on multi-factor productivity in a panel of 23 industries in 18 OECD countries using a novel harmonised database. First, we provide evidence of convergence in productivity levels within most industries across OECD countries. Convergence is however stronger in services than in manufacturing and, in the latter sector, it is weaker for high-tech industries. We also find evidence that the impact of innovation activity (proxied by R&D expenditure) on productivity depends on market structure and technological characteristics, with a stronger impact for technological leaders in high-tech industries. In addition, anti-competitive product market regulations are negatively associated with productivity performance. The negative effect is larger the further a country is from the technological frontier, because such regulations hinder the process of technology adoption. Finally, there is also evidence in the data of a negative impact of tight employment protection legislation on productivity when wages or internal training do not offset the higher adjustment costs associated with high firing costs.



*JEL classification:* O3, O4, L10.
*Key words:* Innovation, productivity, convergence, regulations on product and labour markets.


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**Productivité et convergence sur un panel de secteurs industriels des pays de l'OCDE : une analyse de l'impacte des réglements et des institutions**

Dans ce papier, nous analysons l'impact de l'innovation et de la réglementation sur le marche des biens, ainsi que les réglementation et institutions sur le marche du travail, sur la productivité multifactorielle. L'étude est réalisée sur un panel de 23 secteurs dans 18 pays de l'OCDE, à partir d'une nouvelle base de donnée harmonisée. Tout d'abord, nous montrons qu'il y a eu convergence des niveaux de productivité pour la plupart des industries considérées dans les pays de l'échantillon. Néanmoins, la convergence est plus rapide dans les secteurs des services que dans les secteurs manufacturiers; de plus, au sein de la manufacture, la convergence est faible pour les industries high-tech. Nous montrons aussi que l'impact de la recherche et développement (mesurant l'innovation) sur la productivité dépend de la structure de marche et des caracteristiques technologiques, avec un impact plus fort pour le leader technologique dans les secteurs high-tech. D'autre part, les réglementations qui réduisent les pressions concurrentielles sur le marche des biens (en accentuant par exemple les barrières a l'entrée) ont un impact négatif sur la productivité. Cet impact négatif augmente avec le retard technologique, ce qui suggère que les réglementations anti-competitives tendent a réduire l'adoption de nouvelles technologies. Enfin, nous montrons que les législations de protection de l'emploi ont un impact négatif sur la productivité lorsqu'une insuffisante coordination des négociations salariales ne compense pas l'augmentation des coûts de licenciements.



*Classification JEL:* O3, O4, L10.
*Mots-clés:* Innovation, productivité, convergence, réglementations sur les marchés des biens et du travail.

**PRODUCTIVITY AND CONVERGENCE IN A PANEL OF OECD INDUSTRIES: DO REGULATIONS AND INSTITUTIONS MATTER?**

**Stefano Scarpetta and Thierry Tressel**[1]

## Introduction

The impressive performance of the US economy over the 1990s and the diffusion of information and communication technologies (ICT) had led many commentators to claim that a "new economy" had emerged. US growth patterns over the 1990s include an acceleration in labour and multifactor productivity (MFP) growth together with rising employment levels and thus higher GDP per capita growth, a combination that is rather unusual for a country already at the world productivity frontier in many industries (see e.g. Oliner and Sichel, 2000; Jorgenson and Stiroh, 2000). These growth patterns are also noticeable because they are in sharp contrast with those observed in the other large OECD economies which have experienced a slow down in GDP per-capita and productivity growth (see *e.g.* Bassanini and Scarpetta (2002) and stagnant employment. These growth disparities have also persisted during the past two years which saw the burst of the ICT bubble: GDP growth has decelerated everywhere, but productivity growth has held quite well in the United States along the higher trend pattern set forth in the 1990s.

Growing disparities in growth patterns amongst industrialised countries have been related to the different ability of countries to adopt new and highly productive equipment, and to the size of the rapidly expanding ICT-producing industry. The question is why certain countries have been able to rapidly adopt this new technology and make the best use of its potential, while others have lagged behind. In this context, it has been argued that the process of innovation (and adoption of existing technologies) may vary depending on underlying market conditions as well as by institutions affecting the functioning of product and labour markets. This argument is part of a broader tendency in the growth and IO literature to underline the role of institutions and market structures in explaining economic performance of different industries (see Aghion *et al.*, 2001*a*, Hall and Jones, 1999, Saint-Paul, 2002 and Sutton, 1998). However, to date, the empirical evidence on how market conditions and institutions interact with technological change and explain productivity growth is scarce.

This paper sheds light on these issues by presenting an empirical analysis on how innovation activity (proxied by R&D intensity) and institutional settings affect the observed differences in multifactor productivity across a panel of industries in the OECD countries. The

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analysis draws from a rich dataset covering harmonised data for 23 industries in manufacturing and services in 18 OECD countries over the past two decades. The following points are explored: *i*) the influence of innovative activities and technology adoption on industry productivity, *ii*) the interplay between innovation and market structure conditions, and *iii*) the influences of institutional settings in the product and labour markets on productivity, both directly and *via* the process of adoption of existing technologies.

The main results of the paper are the following: *i*) R&D intensity has a positive impact on productivity growth; however, in high-tech industries, technological leaders tend to benefit more from innovation activity; we show also that, within high-tech industries, the impact of R&D is significant only in industries with homogenous technological trajectories and high concentration; *ii*) anti-competitive product market regulations reduce incentives to adopt better technology and catch-up the technological leader; and *iii*) stringent employment protection legislation has a negative impact on productivity growth in countries where wages or internal training do not offset the adjustment costs associated with high firing costs.

The roadmap of the paper is as follows. Section 1 briefly reviews the recent literature on productivity, innovation and product and labour market conditions. Section 2 presents the theoretical framework used in the empirical analysis of productivity, while Section 3 presents the data. Section 4 discusses our empirical results and Section 5 offers some conclusive remarks and suggestions for further research.

## 1. Productivity, market conditions and institutions

### *Product market competition and productivity*

Textbook theory suggests that competition in the product market 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; a variety of principal-agent models under information asymmetry have indicated additional potential gains 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 understanding better new forms of competition observed in "dynamically" competitive industries (Evans and Schmalensee, 2001).

Models focussing on dynamic efficiency generally originate from the idea that monopoly rents are often captured by managers (and workers) in the form of managerial 'slack' or reduced work effort, and that product market competition would discipline 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). Second, cost-reducing improvements in productivity could generate higher revenue and profit in a more competitive environment where price elasticity of demand tends to be higher. Third, 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 (Shmidt, 1996; 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 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). Similarly, while higher demand elasticity under competition increases the relative rewards from a cost reduction, larger scale operations for a monopolist tend to increase his absolute reward from a similar cost reduction. All in all, depending on the setting of the model, competition is shown to improve efficiency in many, but not all, circumstances.

The effect of competition on productivity through innovative activity has also been extensively analysed. The basic Schumpeterian model suggests that innovation and growth are declining with competition because the monopoly rents from innovations tend to be dissipated more quickly when there is greater competition. The empirical evidence, however, tends to show a positive relationship and Aghion and Howitt (1998) have attempted to extend the basic Schumpeterian model so as to reconcile theory with the empirical evidence. In particular, they offer several theoretical cases where competition can be conducive to greater innovation. First, in a rapidly changing technological environment, there might be a *Darwinian effect*, where intensified competition force managers to speed up the adoption of new technologies in order to avoid loss of control rights due to bankruptcy. Even if technological progress is more gradual, *i.e.* when firms are engaged in step-by-step innovative activities, greater competition may induce *neck-and-neck* firms to invest more into R&D in order to acquire a lead over their rivals. Finally, in the learning-by-doing model of endogenous growth, the steady-state rate of growth may be increased if skilled workers become more adaptable in switching to newer production lines. Increased competition could generate higher growth by increased mobility of skilled workers to newer lines (*mobility effect*).

Despite the vast literature on the links between competition, innovation and performance, empirical evidence is still fairly limited. 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.* (1992) 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). 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).

The limited empirical evidence on the links between productivity and competition is partly due to the difficulty of measuring competitive pressures. Traditional indicators of product market conditions, such as mark-ups or industry concentration indexes, cannot be treated as exogenous determinants of economic outcomes.[2] Moreover, recent research shows that these indicators are not univocally related to product market competition (Boone, 2000).[3] Finally, they fail to provide a direct link to policy or regulation. The empirical analysis in our paper is based on some of the potential policy determinants of competition, rather than on direct measures of it. In particular, the focus is on a set of indicators of product market regulations described in detail in Nicoletti *et al.* (1999) (see below).[4]

### *Labour market institutions and productivity*

We also consider the potential influences of certain labour market policies and institutions. They may 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). First, the industrial relations 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, innovating firms tend to adjust their workforce 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 tends to favour 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. Co-ordination amongst employers in wage setting is also crucial. This is implicit in highly centralised wage setting systems but also exists in some countries with predominantly sectoral bargaining systems (*e.g.* Austria, Germany). Co-ordination tends to further reduce the variability of wage offers across firms, and often leads to close inter-firm practices where poaching is considered as unfair behaviour (see Bassanini and Ernst, 2002 for a discussion).

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2 . Amongst the very few cross-country studies that explore the role of competition on productivity, Cheung and Garcia Pascual (2001) use mark-ups and concentration indexes. At the firm-level, Nickell (1996), Nickell *et al.* (1997) and Disney *et al.* (2000) use market share indicators to capture competitive pressures. However, the potential problem of endogeneity is even more serious in firm-level as observed high productivity firms may gain market shares and enjoy innovation rents.

3 . Boone (2000*a*) suggests that there may be a hump-shaped relationship between competition and mark-ups.

4 . Koedijk and Kremers (1996) offer some evidence of the effects of *excessive* regulation on performance. However, their analysis is based on less refined indicators of regulation and simple cross-section regressions.

### *Innovation, R&D and productivity*

The direct effects of policy and institutions on productivity are likely to be combined with the indirect effects stemming from their influence on R&D activity. First, both theoretical and empirical literature seem to agree on the importance of such activities for productivity (see *e.g.* Griliches, 1980; Griliches and Lichtenmerg, 1984; and recently Guellec and von Pottelsberghe, 2001). The main assumption is that R&D drives productivity by the stream of innovation it produces. However, recent studies (*e.g.* Cohen and Levinthal, 1989; Griffith *et al.*, 2000) suggest an additional channel whereby R&D can boost productivity *via* the adoption of existing technologies developed elsewhere. This implies that the further a country is away from the technology frontier, the greater the benefits from R&D, by stimulating domestic and international knowledge spillovers. Second, Bassanini and Ernst (2002) found evidence that the interaction between strict employment protection legislation (EPL) and certain industrial relations regimes may have detrimental effect on R&D activity.[5] Likewise, the same paper offers some tentative evidence of a significant impact of certain aspects of product market regulations (e.g. *economic regulations*, comprising state control, legal barriers to entry etc.) on R&D activity.

### *Does market structure influence productivity and the effects of innovation on it?*

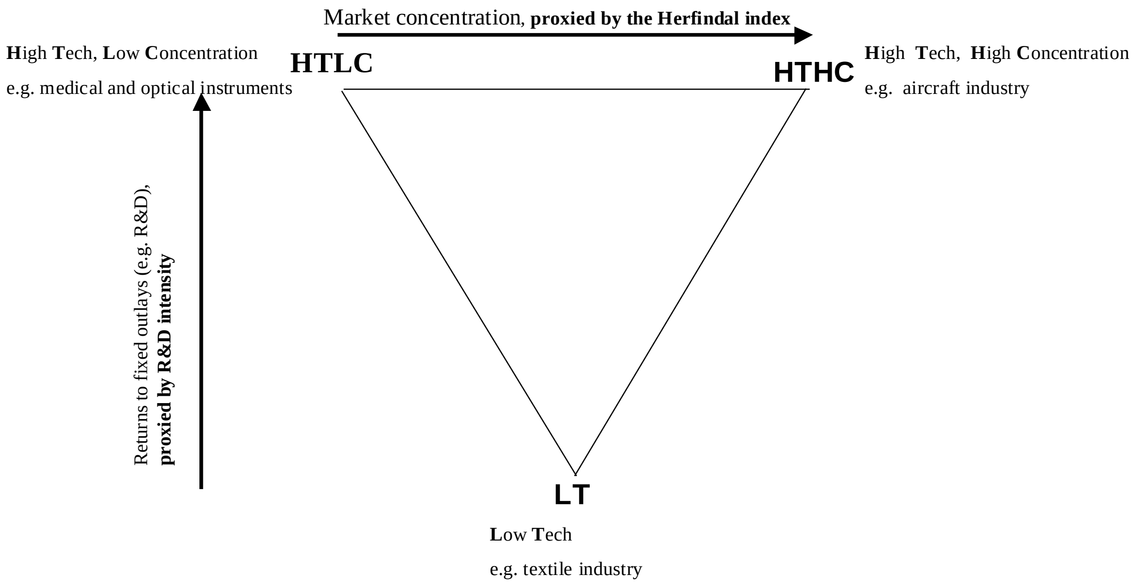
The industrial organisation literature suggests three main elements that characterise market conditions across industries. First, differences in market power relate to differences in entry barriers, due to exogenous technological conditions, such as economies of scale (see *e.g.* Panzar, 1989) and scope (Baumol *et al*., 1982). Second, it has been argued that entry barriers may be due to high sunk costs rather than economies of scale. Finally, more recent research has focused on *horizontal* and *vertical* product differentiation (Eaton and Lipsey, 1989). When consumers cannot rank products unambiguously by quality, the taste for variety is valued *per se* and products can be considered to be differentiated horizontally. Products can be considered as differentiated vertically when consumers can rank them by quality.

In practice, the degree of economies of scale and scope, sunk costs and product differentiation are often combined in different ways, but depending on their relative importance, one (or few) will dominate the others, leading to a reduced number of market structure prototypes. In practical terms, Sutton (2000) offers a simple market-structure classification based on the returns to innovation and the degree of market concentration (see Figure 1 below). If the returns to innovation (*e.g.* R&D) are low, the fraction of revenue devoted to such activity will be low: this configuration indicates low-tech industries where production processes and product design are fairly standardised (indicated by LT in the figure). In this context set-up costs are low and a large number of firms compete fiercely on price, which is close to marginal cost. If the returns to innovation are high, firms will invest heavily in technologies that improve process and products. However, markets may develop differently depending on the technical trajectories. When different trajectories lead to alternative types of products (product differentiation), the equilibrium configuration comes close to Chamberlain's monopolistic competition. In this case product differentiation means that there is always demand for a new product, leading to a large number of producers (high-tech, low concentration, indicated by HTLC in the Figure). Each firm has some

5 . See also Soskice (1997); Eichengreen and Iversen (1999); Acemoglu and Pischke (1999*a,b*).

market power, but free entry of new firms hinders the development of excess profits or monopoly rents. In contrast, if high returns to innovation can be attained along any one trajectory, firms will inevitably move towards a highly concentrated market structure, in which a small number of players dominate the market (high-tech, high concentration, indicated by HTHC in the Figure).

**Figure 1. A simple taxonomy of market structure**




The nature of competition, the impact of given policy and institutional settings and, ultimately, productivity performance may vary across these different market structures. For example, high mark ups could be taken as a sign of market power in industries with low R&D, although they may well be an indication of innovation rents in those with high R&D (Oliveira Martins and Scarpetta, 1999). Similarly, high R&D expenditure may not result in high productivity growth, but rather in higher market shares in markets with highly differentiated products. The three market structure prototypes presented in Figure 1 will be used in the empirical analysis to assess potential differences in productivity performance, in the technological catch-up and the impact of innovation on productivity.

## 2. The theoretical framework

We follow the approach developed in recent papers that analyse convergence across countries or states within manufacturing and service sectors (*e.g.* Bernard & Jones, 1993, 1996*a*, 1996*b*; Griffith *et al.* 2000; Harrigan, 1998; Dollar & Wolff, 1988, 1994). We start with a standard production function (in country *i* and sector *j*), under perfect competition and constant returns to scale:

$$Y_{ijt} = A_{ijt} \cdot F_{ij}\left(L_{ijt}, K_{ijt}\right)$$

where Y is output[6], $A$ is a Hicks-neutral parameter of technical change[7], $F_{ij}$ is a country/sector-specific production function, $K$ is physical capital and $L$ labour. Assuming a translog production function and taking logs yield:

$$y_{ijt} = a_{0ijt} + a_{1ijt} \cdot l_{ijt} + a_{2ijt} \cdot k_{ijt} + a_{3ijt} \cdot l_{ijt}{}^{2} + a_{4ijt} \cdot k_{ijt}{}^{2} + a_{4ijt} \cdot l_{ijt} \cdot k_{ijt}$$

Under constant returns to scale, multi-factor productivity growth is measured by a superlative index derived from the translog production function (see Caves *et al.*, 1982):

$$\Delta MFP_{ijt} = \Delta y_{ijt} - \frac{1}{2}\left(\alpha_{ijt} + \alpha_{ijt-1}\right) \cdot \Delta l_{ijt} - \left(1 - \frac{1}{2}\left(\alpha_{ijt} + \alpha_{ijt-1}\right)\right) \cdot \Delta k_{ijt}$$

***The convergence equation***

What drives the growth rate of multi-factor productivity? We consider 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 for a given industry $j$ of country $i$ at date $t$ ($MFP_{ijt}$) can be modelled as an auto-regressive 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,

$$\ln MFP_{ijt} = \beta_1 \ln MFP_{ijt-1} + \beta_2 \ln MFP_{Fjt} + \beta_3 \ln MFP_{Fjt-1} + \omega_{ijt} \qquad [1]$$

where $\omega$ stands for all observable and non-observable factors influencing the level of MFP. Under the assumption of long-run homogeneity ($1-\beta_1=\beta_2+\beta_3$) and rearranging equation [1] yields the convergence equation:

$$\Delta \ln MFP_{ijt} = \beta_2 \Delta \ln MFP_{Fjt} - \left(1 - \beta_1\right) RMFP_{ijt} + \omega_{ijt} \qquad [2]$$

where $RMFP_{ijt}=\ln(MFP_{ijt})-\ln(MFP_{Fjt})$ is the technological gap between country $i$ and the leading country $F$. The following (productivity) index is used as a measure of the MFP level:

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

6 For this purpose, we follow a value-added concept of output where measures of intermediate consumption is unnecessary. This is the proper approach because the industries that we use may have different levels of aggregation.

7 Technical change is "Hicks neutral", or "output augmenting", when it can be represented as an outward shift of the production function that affects all factors of production in the same proportion.

where a *bar* denotes a geometric average over all the countries for a given industry *j* and year *t*. The variable $\sigma_{ijt} = \frac{1}{2}\left(\alpha_{ijt} + \overline{\alpha}_{jt}\right)$ is the average of the labour share in country *i* and the geometric mean labour share across 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), after a proper conversion of data into a common currency (see next section).

The residual term in equation [2] is modelled as follows:

$$\omega_{ijt} = \sum_k \gamma_k V_{kijt-1} + f_i + g_j + d_t + \varepsilon_{ijt} \qquad [4]$$

where ($V_{ijt}$) is a vector of covariates (e.g. product and labour market regulations, human capital and R&D) affecting the level of MFP; $f_i$, $g_j$, and $d_t$ are respectively country, industry and year fixed effects. $\varepsilon$ is an *iid* shock. Moreover, equation [2] can be solved for steady-state MFP in country *i* relative to the frontier in industry *j* which gives insights on the effects of these country and/or country-industry specific factors on the steady-state level of MFP.

***The steady-state equilibrium***

At a steady-state equilibrium, the independent variables are constant over time ( $\omega_{ijt}$ = $\omega_{ij}$) and the multi-factor productivity in sector *j* grows at the same constant rate in all countries: $\Delta lnMFP_{ijt} = \Delta lnMFP_{Fj}$ .

For the ease of exposition, the residual in equation [2] is noted:

$$\omega_{ijt} = \omega'_{ijt} + \omega''_{ijt} \cdot RMFP_{ijt} \qquad [5]$$

where $\omega'$ and $\omega''$ correspond to the factors affecting the rate of growth of MFP respectively directly or through the diffusion of technology and organisational practises. Solving for the steady-state, we obtain the following *MFP* in country *i* relative to the frontier in industry *j*:

$$RMFP_{ij} = \frac{\omega'_{ij} - (1-\beta_2)\Delta MFP_{Fj}}{(1-\beta_1) - \omega''_{ij}} \qquad [6]$$

## 3. The data

Our analysis covers 23 two-digit industries in manufacturing and business services in 18 OECD countries over the period 1984-1998. The countries are: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, (western) Germany, Greece, Italy, Japan, Netherlands, Norway, Portugal, Sweden, United Kingdom and United States. The industry breakdown is as follows: 17 manufacturing industries and 6 business services industries. Agriculture, mining and quarrying, construction, electricity gas and water as well as community and personal services have been excluded from the analysis, either because of poor quality of the data or because of the dominance of public-owned firms whose performances are likely to depend on a different set of factors. In the more detailed analysis of the possible effects of R&D on productivity and its variance across different market structures (see below), *the electrical and optical equipment* industry (ISIC 30 to 33) is broken down into its three-digit components, *i.e. office accounting and computing machinery*, *electrical machinery NEC*, *radio TV and communications equipment* and *medical precision and optical instruments*. As discussed below, these three-digit industries all belong to the high technology group, but are characterised by different patterns of innovation that are important in assessing the impact of R&D on productivity.

The industries considered in the analysis and, for manufacturing, their classification according to the market structure typologies discussed above is presented in Table 1, while Table 2 presents the coverage of the data for multi-factor productivity growth.

**Table 1. Industries considered in the empirical analysis and classification according to market structure**

| STAN code | Industry Name | Market Structure * |
|---|---|---|
| 5 | Food Products, Beverages and Tobacco | LT |
| 6 | Textiles | LT |
| 7 | Wood and Products of Wood and Cork | LT |
| 8 | Pulp Paper Paper Products Printing and Publishing | LT |
| 11 | Coke refined Petroleum Products and Nuclear Fuel | LT |
| 13 | Chemicals Excluding Pharmaceuticals | HTHC |
| 14 | Pharmaceuticals | HTHC |
| 15 | Rubber and Plastic Products | LT |
| 16 | Other Non-Metallic Mineral Products | LT |
| 20 | Basic Metals | LT |
| 21 | Fabricated Metal Products Except Machinery & Equipment | LT |
| 23 | Machinery & Equipment N.E.C. | HTLC |
| 24 | Electrical and Optical Equipment | HTHC |
| 25 | Office Accounting and Computing Machinery | HTHC |
| 26 | Electrical machinery & Apparatus N.E.C. | HTHC |
| 27 | Radio Television & Communication Equipment | HTHC |
| 28 | Medical Precision & Optical Equipment | HTLC |
| 30 | Motor Vehicles Trailers & Semi-Trailers | HTHC |
| 32 | Building & Repairing of Ships & Boats | LT |
| 33 | Aircraft & Spacecraft | HTHC |
| 34 | Railroad Equipment & Transport Equipment N.E.C. | HTHC |
| 35 | manufacturing N.E.C. ; Recycling | HTLC |
| 41 | Wholesale & Retail Trade; Repairs | . |
| 42 | Hotels & Restaurants | . |
| 44 | Transport & Storage | . |
| 45 | Post & Telecommunication | . |
| 47 | Financial Intermediation | . |
| 51 | Real Estate Renting & Business Activities | . |

* : HTHC, HTLC and LT stand respectively for High-Tech High Concentration, High-Tech Low Concentration and Low-Tech industries.

**Table 2. Coverage of Multi-Factor Productivity Data**
**(Number of Observations)**

| stan code | AUS | AUT | BEL | CAN | DEU | DNK | ESP | FIN | FRA | GBR | GRC | ITA | JPN | NLD | NOR | PRT | SWE | USA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5** | 8 | 12 | 14 | 15 | 12 | 12 | 13 | 16 | 15 | 14 | 10 | 16 | 16 | 11 | 15 | 13 | 12 | 16 |
| **6** | 8 | 12 | 14 | 15 | 12 | 12 | 13 | 16 | 15 | 14 | 10 | 16 | 12 | 11 | 15 | 13 | 12 | 16 |
| **7** | 8 | 12 | 10 | 14 | 11 | 10 | 13 | 16 | 11 | 14 | 10 | 16 | 11 | 11 | 15 | 13 | 5 | 16 |
| **8** | 8 | 12 | 14 | 15 | 12 | 12 | 13 | 16 | 15 | 14 | 10 | 16 | 12 | 11 | 15 | 13 | 12 | 16 |
| **11** | 8 | 12 | 10 | 14 | 12 | 9 | 9 | 16 | 14 | 14 | 10 | 16 | 11 | 11 | 13 | 0 | 12 | 16 |
| **13** | 8 | 0 | 10 | 14 | 12 | 9 | 0 | 12 | 14 | 12 | 8 | 9 | 10 | 10 | 13 | 0 | 10 | 10 |
| **14** | 8 | 0 | 10 | 14 | 11 | 9 | 0 | 12 | 10 | 12 | 7 | 9 | 10 | 10 | 13 | 0 | 10 | 10 |
| **15** | 8 | 12 | 0 | 14 | 12 | 9 | 13 | 16 | 14 | 14 | 10 | 16 | 11 | 11 | 13 | 7 | 12 | 16 |
| **16** | 8 | 12 | 14 | 15 | 12 | 12 | 13 | 16 | 15 | 14 | 10 | 16 | 12 | 11 | 15 | 13 | 12 | 16 |
| **20** | 8 | 12 | 14 | 15 | 12 | 12 | 13 | 16 | 15 | 14 | 10 | 12 | 16 | 12 | 15 | 13 | 12 | 16 |
| **21** | 8 | 12 | 13 | 14 | 12 | 10 | 13 | 16 | 14 | 14 | 10 | 12 | 16 | 11 | 13 | 13 | 10 | 16 |
| **23** | 8 | 0 | 0 | 14 | 12 | 9 | 0 | 16 | 6 | 10 | 0 | 16 | 16 | 3 | 13 | 0 | 0 | 0 |
| **24** | 8 | 0 | 0 | 14 | 12 | 9 | 0 | 16 | 6 | 10 | 0 | 16 | 16 | 3 | 13 | 0 | 0 | 0 |
| **30** | 8 | 0 | 0 | 14 | 12 | 8 | 0 | 16 | 15 | 10 | 10 | 0 | 11 | 0 | 13 | 0 | 0 | 16 |
| **32** | 8 | 0 | 0 | 14 | 12 | 9 | 0 | 12 | 9 | 10 | 10 | 9 | 11 | 10 | 13 | 0 | 12 | 11 |
| **33** | 6 | 0 | 8 | 14 | 12 | 6 | 0 | 12 | 9 | 10 | 0 | 9 | 0 | 10 | 13 | 0 | 0 | 10 |
| **34** | 0 | 0 | 0 | 14 | 11 | 3 | 0 | 12 | 9 | 10 | 0 | 9 | 5 | 0 | 9 | 0 | 0 | 10 |
| **35** | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 16 | 6 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 16 |
| **41** | 0 | 0 | 13 | 15 | 12 | 10 | 0 | 16 | 15 | 0 | 0 | 16 | 16 | 3 | 9 | 0 | 12 | 16 |
| **42** | 0 | 0 | 13 | 15 | 11 | 0 | 0 | 16 | 15 | 0 | 0 | 16 | 0 | 3 | 9 | 0 | 12 | 13 |
| **44** | 0 | 0 | 13 | 15 | 11 | 10 | 0 | 16 | 15 | 0 | 0 | 12 | 0 | 4 | 0 | 0 | 12 | 16 |
| **45** | 0 | 0 | 13 | 15 | 11 | 10 | 0 | 16 | 15 | 0 | 0 | 12 | 0 | 4 | 0 | 0 | 12 | 16 |
| **47** | 12 | 0 | 13 | 11 | 11 | 10 | 0 | 16 | 5 | 0 | 0 | 16 | 13 | 0 | 9 | 0 | 12 | 16 |
| **51** | 12 | 0 | 0 | 11 | 0 | 10 | 0 | 16 | 5 | 0 | 0 | 16 | 0 | 8 | 9 | 0 | 12 | 16 |

### *Measuring Multi-factor Productivity*

Several issues arise when measuring multi-factor productivity (OECD, 2001*b* and Schreyer and Pilat, 2001). They relate to (1) the measurement of capital and labour inputs, (2) the prices of output and inputs in order to obtain comparable measures of MFP, (3) the remuneration of factor inputs.

Three main data-sets have been used to construct the value-added, capital stock, employment and labour compensation series. The main data-set is the OECD STAN2000 database. It was updated for missing series from other OECD database (e.g. ISDB, STAN1998, and STAN1992) for a small subset of sectors[8] for which disaggregated data were not available in the other data-sets.

As the analysis is conducted at the sectoral level with different levels of aggregation across sectors, we follow a value-added based measure of productivity. In a few cases when value-added (or investment) deflators were missing, we used deflators from more aggregated sectors. Clearly, the measure of value-added may not record accurately the productivity gains in sectors in which quality changes have been important over the past decade. For instance, ICT industries for which price indices are not corrected for such changes.

Finally, the calculations of MFP levels requires the use of comparative product price levels across countries in order to convert the value of production to common units, while taking into account differences in the purchasing power of each country's currency. Ideally, comparative

8 Chemicals excluding Pharmaceuticals, Pharmaceutical, Building and Repairing of Ships and Boats, Aircraft and Spacecraft, Railroad Equipment and Transport Equipment N.E.C.

product prices should be measured at the producer level, but survey data on production prices are usually available only for a few countries and for even fewer products. Thus, we use estimates of industry-specific expenditure PPPs.[9]

### *Measuring inputs*

The labour input used in our analysis is the total number of hours worked calculated on the basis of employment and average hours worked at the sectoral level. As a test of robustness we also adjusted this measure of labour for the skill composition at the sectoral level (see the sensitivity analysis in the Appendix). We differentiate between four occupational categories: high-skill white collar, low-skill white collar, high-skill blue collar and low-skill blue collar.[10] Following Harrigan (1998), for each sector *j* (country and time subscripts are dropped for simplicity) aggregate labour input can be expressed as a translog index of the four types of labour:

$$\overline{L}_j = \sum_{1 \le s \le 4} \left( \frac{L_{sj}}{L_j} \right)^{w_{sj}} \cdot \hat{L}_j \qquad [7]$$

where $s$ is indexing the four labour categories, $w_{sj}$ is the share of category $s$ in total labour compensation, $L$ is total employment, $\hat{L}$ is total employment adjusted for hours worked, $L_{sj}$ is employment for the skill category $s$. For details on these calculations, see the Appendix.

We used the gross fixed capital stock reported in the sectoral database. Series are incomplete in several instances. In such cases, we constructed gross fixed capital stock series, using the procedure discussed in the Appendix.

The calculation of MFP also requires estimates of the $\alpha$ parameter. Under perfect competition, $\alpha$ is the share of labour compensation in total costs. However, the share of labour in value added is however volatile, reflecting short-term market conditions. This suggests that measurement errors can be substantial. In order to minimise this problem, we regressed the share of labour compensation on country-industry specific fixed effects and on the logarithm of capital-

9 . The alternative is to use aggregate purchasing power parities (PPPs) for GDP as often done in the empirical literature (see e.g., Bernard and Jones, 1996*a,b*). However, aggregate PPPs are problematic if relative prices of given industries evolve differently across countries. For example, Sørensen (2001) shows that while relative productivity levels are independent of the choice of the base year, using PPPs for total GDP leads to different degrees of convergence, depending on the base year chosen for PPPs. This may be due to the fact that relative prices of manufacturing have evolved differently across countries, but may also reflect the fact that PPPs for total GDP have improved over time.

10 White-collar high-skill: legislators, senior officials and managers, professionals, technicians and associate professionals.

White-collar low-skill: clerks, service workers, shop & sales workers.

Blue-collar high-skill: skilled agricultural and fishery workers.

Blue-collar low-skill: plant & machine operators and assemblers, elementary occupations.

labour ratio[11]. Fixed effects account for unobserved factors influencing the technology used (such as endowments, available technologies, institutional factors). Next, we define two country/sector-specific measures of the labour share:

a) we take the fitted value from this equation, which accounts for country-industry fixed components plus variations due to changes in the capital intensity.

b) we take the average of the previous measure per country-industry.

Our preferred measure of the labour share is given by a) because it allows country specific production functions in each industry, reflecting permanent effects and specific capital-labour ratios. However, the capital-labour ratio is influenced by business cycle conditions that may vary across countries. In this context, b) provides a smoother estimate of the capital-labour ratio that depends only on unobserved country-industry fixed factors and the average capital-labour ratio.

### *Definition of Other Variables*

Data on **R&D intensity** are drawn from the OECD ANBERD database. R&D intensity is defined as the ratio Business Expenditure in Research and Development (BERD) to value-added. Value-added is from our main data-set previously defined.

We investigated several measure of **human capital**. First, we started with standard macro-economic proxy for general human capital, such as the proportion of individuals with secondary school attainment and the average number of years of schooling (see de la Fuente and Donenech, 2000). Contrary to Griffith *et al.*, 2000, these two variables turned out to have an insignificant effect of MFP, or in a few cases the coefficient was significant and negative. This problem of macro-economic measures of human capital is well known in the growth literature (de la Fuente et Donenech, 2000). Next, we constructed an industry level proxy of human capital based on the skill data. The measure of human capital is defined by (the subscripts $j$, $i$ and $t$ are omitted):

$$HumanCapital = \log\left[1 + \frac{\omega_{HWh}}{\omega_{LWh}} . \frac{L_{HWh}}{L} + \frac{\omega_{HBl}}{\omega_{LBl}} . \frac{L_{HBl}}{L}\right] \quad [8]$$

where $\omega_{HWh}$, $\omega_{LWh}$, $\omega_{HBl}$, $\omega_{LBl}$ are respectively the wage rate for the white-collar high-skill, white-collar low-skill, blue-collar high-skill and blue-collar low-skill workers. $L_{HWh}$, $L_{HBl}$ and $L$ are respectively white-collar high-skill employment, blue-collar high skill employment and total employment. Thus, this measure is rising with the wage premium of (white-collar and blue-collar) skilled workers relative to unskilled workers, weighted with the proportion of (white-collar and blue-collar) skilled workers in total employment.

11 This procedure is consistent with the translog production function in which the labour share can be expressed as a function of the capital-labour ratio and a country-industry constant.

In the next step, this variable is regressed on: country specific and industry-specific fixed effects and on time dummies that are country and industry specific. The predicted value is used as a measure of human capital in our regressions.[12]

Three types of indicators of **product market regulations** are considered.

- *The overall index of the stringency of product market regulation* (PMR) is a static indicator (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 (see Nicoletti, Scarpetta and Boylaud, 1999 for more details). The indicator has a wide coverage of regulatory aspects, but no industry or time dimension. In order to further characterise the regulatory settings, this indicator is further split into two components: *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 industry-specific indicator of product regulation* (PMR sectoral) is also a static indicator (1998), but it varies across service-sector industries (retail and wholesale trade; transport and communication; financial intermediation and business services). The indicator always includes barriers to entrepreneurial activity and public ownership, while for certain industries it also considers other aspects of regulation. For the manufacturing industries, for which no specific information on regulations is available, the economy-wide indicator of administrative regulations is used as a proxy in the construction of this sector-specific indicator.[13]

- *The aggregate time-varying indicator of the stance of regulation* (PMR time-varying) is a simple average of time-varying indicators of the stringency of regulations in *electricity, gas* and *transport and communication*. This average is used to proxy the overall stance of regulatory reform in each OECD country. Its clear advantage in the empirical analysis is the time dimension but, given that it only covers certain (albeit key) service industries, it should be considered as a first approximation of the economy-wide regulatory reform stance of OECD countries (see Nicoletti *et al.*, 2001 for more details).

The indicators of **employment protection legislation** are available for two periods (late 1980s and 1998) and focus on both regular and temporary contracts (see Nicoletti *et al.* 1999). Regulations for regular contracts include: i) procedural inconveniences that employers face when trying to dismiss a worker; ii) advance notice of the dismissal and severance payments; and iii)

12. The coefficient remains significant with the same sign if the initial variable is used instead in the regressions. This implies however a smaller sample, so we concentrated on the predicted human capital variable instead.

13 . The indicator of administrative regulations is used as a proxy instead of the overall indicator of product market regulations because it refers to norms and regulations that are applied to all industries, while the overall indicator also includes economic regulations some of which are more sector specific, and do not apply to manufacturing industries.

prevailing standards of, and penalties for, "unfair" dismissals. Indicators of the stringency of EPL for temporary contracts include: i) the "objective" reasons under which they can be offered; ii) the maximum number of successive renewals; iii) and the maximum cumulated duration of the contract. The EPL indicator used in the econometric analysis is time-varying, with the shift in regime from the late 1980s stance to that of 1990s being defined on the basis of information about the timing of major EPL reforms (concerning both temporary and regular workers) in OECD countries.

It should be stressed that all indicators (both PMRs and EPL) are constructed on the basis of differences in regulatory settings across OECD countries. They identify two types of cross-country patterns: *i*) differences in the stringency of regulatory provisions that exist in all countries, without questioning the need for some level of regulation; and *ii)* differences due to the presence of specific restrictions to market mechanisms that only exist in certain countries. Thus, the focus is on *excessive* regulation that could unnecessarily restrict market mechanisms, either because it thwarts competition where competition could be viable, or because it makes reallocation of resources difficult, hindering the response of the economy to structural changes.

The summary indicator of the **bargaining system** (*corporatism*) combines two variables: *i*) the level of bargaining: centralised, intermediate (at sector or regional), or decentralised (firm level); and *ii*) the degree of co-ordination amongst, on the one hand, employers' associations and, on the other, trade unions. This combined variable allows consideration of cases where co-operation between employers and unions in an industry bargaining setting (*e.g.*, Germany and Austria and, more recently, Italy, Ireland and the Netherlands with the income policy agreements) may be an alternative, or functionally equivalent, to centralised systems, thereby mimicking their outcomes. In the table, the two variables referring to corporatism indicate the effects of intermediate or high/low centralisation/co-ordination with respect to that of an intermediate system. The distribution of countries according to the different aspects of collective bargaining and changes over time is presented in Elmeskov, Martin and Scarpetta (1998).

## 4. The empirical results

### *Method of Estimation*

We followed a standard pooled cross-country cross-industry time series analysis. In order to control for unobserved factors affecting the rate of growth of MFP, we included a full set of industry and country fixed effects, in addition to a full set of year dummies (OLS with fixed effects). Since there is evidence of heteroschedasticity in our data, we used the Huber-White-Sandwich estimator of variance. We also excluded outliers using a procedure based on the residual and leverage of each observation, based on the notion of the influence curve. The influence curve assesses the asymptotic marginal effect of adding a specific observation *i* on the coefficient estimates, on the basis of the original regression model. The influence curve is an asymptotic concept. However, the DFITS or Welsch-Kuh distance and the Welsch distance are two indicators used in the paper to approximate empirically the influence curve and detect influential observations from it (Chatterjee and Hadi, 1988).

However, as most product and labour market indicators do not have an industry dimension, country dummies must be dropped in the regressions including these regulatory variables. We provided two tests that the omitted variable bias is limited. First, we performed a standard Ramsey regression specification error test.[14] Second, we checked that the coefficients on both leader and technology gap remain mostly unchanged when country dummies are omitted. In any event, in those specifications where country dummies are omitted, standard errors and variance-covariance matrix of the estimators are adjusted for cluster level effects on country-industry groups using the procedure suggested by Moulton (1986).

### *Results*

As an illustration, Table 3 shows the three countries with the highest level of MFP in each industry at the beginning and at the end of our sample: the United States, Canada and Japan were often at the frontier (or close to it) in most industries. However, if MFP is computed to take into account the number of hours worked, several European countries turn out to be relatively close to the frontier.[15] The comparison of MFP levels also suggests that only in a few cases does the identity of the frontier remain constant; i.e. in most industries, some countries 'leapfrogged' others in terms of technology leadership. As shown below, however, what matters for productivity growth is the distance from the technological frontier -- which captures the potential for technology transfer -- rather than the identity of the frontier itself.

In order to compare the empirical results with those of previous studies, Table 4 presents different specifications of a baseline equation in which MFP growth is regressed only on the industry leader and the technology-gap term. It should be stressed at the outset that most of the results discussed in this section are robust to the use of different estimates of MFP (see the detailed sensitivity analysis presented in the Appendix).[16]

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14 This test amounts to testing $y = xb + zt + u$ and then testing t=0. Powers of the fitted values and other powers of the variables included in $x$ are used for $z$.

15 MFP levels are reported only for manufacturing industries.

16 . In particular in a sensitivity analysis we used three alternative estimates of MFP that consider: *a)* total employment instead of total hours worked as the labour input; *b)* changes in the skill composition of employment in the calculation of the labour input; *c*) labour shares that are corrected for the presence of mark-ups of prices over marginal costs. The first alternative estimate of MFP uses a cruder proxy for labour input than the preferred one, but avoids the use of some approximations in the calculation of hours worked for some countries/industries. The second alternative estimate uses a refined proxy for labour input, but at the expense of country/industry coverage and with some approximations in the estimation of the skill composition of the workforce for some countries/industries. The third alternative measure of MFP is only available for a sub-set of manufacturing industries, although it takes into account market imperfections. Finally, in a previous version of this paper, we used a Cobb-Douglas production function, instead of a *translog* specification, and for which we realised the whole sensitivity analysis described above. The conclusions of the paper are robust to this change of specification.

Table 3. **Relative MFP levels and the technology leaders, 1984, 1997**

| | | | | | | with control for hours worked | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1984 | 1997 | Basic statistics [1] (1997) Mean | Basic statistics [1] (1997) S. D. | 1984 | 1997 | Basic statistics [1] (1997) Mean | Basic statistics [1] (1997) S. D. |
| Food products, beverages and tobacco | 1st | **USA** | **CAN** | 0.69 | 0.17 | **USA** | **CAN** | 0.69 | 0.14 |
| | 2d | JPN | USA | | | JPN | USA | | |
| | 3d | CAN | JPN | | | CAN | JPN | | |
| Textiles, textile products, leather and footwear | 1st | **FRA** | **CAN** | 0.71 | 0.15 | **FRA** | **CAN** | 0.75 | 0.15 |
| | 2d | CAN | FRA | | | CAN | FRA | | |
| | 3d | AUS | USA | | | AUT | ITA | | |
| Wood and products of wood and cork | 1st | **USA** | **USA** | 0.60 | 0.23 | **CAN** | **USA** | 0.59 | 0.21 |
| | 2d | CAN | FIN | | | USA | FIN | | |
| | 3d | GRC | ITA | | | GRC | NOR | | |
| Pulp paper, paper products, printing and publishing | 1st | **CAN** | **CAN** | 0.70 | 0.15 | **CAN** | **FRA** | 0.74 | 0.13 |
| | 2d | USA | FRA | | | FRA | CAN | | |
| | 3d | FRA | FIN | | | USA | ITA | | |
| Coke, refined petroleum products and nuclear fuel | 1st | **ITA** | **ITA** | 0.38 | 0.24 | **ITA** | **ITA** | 0.38 | 0.24 |
| | 2d | FRA | USA | | | FRA | FIN | | |
| | 3d | KOR | FIN | | | USA | USA | | |
| Chemicals excluding pharmaceuticals | 1st | **FIN** | **FIN** | 0.50 | 0.26 | **FIN** | **FIN** | 0.50 | 0.26 |
| | 2d | BEL | FRA | | | BEL | FRA | | |
| | 3d | CAN | CAN | | | GER | CAN | | |
| Pharmaceuticals | 1st | **JPN** | **CAN** | 0.60 | 0.39 | **JPN** | **CAN** | 0.65 | 0.40 |
| | 2d | USA | NOR | | | USA | NOR | | |
| | 3d | CAN | GBR | | | NOR | GER | | |
| Rubber and plastics products | 1st | **AUT** | **USA** | 0.64 | 0.14 | **AUT** | **ITA** | 0.69 | 0.13 |
| | 2d | ESP | ITA | | | DNK | FIN | | |
| | 3d | NLD | FIN | | | ESP | USA | | |
| Other non-metallic mineral products | 1st | **CAN** | **CAN** | 0.71 | 0.15 | **CAN** | **CAN** | 0.76 | 0.15 |
| | 2d | BEL | FRA | | | AUT | FRA | | |
| | 3d | GER | USA | | | BEL | USA | | |
| Basic metals | 1st | **JPN** | **JPN** | 0.71 | 0.18 | **NLD** | **FIN** | 0.72 | 0.17 |
| | 2d | NLD | FIN | | | DNK | JPN | | |
| | 3d | USA | CAN | | | JPN | NOR | | |
| Fabricated metal products except machinery and equipment | 1st | **CAN** | **USA** | 0.71 | 0.17 | **CAN** | **USA** | 0.76 | 0.17 |
| | 2d | USA | FIN | | | BEL | FIN | | |
| | 3d | BEL | JPN | | | GER | JPN | | |
| Machinery and equipment n.e.c. | 1st | **CAN** | **FRA** | 0.70 | 0.20 | **CAN** | **FRA** | 0.77 | 0.12 |
| | 2d | GER | FIN | | | GER | FIN | | |
| | 3d | JPN | ITA | | | DNK | ITA | | |
| Electrical and optical equipment | 1st | **AUS** | **FIN** | 0.62 | 0.25 | **AUS** | **FIN** | 0.70 | 0.21 |
| | 2d | JPN | JPN | | | DNK | JPN | | |
| | 3d | ITA | FRA | | | JPN | FRA | | |
| Motor vehicles trailers and semi-trailers | 1st | **USA** | **USA** | 0.64 | 0.21 | **USA** | **USA** | 0.82 | 0.13 |
| | 2d | GRC | FRA | | | GRC | FRA | | |
| | 3d | CAN | FIN | | | CAN | FIN | | |
| Building and repairing of ships and boats | 1st | **FRA** | **USA** | 0.63 | 0.24 | **FRA** | **CAN** | 0.76 | 0.21 |
| | 2d | USA | JPN | | | USA | GER | | |
| | 3d | JPN | CAN | | | ITA | NOR | | |
| Aircraft and spacecraft | 1st | **FRA** | **CAN** | 0.47 | 0.31 | **FRA** | **CAN** | 0.47 | 0.30 |
| | 2d | CAN | NLD | | | CAN | GER | | |
| | 3d | NLD | GER | | | GER | NLD | | |
| Railroad equipment and transport equipment n.e.c. | 1st | **CAN** | **CAN** | 0.47 | 0.28 | **ITA** | **CAN** | 0.56 | 0.24 |
| | 2d | ITA | FIN | | | CAN | FIN | | |
| | 3d | FRA | JPN | | | FRA | GBR | | |
| Manufacturing n.e.c; recycling | 1st | **CAN** | **USA** | 0.84 | 0.17 | **CAN** | **FRA** | 0.83 | 0.15 |
| | 2d | USA | FRA | | | USA | USA | | |
| | 3d | FIN | FIN | | | FIN | FIN | | |
| Wholesale and retail trade; repairs | 1st | **ITA** | **USA** | 0.82 | 0.13 | **ITA** | **ITA** | 0.84 | 0.11 |
| | 2d | BEL | ITA | | | BEL | CAN | | |
| | 3d | USA | FRA | | | USA | FRA | | |
| Hotels and restaurants | 1st | **FRA** | **USA** | 0.70 | 0.23 | **BEL** | **USA** | 0.69 | 0.21 |
| | 2d | BEL | ITA | | | FRA | ITA | | |
| | 3d | ITA | FRA | | | NOR | FRA | | |
| Transport and storage | 1st | **BEL** | **USA** | 0.75 | 0.17 | **BEL** | **FRA** | 0.75 | 0.16 |
| | 2d | FRA | FRA | | | ITA | USA | | |
| | 3d | ITA | CAN | | | FRA | CAN | | |
| Post and telecommunications | 1st | **USA** | **USA** | 0.76 | 0.14 | **USA** | **FRA** | 0.83 | 0.14 |
| | 2d | CAN | FRA | | | CAN | USA | | |
| | 3d | FRA | CAN | | | FRA | CAN | | |
| Financial intermediation | 1st | **NOR** | **JPN** | 0.90 | 0.09 | **NOR** | **ITA** | 0.83 | 0.13 |
| | 2d | CAN | ITA | | | CAN | FRA | | |
| | 3d | USA | FIN | | | ITA | FIN | | |
| Real estate renting and business activities | 1st | **AUS** | **USA** | 0.73 | 0.17 | **AUS** | **USA** | 0.75 | 0.15 |
| | 2d | USA | FRA | | | USA | FRA | | |
| | 3d | SWE | ITA | | | SWE | NLD | | |

*Note:* Data for Germany refer to western Germany.

1. If 1997 data were not available, basic statistics refer to the most recent year with sufficiently large country coverage.

The technology-gap term (*RTFP*) enters negatively and is significant at conventional levels in all specifications, suggesting that, within each industry, countries that are further behind the frontier experience higher rates of productivity growth (the analysis for manufacturing industries will show however that this may not be the case in high-tech manufacturing industries). The table also indicates a positive effect (at 5% significance) of human capital on productivity growth (equations B and D), as would be expected.[17] Moreover, consistent with some previous results (*e.g.* Bernard and Jones, 1996*a*, 1996*b*), there is evidence in the data of a more rapid technological catch-up in service industries as compared with manufacturing[18] (columns C and D).[19]

In Table 5 the analysis is extended to cover product market regulations and certain institutional arrangements in the labour market (see above). The results indicate a negative direct effect of product market regulations on productivity, whatever indicator is considered.[20] However, if the interaction of regulation with the technology gap is also considered (equations E to J), the results point instead to a significant indirect effect and a more mild direct effect. This suggests that strict regulations seem to have a particular detrimental effect on productivity the further the country is from the technology frontier, possibly because they reduce the scope for knowledge spillovers by reducing the entry of new firms or the incentives of incumbent firms to adopt new technologies or innovate.

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17. This positive association between industry-specific human capital and productivity should not be over-emphasised because of possible problems of reverse causality. Strong productivity performance is likely to stimulate the accumulation of human capital by firms and attract highly qualified workers. This possible reverse causality problem can be particularly serious at the industry or firm level, *e.g.* firms/industries with high productivity patterns are more likely to invest in highly-skilled workers, by hiring them or recurring to internal training. In the present study, the estimated indicator of human capital is based on industry-specific employment shares and relative wages of four groups of workers according to their skills (highly-skilled white collars, low-skilled white collars; highly skilled blue collars and low skilled blue collars). Alternative measures of human capital based on aggregate data (*e.g.* average years of schooling of the total working-age population) did not yield significant results. Heterogeneity in MFP and skill composition across industries in most OECD countries is likely to explain the inconclusive result of this country-average measure of human capital. The human capital variable is dropped in the rest of the analysis (see Scarpetta and Tressel (2002) for an analysis focusing on this variable).

18. Equality of the coefficients on the productivity gap variable is rejected at the 3% level.

19 . In particular, using a cross section data Bernard and Jones (1996*a*,*b*) found evidence of convergence in the service sector but not in manufacturing. However, in another paper based on U.S. state data (1996*c*), they found convergence in manufacturing but not in other sectors. Moreover, Garcia Pascual and Westermann (2001), using more disaggregated manufacturing industries (along the lines of the current study) for some OECD countries, find evidence of convergence even in manufacturing.

20 . These results are broadly consistent with those of Blundell *et al*. (1995) and Nickell (1996) and Cheung and Garcia Pascual (2001), although these papers use direct proxies for the degree of product market competition which are subject to an endogeneity problem.

Table 4. **Productivity Regressions: Selection of the Baseline Specification**
(dependent variable: $\Delta TFP_{ijt}$)

| | A | | B | | C | | D | |
|---|---|---|---|---|---|---|---|---|
| Constant | **-0.020** | | **-0.099** | ** | **-0.021** | | **-0.108** | *** |
| | *(0.011)* | | *(0.042)* | | *(0.011)* | | *(0.042)* | |
| $\Delta TFP_{Leader\ jt}$ | **-0.005** | | **-0.004** | | . | | . | |
| | *(0.008)* | | *(0.008)* | | | | | |
| $RTFP_{ijt-1}$ | **-0.028** | *** | **-0.028** | *** | . | | . | |
| | *(0.004)* | | *(0.004)* | | | | | |
| Human $Capital_{ijt}$ | . | | **0.170** | ** | . | | **0.187** | ** |
| | | | *(0.081)* | | | | *(0.082)* | |
| $\Delta TFP_{Leaderjt}$ (MAN) | . | | . | | **-0.012** | | **-0.011** | |
| | | | | | *(0.008)* | | *(0.008)* | |
| $RTFP_{ijt-1}$(MAN) | . | | . | | **-0.028** | *** | **-0.028** | *** |
| | | | | | *(0.004)* | | *(0.004)* | |
| $\Delta TFP_{Leaderjt}$ (SER) | . | | . | | **0.085** | *** | **0.087** | *** |
| | | | | | *(0.018)* | | *(0.018)* | |
| $RTFP_{ijt-1}$(SER) | . | | . | | **-0.049** | *** | **-0.049** | *** |
| | | | | | *(0.009)* | | *(0.010)* | |
| RESET | 0.89 | | 0.54 | | 1 | | 0.89 | |
| Industry dummies | Yes | | Yes | | Yes | | Yes | |
| Country dummies | Yes | | Yes | | Yes | | Yes | |
| Year dummies | Yes | | Yes | | Yes | | Yes | |
| Observations | 3191 | | 3111 | | 3191 | | 3191 | |

Note: Robust standard errors are in brackets. *: significant at 10% level; ** at 5% level; *** at 1% level.
Reset is the Sargan test for misspecification.

Table 5. **Productivity regressions: the Role of Regulations and Institutions - Total Economy**
(dependent variable: $\Delta TFP_{ijt}$)

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant | **-0.002** | **-0.004** | **-0.004** | **-0.004** | **-0.019** * | **-0.018** * | **-0.015** | **-0.015** | **-0.026** ** | **-0.026** ** |
| | *(0.010)* | *(0.010)* | *(0.010)* | *(0.010)* | *(0.011)* | *(0.010)* | *(0.011)* | *(0.011)* | *(0.011)* | *(0.011)* |
| $\Delta$ $TFP_{Leader\ j\ t}$ (MAN) | **-0.013** | **-0.013** | **-0.013** | **-0.013** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** |
| | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.008)* | *(0.008)* |
| $\Delta$ $TFP_{Leader\ j\ t}$ (SERV) | **0.082** *** | **0.085** *** | **0.081** *** | **0.084** *** | **0.079** *** | **0.098** *** | **0.079** *** | **0.078** *** | **0.081** *** | **0.080** *** |
| | *(0.013)* | *(0.013)* | *(0.014)* | *(0.013)* | *(0.014)* | *(0.014)* | *(0.015)* | *(0.014)* | *(0.018)* | *(0.018)* |
| $RTFP_{i\ j\ t-1}$(MAN) | **-0.023** *** | **-0.023** *** | **-0.024** *** | **-0.024** *** | **-0.048** *** | **-0.045** *** | **-0.042** *** | **-0.047** *** | **-0.042** *** | **-0.046** *** |
| | *(0.004)* | *(0.004)* | *(0.005)* | *(0.005)* | *(0.009)* | *(0.008)* | *(0.008)* | *(0.012)* | *(0.009)* | *(0.011)* |
| $RTFP_{i\ j\ t-1}$ (SERV) | **-0.048** *** | **-0.049** *** | **-0.047** *** | **-0.048** *** | **-0.073** *** | **-0.060** *** | **-0.064** *** | **-0.070** *** | **-0.064** *** | **-0.066** *** |
| | *(0.008)* | *(0.008)* | *(0.008)* | *(0.008)* | *(0.011)* | *(0.009)* | *(0.010)* | *(0.013)* | *(0.013)* | *(0.013)* |
| PM regulations (PMR) | **-0.007** *** | | | | **0.004** | | | | | |
| | *(0.002)* | | | | *(0.003)* | | | | | |
| PMR (sectoral) | | **-0.030** ** | | | | **0.023** | | | | |
| | | *(0.012)* | | | | *(0.015)* | | | | |
| PMR (economic regulation) | | | **-0.004** *** | | | | **0.002** | | | |
| | | | *(0.001)* | | | | *(0.002)* | | | |
| PMR (time-varying) | | | | **-0.003** *** | | | | **-0.0004** | | |
| | | | | *(0.001)* | | | | *(0.001)* | | |
| PMR * $RTFP_{i\ j\ t-1}$ | | | | | **0.016** *** | | | | **0.009** * | |
| | | | | | *(0.005)* | | | | *(0.006)* | |
| PMR (sectoral) * $RTFP_{i\ j\ t-1}$ | | | | | | **0.086** *** | | | | |
| | | | | | | *(0.027)* | | | | |
| PMR (econ. reg.) * $RTFP_{i\ j\ t-1}$ | | | | | | | **0.009** *** | | | |
| | | | | | | | *(0.003)* | | | |
| PMR (time-varying) * $RTFP_{i\ j\ t-1}$ | | | | | | | | **0.005** ** | | **0.004** * |
| | | | | | | | | *(0.002)* | | *(0.002)* |
| Industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country dummies | No | No | No | No | No | No | No | No | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 |

*Notes:* In all equations with (time invariant) product market regulatory indicators in which country dummies are omitted, standard errors are adjusted for cluster level effects. Robust standard errors are in brackets. * : significant at 10 % level; ** at 5% level; *** at 1 % level.

Table 6. **Productivity regressions: the Role of Regulations and Institutions** (continued)
(dependent variable: $\Delta TFP_{ijt}$)

| | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant | **-0.008** | **-0.012** | **-0.018** | **-0.018** | **-0.010** | **-0.001** | **-0.010** | **-0.011** | **-0.011** | **-0.014** |
| | *(0.010)* | *(0.010)* | *(0.013)* | *(0.011)* | *(0.012)* | *(0.013)* | *(0.010)* | *(0.010)* | *(0.009)* | *(0.009)* |
| $\Delta$ $TFP_{Leader\ j\ t}$ (MAN) | **-0.013** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** | **-0.012** |
| | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* | *(0.009)* |
| $\Delta$ $TFP_{Leader\ j\ t}$ (SERV) | **0.085** *** | **0.083** *** | **0.078** *** | **0.093** *** | **0.077** *** | **0.074** *** | **0.078** *** | **0.090** *** | **0.077** *** | **0.075** *** |
| | *(0.013)* | *(0.014)* | *(0.015)* | *(0.015)* | *(0.015)* | *(0.014)* | *(0.014)* | *(0.014)* | *(0.015)* | *(0.014)* |
| $RTFP_{i\ j\ t-1}$(MAN) | **-0.024** *** | **-0.023** *** | **-0.042** *** | **-0.040** *** | **-0.036** *** | **-0.041** *** | **-0.037** *** | **-0.035** *** | **-0.037** *** | **-0.047** *** |
| | *(0.005)* | *(0.005)* | *(0.009)* | *(0.008)* | *(0.008)* | *(0.012)* | *(0.007)* | *(0.007)* | *(0.007)* | *(0.011)* |
| $RTFP_{i\ j\ t-1}$ (SERV) | **-0.049** *** | **-0.049** *** | **-0.067** *** | **-0.057** *** | **-0.058** *** | **-0.062** *** | **-0.062** *** | **-0.055** *** | **-0.058** *** | **-0.069** *** |
| | *(0.008)* | *(0.008)* | *(0.012)* | *(0.009)* | *(0.010)* | *(0.013)* | *(0.010)* | *(0.009)* | *(0.009)* | *(0.012)* |
| High corporatism | | **-0.002** | **-0.001** | **-0.002** | **-0.001** | **-0.003** | **-0.002** | **-0.002** | **-0.001** | **-0.002** |
| | | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* |
| Low corporatism | | **-0.001** | **-0.001** | **-0.001** | **-0.002** | **-0.007** * | **-0.002** | **-0.002** | **-0.002** | **-0.004** |
| | | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.004)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* |
| EPL (high corporatism) | | **-0.002** | **-0.002** | **-0.002** | **-0.002** | **-0.001** | **-0.001** | **-0.001** | **-0.002** | **-0.002** |
| | | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* | *(0.003)* |
| EPL (medium corporatism) | | **-0.010** *** | **-0.008** *** | **-0.008** *** | **-0.008** *** | **-0.007** *** | **-0.007** *** | **-0.008** *** | **-0.008** *** | **-0.009** *** |
| | | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* |
| EPL (low corporatism) | | **0.0005** | **0.001** | **0.001** | **0.003** | **0.004** * | **0.002** | **0.002** | **0.003** * | **0.002** |
| | | *(0.001)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.002)* | *(0.001)* | *(0.001)* | *(0.001)* | *(0.001)* |
| EPL | **-0.002** ** | | | | | | | | | |
| | *(0.001)* | | | | | | | | | |
| PM regulations (PMR) | | | **0.004** | | | | | | | |
| | | | *(0.004)* | | | | | | | |
| PMR (sectoral) | | | | **0.023** | | | | | | |
| | | | | *(0.018)* | | | | | | |
| PMR (economic regulation) | | | | | **-0.0002** | | | | | |
| | | | | | *(0.003)* | | | | | |
| PMR (time-varying) | | | | | | **-0.003** | | | | |
| | | | | | | *(0.002)* | | | | |
| PMR * $RTFP_{i\ j\ t-1}$ | | | **0.012** ** | | | | **0.009** ** | | | |
| | | | *(0.005)* | | | | *(0.004)* | | | |
| PMR (sectoral) * $RTFP_{i\ j\ t-1}$ | | | | **0.064** ** | | | | **0.047** ** | | |
| | | | | *(0.027)* | | | | *(0.022)* | | |
| PMR (econ. reg.) * $RTFP_{i\ j\ t-1}$ | | | | | **0.006** ** | | | | **0.007** ** | |
| | | | | | *(0.003)* | | | | *(0.003)* | |
| PMR (time-varying) * $RTFP_{i\ j\ t-1}$ | | | | | | **0.004** * | | | | **0.005** ** |
| | | | | | | *(0.002)* | | | | *(0.002)* |
| Industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country dummies | No | No | No | No | No | No | No | No | No | No |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 | 3191 |

*Notes:* In all equations with (time invariant) product market regulatory indicators, standard errors are adjusted for cluster level effects.
Robust standard errors are in brackets. * : significant at 10 % level; ** at 5% level; *** at 1 % level.

The analysis is also extended to consider the industrial relations regimes and summary indicators of employment protection legislation that proxy for the cost of labour adjustment. Different industrial relations regimes, *per se*, do not seem to have a significant impact on productivity (equation L). However, differences in these regimes seem to affect significantly the estimated impact of EPL on multifactor productivity. In equation K, the EPL coefficient is negatively signed and statistically significant. However, if allowed to vary across the different industrial relations regimes (from equation L onwards), 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 -- while it is not statistically significant in either highly centralised/co-ordinated or decentralised countries. One explanation is that dynamic efficiency requires a continuous process of technological change, and the latter is often associated with skill upgrading of the workforce. The required adjustment of the workforce can be achieved either by recurring to the internal labour market *via* firm-sponsored training, if EPL is strict, or by acquiring the necessary skills on the external labour market. In this context, strict EPL raises the costs of adjusting the workforce, and this may have a particularly detrimental effect on 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.

Manufacturing data also permit investigation of the possible influences of different market structures and technology regimes (see above) (Table 7). The technology gap coefficients are stronger in low-tech, low-concentration industries (denoted by LT in the table). This is consistent with the view that industries operating in these markets largely share the same technology, and spillover effects may be more significant when the technology is relatively stable compared with cases where technological trajectories stimulate product or process diversification and lead to market power. This is clearly the case of industries operating in a monopolistic competition regime (they are denoted by HTLC in the table). There, firms (or industries in each country) tend to specialise in specific products/market niches, which reduces the scope for technological spillovers. The coefficient of the technology gap variable for the third group in the table -- high-tech industries with high concentration, HTHC -- is smaller than that for low-tech industries but is statistically significant: the dominance of one (or few) technologies gives scope for some convergence in productivity, albeit more limited than in fully competitive markets.

The links between product and labour market regulatory and institutional variables and productivity are broadly unchanged when controls for market structure and R&D are applied (Table 7). Again, strict regulations on the product market have an indirect effect *via* the process of *technological adoption*, as shown by the significantly positive coefficient of the interaction term between product market regulation and the technology catch-up variable. In other words, the further an industry/country is from the frontier, the stronger the cumulative negative effect of strict regulations on productivity: they 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. These findings suggest that, in manufacturing, strict product market regulatory settings affect multifactor productivity, both directly *via* their negative impact on R&D activity (see Bassanini and Ernst, 2002), and indirectly by slowing down the adoption of existing technologies.

Table 7. **The Role of R&D, market structure and regulatory settings, manufacturing**

| **Dependant variable: $\Delta TFP_{ijt}$** | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Constant | **-0.030** | **-0.030** * | **0.018** | **0.029** * | **-0.014** | **0.035** *** | **0.004** | **0.002** | **0.016** | **0.004** | **0.047** |
| | *(0.030)* | *(0.017)* | *(0.015)* | *(0.016)* | *(0.011)* | | *(0.018)* | *(0.013)* | *(0.015)* | *(0.020)* | *(0.031)* |
| $\Delta TFP_{Leader\ j\ t}$ | **-0.020** * | **-0.007** | **-0.007** | **-0.007** | **-0.006** | **0.001** | **-0.005** | **-0.005** | **-0.005** | **-0.005** | |
| | *(0.013)* | *(0.008)* | *(0.009)* | *(0.009)* | *0.008* | *(0.009)* | *0.009* | *(0.009)* | *(0.008)* | *(0.008)* | |
| $\Delta TFP_{Leader\ j\ t}$ (HTLC) | | | | | | | | | | | **0.096** |
| | | | | | | | | | | | *(0.062)* |
| $\Delta TFP_{Leader\ j\ t}$ (HTHC) | | | | | | | | | | | **-0.014** |
| | | | | | | | | | | | *(0.011)* |
| $RTFP_{i\ j\ t-1}$ | **-0.060** *** | **-0.029** *** | **-0.029** *** | **-0.019** ** | | | | | | | |
| | *(0.006)* | *(0.003)* | *(0.005)* | *(0.009)* | | | | | | | |
| $RTFP_{i\ j\ t-1}$ (LT) | | | | | **-0.039** *** | **-0.020** *** | **-0.050** *** | **-0.059** *** | **-0.036** *** | **-0.053** *** | |
| | | | | | *(0.006)* | *(0.004)* | *(0.016)* | *(0.012)* | *(0.006)* | *(0.012)* | |
| $RTFP_{i\ j\ t-1}$ (HT) | | | | | **-0.021** *** | **-0.006** | **0.007** | **-0.010** | **-0.005** | **-0.019** | |
| | | | | | *(0.005)* | *(0.004)* | *(0.015)* | *(0.017)* | *(0.014)* | *(0.017)* | |
| $RTFP_{i\ j\ t-1}$ (HTLC) | | | | | | | | | | | **-0.053** |
| | | | | | | | | | | | *(0.056)* |
| $RTFP_{i\ j\ t-1}$ (HTHC) | | | | | | | | | | | **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** | **0.006** *** | **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** ** | **0.014** ** | **0.007** | **0.007** | |
| | | | | | | *(0.002)* | *(0.006)* | *(0.006)* | *(0.006)* | *(0.006)* | |
| $R\&D_{i\ j\ t-1}$ (HTLC) | | | | | | | | | | | **0.00004** |
| | | | | | | | | | | | *(0.017)* |
| $R\&D_{i\ j\ t-1}$ (HTHC) | | | | | | | | | | | **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** * | **0.013** ** | **0.005** | **0.006** | |
| | | | | | | | *(0.006)* | *(0.006)* | *(0.006)* | *(0.006)* | |
| $(R\&D * RTFP)_{i\ j\ t-1}$(HTLC) | | | | | | | | | | | **-0.011** |
| | | | | | | | | | | | *(0.024)* |
| $(R\&D * RTFP)_{i\ j\ t-1}$(HTHC) | | | | | | | | | | | **0.021** *** |
| | | | | | | | | | | | *(0.007)* |
| PM regulations (PMR) | | | | | | | | | | **0.007** | |
| | | | | | | | | | | *(0.006)* | |
| $PMR * RTFP_{i\ j\ t-1}$ | | | | | | | | **0.014** ** | | **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 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No | Yes |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Reset | 76.67 *** | 0.79 | 1.57 | 2.34 * | 1.64 | 0.77 | 1.74 | 2.13 * | 3.73 ** | 3.21 ** | 12.75 *** |
| Observations | 2625 | 2569 | 2063 | 2063 | 2570 | 2063 | 2063 | 2063 | 2063 | 2063 | 932 |

*Notes:* In all equations with (time invariant) product market regulatory indicators, standard errors are adjusted for cluster level effects.

Robust standard errors are in brackets. * : significant at 10 % level; ** at 5% level; *** at 1 % level.

Reset is the Sargan test for misspecification

The results on R&D also raise some interesting issues. While there is evidence of a significant positive effect of R&D on productivity (as would be expected) (equation C), there is no evidence of R&D also boosting productivity indirectly by improving the ability of firms to learn about advances in the leading edge ("absorptive capacity"). This latter effect is shown by the interaction variable between R&D and the technology catch-up variable, which is not statistically significant in equation D.[21] Note that dropping country fixed effects (in order to introduce EPL or PMR variables) weakens the effect of R&D in hi-tech industries. This suggests that the effect of R&D for hi-tech industries reflects differences among industries within countries, and not differences between countries.

It has also been argued that the nature of R&D and its impact on productivity may vary depending on market conditions in which firms operate (see also Cohen and Levin, 1989; Sutton, 1998; Symeonidis, 1996).[22] This hypothesis is tested empirically by differentiating the estimated coefficient of R&D between low and high-tech industries in equations F to J. The direct effect of R&D on productivity is significant in both types of industries. However, in the high-tech group, there is some weak evidence of a negative interaction between R&D and the technology gap (contrary to the hypothesis discussed above); that is to say, R&D seems to have a greater impact on productivity the closer a country is to the technological frontier (equations G and H). This suggests that innovation rents are greater for technological leaders than for followers.

To shed more light on the indirect effect of R&D on productivity in high-tech industries we further differentiate the group according to technological trajectories (see above). High-tech industries with low concentration are often characterised by ‘creative destruction’ with technological ease of entry and a major role played by new firms in innovative activities (see also Nelson and Winter, 1982). Returns on R&D in these industries 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. In this context, high R&D intensity may not necessarily result in higher *measured* productivity, at least unless quality differentiation is taken into account in measuring industry

21 . 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). They found this interaction term to be strongly significant, suggesting that, within each industry, the countries that are further behind the frontier could benefit more from R&D activity because the latter play a dual role of fostering innovation but also developing ‘absorptive’ capacity. The authors use a similar dataset (the OECD STAN) for a smaller set of OECD countries, more aggregated industries but a longer time period (1970-92). These differences could all contribute to explain the different empirical results. However, the quality of R&D data for the 1970s is questionable, and that decade was characterised by aggregate and sectoral shocks that may not be fully grasped in the empirical analysis. Another possible source of the discrepancy is the greater industry disaggregation used in the present analysis. In general, the greater the industry disaggregation, there more likely it is to identify areas of country specialisation which, in turn, weaken the estimated technology catch up process and any possible role of R&D in stimulating this process.

22. In spite of the large number of studies, the links between innovation activity and market structure remain the subject of intense discussion (see, amongst others, Symeonidis, 1996 for a survey). Sutton (1996, 1998) extends the analysis to include product differentiation: while there no is reason to expect a relationship between product differentiation and market structure in low R&D industries, in R&D-intensive industries the lower bound of concentration decreases as product differentiability rises and product proliferation increasingly dominates product enhancement.

value added (which is the case of only a few industries in a very few countries).[23] By contrast, high-tech but concentrated 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 low concentration ones, possibly leading to persistent technological leadership.[24] The last column (K) of Table 7 presents a specification based on a more disaggregated classification of high-tech industries (note that both country and time coverage are reduced). The results broadly adhere to the theoretical considerations discussed above. R&D has a strong positive effect in high concentrated industries but not in low concentrated industries. Moreover, the negative interaction between R&D and the technology gap obtained when the high-tech group was not differentiated is entirely attributable to high concentrated 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.

### *Quantifying the Impact of PMR and EPL on Multi-factor Productivity*

The impact of product and labour market regulations on the long-run steady-state level of *MFP* is quantified from equation [6] above. Let $x$ be the indicator considered (PMR or EPL), and $G_{ij} = MFP_{ij} / MFP_{Fj}$ the *MFP* gap between country $i$ and the leading country for industry $j$.

The long-run impact of a small variation $\delta x$ of the indicator on the long-run level of MFP gap is:

$$\delta G_{ij} = G'_{ij}(x) \cdot \delta x = G_{ij}(x) \cdot RMFP'_{ij}(x) \cdot \delta x \qquad [9]$$

Taking this relation as a first-order approximation, the long-run impact on the level of MFP gap of a change $\delta x$ of the variable $x$ is:

$$\Delta G_{ij} = G'_{ij}(x) \cdot \Delta x = G_{ij}(x) \cdot RMFP'_{ij}(x) \cdot \Delta x \qquad [10]$$

Letting $\omega^{x}_{ij}{'}$ and $\omega^{x}_{ij}{''}$ be the regression coefficients in $\omega_{ij}{'}$ and $\omega_{ij}{''}$ related to $x$, equation [6] gives the relative change of the *MFP* gap:

23. However, even if quality differences could be fully measured, firms in highly product differentiated markets may still be caught in a process of R&D escalation, leading to a rise in R&D expenditures but not necessarily higher productivity (Sutton, 1996).

24. These two groups of high-tech industries have also been labelled Shumpeterian Mark I and Mark II industries (see Malerba and Orsenigo, 1995, 1997, for an exhaustive characterisation of these technological regimes). In *Mark I* industries, many different firms are likely to engage in the search for new technologies; new entrepreneurs come with new ideas and innovations and challenge established firms, thus wiping out the quasi-rents associated with previous innovations. In contrast, *Mark II* industries are characterised by the presence of high barriers to entry to new innovators, because incumbents have an accumulated stock of knowledge and technology is cumulative rather than disruptive. However, the measurement problem of both output and R&D in Mark 1 type industries may also explain this result. These industries are characterised by strong product differentiation, by (perceived) quality, and a dominance of small firms, where R&D remains partly unmeasured.

$$\frac{\Delta G_{ij}}{G_{ij}} = \frac{\Delta x}{1-\beta_1-\omega_{ij}^{x''}} \cdot \left[\omega_{ij}^{x'} + RMFP_{ij} \cdot \omega_{ij}^{x''}\right]$$

It can be decomposed in the following way:

$\frac{\Delta G^1_{ij}}{G^1_{ij}} = \frac{\Delta x}{1-\beta_1-\omega_{ij}^{x''}} \cdot \omega_{ij}^{x'}$ is the relative change of *MFP* gap due to the direct effect of *x* on the rate of growth of *MFP*, whereas:

$\frac{\Delta G_{ij}}{G_{ij}} = \frac{\Delta x}{1-\beta_1-\omega_{ij}^{x''}} \cdot RMFP_{ij} \cdot \omega_{ij}^{x''}$ is the indirect effect (interaction term) of *x* on *MFP* growth through technological transfer.

Table 8 displays respectively the effect of a 1 standard deviation increase in PMR and EPL on the rate of growth of MFP and the level of the long-term MFP gap between a country and the frontier. For the impact of PM regulations, the effect depends on the MFP gap. It is computed industry by industry and aggregated by taking an average weighted by the initial sectoral value-added.

Table 8. **Estimated Effect of 1 SD increase in PMR or EPL on the MFP gap level or the MFP growth rate (% rate)**

| | **PM regulations** *Diffusion Effect* | | **EPL[1]** *Direct Effect* | |
|---|---|---|---|---|
| **country** | MFP gap (relative to leader) | MFP growth | MFP gap (relative to leader) | MFP growth |
| AUS | -7.5% | -0.24% | 10.80% | -0.26% |
| AUT | -8.3% | -0.23% | | |
| BEL | -4.8% | -0.15% | 10.80% | -0.26% |
| CAN | -3.8% | -0.16% | | |
| DNK | -7.4% | -0.25% | | |
| ESP | -9.2% | -0.26% | 10.80% | -0.26% |
| FIN | -10.2% | -0.34% | 10.80% | -0.26% |
| FRA | -5.5% | -0.19% | 10.80% | -0.26% |
| GBR | -12.2% | -0.34% | 10.80% | -0.26% |
| GRC | -19.0% | -0.53% | | |
| ITA | -5.0% | -0.16% | | |
| JPN | -12.9% | -0.36% | | |
| NLD | -5.0% | -0.16% | | |
| NOR | -9.5% | -0.30% | | |
| PRT | -16.6% | -0.46% | 10.80% | -0.26% |
| SWE | -7.5% | -0.26% | 10.80% | -0.26% |
| USA | -2.2% | -0.08% | | |
| GER | -9.8% | -0.31% | | |

Note: the coefficient for PMR is from Table 6, column M and for EPL from Table 6, column K.
1. Reported only for countries with an intermediate degree of corporatism in wage bargaining.

As an illustration, Table 8 shows that a one SD increase in PM regulations would lead to a decrease by 2.2% of the long-run level of MFP (relative to the frontier) in the United States, while it would lead to a decrease by more than 15% in Portugal and Greece. The long-run impact of a 1 SD increase of EPL is such that it would lead to a decrease by 10.8% of the level of MFP. Computing the impact on the rate of growth of MFP directly from equation [2] implies that a 1 SD increase in the PM regulations would reduce MFP growth by 0.17% per annum in the US and by 0.95% in Portugal. Similarly, a 1 SD increase in EPL would lead to a fall of MFP growth by 0.26% per annum.

## 5. Concluding remarks

In this paper we have used a novel data set covering 23 two-digit industries of 18 OECD countries over the 1984-98 period to assess differences in multifactor productivity across countries and industries. Our empirical analysis offers a number of insights on the observed differences in productivity growth patterns and technology spillovers, and how these patterns are influenced by product and labour market regulations and institutional settings.

First of all, there is clear evidence of a productivity catch-up in most industries, with a stronger effect in service than in manufacturing. However, in high-tech industries the evidence on convergence is mixed.

The empirical evidence also suggests that there is considerable variation in the effect of R&D activity according to market structures and technology regimes. For example, the findings lend some support to the idea that strong R&D activity does not necessarily bring about higher productivity when firms are engaged in strong product differentiation and when there are different technology trajectories. Market structure and technology regimes are, of course, largely driven by market forces. But, to the extent differences in the sectoral composition of each country also implies differences in market structure conditions, these results may be of importance for policy makers is assessing the potential effects of their strategy to directly or indirectly support innovation activity.

We also found that anti-competitive regulatory settings in the product market have a negative bearing on productivity. In addition, strict employment protection legislation, by reducing employment turnover, may in a number of circumstances lead to lower productivity performance and discourage the entry of firms. However, the impact of regulations and institutions on performance 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 the technology frontier. This suggests that strict regulation hinders the adoption of existing technologies, possibly because it reduces competitive pressures or technology spillovers. The link between EPL and productivity is also complex. There is evidence to suggest that high hiring and firing costs deter productivity, especially when wages and/or internal training do not offset these higher costs, thereby inducing sub-optimal adjustments of the workforce to technology changes and less incentive to innovate.

## References


ACEMOGLU, D. and S. PISCHKE (1999*a*), “The Structure of Wages and Investment in General Training”, *Journal of Political Economy*, Vol. 107, pp. 539-572.

ACEMOGLU, D. and S. PISCHKE (1999*b*), “Beyond Becker: Training in Imperfect Labor Markets”, *Economic Journal*, Vol. 109, pp. F112-142.

AGHION, P., and P. HOWITT , (1998), *Endogenous Growth Theory*, Cambridge: Mass.: The MIT Press.

AGHION, P., C. HARRIS, P. HOWITT and J. VICKERS (2001*a*), “Competition, Imitation and Growth with Step-by-Step Innovation”, *Review of Economic Studies*, forthcoming.

AGHION, P., N. BLOOM, R. BLUNDELL, R. GRIFFITH and P. HOWITT (2001*b*), “Empirical Estimates of Product Market Competition and Innovation”, University College London, *Mimeo*.

BAILY, M.N., and H. GERSBACH (1995), “Efficiency in Manufacturing and the Need for Global Competition”, *Brooking Papers on Economic Activity: Microeconomics* p.307-308.

BASSANINI A. and E. ERNST (2002), "Labour Market Institutions, Product Market Regulations and Innovation: Cross-Country Evidence, OECD Economics Department Working Papers No 316, Paris.

BASSANINI, A. and S. SCARPETTA (2002), "Growth, Technological Change and ICT Diffusion: Recent Evidence from OECD Countries", *Oxford Review of Economic Policy*, forthcoming.

BAUMOL W., PANZAR J. and WILLIG R. (1982*), Contestable markets and the Theory of Industry structure*, New York: Harcourt Brace Jovanovitch.

BERNARD, A., and C.I. JONES (1996a), “Comparing Apples to Oranges: Productivity Convergence and Measurement across Industries and Countries”, The American Economic Review, vol.86 No.5, pp. 1216-38.

BERNARD, A., and C.I. JONES (1996b), “Productivity Across Industries and Countries: Time-Series Theory and Evidence”, *The Review of Economics and Statistics*, pp 135-146.

BERNARD, A., and C.I. JONES (1996c), “Productivity and Convergence across U.S. States and Industries”, *Empirical Economics*, 21, 113-135.

BLANCHFLOWER, D. and S. MACHIN (1996), “Product market competition, wages and productivity: international evidence from establishment-level data”, *Centre for Economic Performanc*e, Discussion paper No. 286, April.

BLUNDELL, R., R. GRIFFITH and J. VAN REENEN (1995), “Dynamic Count Data Models of Technological Innovation”, *Economic Journal*, Vol. 105, pp. 333-344.

BLUNDELL, R., R. GRIFFITH and J. VAN REENEN (1999), “Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms”, *Review of Economic Studies*, Vol. 66, pp. 529-554.

BOONE, J. (2000*a*), “Competition”, *Center Discussion Paper No.2000-104*, Tilburg University, Netherlands, October.

BOONE, J. (2000*b*), “Competitive Pressure: The Effects on Investments in Product and Process Innovation”, *RAND Journal of Economics*, Vol. 31, No. 3, pp. 549-569.

CAVES, D. L. CHRISTENSEN and E. DIEWERT (1982), "Multilateral comparisons of output, input, and productivity using superlative index numbers", Economic Journal, 92.

CHATTERJEE, S. and A. HADI, (1988) *Sensitivity Analysis in Linear Regression*, John Wiley.

CHEUNG, Y.W., and A. GARCIA PASCUAL (2001), "Market Structure, Technology Spillovers, and Persistence in Productivity Differentials", *CESifo working paper series No. 517*.

COHEN, W. and D. LEVINTHAL (1989), "Innovation and Learning: The Two Faces of R&D", *Economic Journal*, Vol. 99, pp. 569-596.

CURTIS, E.B. and R.G. LIPSEY (1989), "Product differentiation", in *Handbook of Industrial Organization*, Vol. 1, ed. R. Schmalensee and R. Willig (Amsterdam: North-Holland).

DE LA FUENTE, A., and R. DONENECH (2000), "Human Capital in Growth Regressions: How Much Difference Does Data Quality Make?", OECD Economics Department Working Paper No. 262.

DISNEY, R., J. HASKEL and Y. HEDEN (2000), "Restructuring and productivity growth in UK manufacturing", *CEPR Discussion paper series*, No. 2463, May.

DOLLAR, D. and E. WOLFF (1994), "Capital intensity and TFP convergence by industry in anufacturing, 196385", in (eds.) Baumol, W. R. Nelson and E. Wolff "Convergence of productivity: cross-national studies and historical evidence", Oxford Univ. Press.

DOLLAR, R., and E. WOLFF (1988), "Convergence of Industry Labor Productivity among Advanced Economies 1963-1982", *The Review of Economics and Statistics*, vol. 70, No.4, p549-58.

EICHENGREEN, B. and T. IVERSEN (1999), "Institutions and Economic Performance: Evidence from the Labour Market", *Oxford Review of Economic Policy*, Vol. 15, pp. 121-138.

ELMESKOV, J., J. MARTIN and S. SCARPETTA (1998), "Key Lessons for Labour Market Reforms: Evidence from OECD Countries' Experiences", *Swedish Economic Policy Review*, Vol. 5, pp. 205-252.

EVANS, D., and R. SCHMALENSEE (2001), "Some Economic Aspects of Antitrust Analysis in Dynamically Competitive Industries" NBER Working Paper Series No.8268.

GARCIA PASCUAL, A and F. WESTERMANN (2001), "Productivity Convergence in European Manufacturing", Review of International Economics.

GREEN, A. and D.G. MAYES (1991). "Technical Efficiency in Manufacturing Industries" *Economic Journal*, 101, 523-538.

GRIFFITH R., S. REDDING and J. van REENEN (2000), "Mapping the two faces of R&D: Productivity growth in a panel of OECD industries", IFS working paper W00/02.

GRIFFITH, R. (1999), "Using the ARD establishment level data to look at foreign ownership and productivity in the United Kingdom", *The Economic Journa*l, 109, F416-F442, June.

GRILICHES, Z., and F. LICHTENBERG. 1984. "R&D and Productivity Growth at the Firm Level: Is There a Relationship?" In *R&D, Patents and Productivity*, edited by Zvi Griliches. Chicago: University of Chicago Press, 46-96.

GRILICHES, Z. (1980), *R&D and Productivity – The Econometric Evidence*, NBER Monograph, The University of Chicago Press.

GUELLEC, D. and B. VAN POTTELSBERGHE (2001), "R&D and productivity growth: panel data analysis of 16 OECD countries", *OECD STI Working Papers*, No. 2001/3.

HALL, R. and C. JONES (1999) "Why Do Some Countries Produce So Much More Output per Worker than Others?", Quarterly Journal of Economics, pp. 83-116.

HARRIGAN, J. (1997), "Technology, Factor Supplies, and International Specialisation: Estimating the Neo-classical Model", *The American Economic Review,* vol.87, No.4, 475-494.

HARRIGAN, J. (1998), "Estimation of Cross-country Differences in Industry Production Functions", *Journal of International Economics*, forthcoming.

HASKEL, J. and A. SANCHIS (1995), "Privatisation and X-inefficiency: A Bargaining Approach", *The Journal of Industrial Economics,* Vol. 43, No. 3, September.

HOLMSTROM, B., (1982), "Moral Hazard in Teams", Bell Journal of Economics 13, 392-415.

JORGENSON, D.W., and K.J. STIROH (2000), "Raising the Speed Limit: U.S. Economic Growth in the Information Age", May, *Brooking Papers on Economic Activity*.

KOEDIJK, K. and J. KREMERS (1996), "Market opening, regulation and growth in Europe", *Economic Policy,* No. 23, October, pp. 445-467.

LAZAER,E.P and S. ROSEND (1981), "Rank-order tournaments as optimum labor contracts". *Journal of Political Economy*, 89, 841-864.

LICHTENBERG, F.R. and D. SIEGEL (1992), "Takeovers and corporate overhead", in: F.R. Lichtenberg, *Corporate Takeovers and Productivit*y, MIT Press, Cambridge.

LICHTENBERG, F.R. and D. SIEGEL (1991), "The Impact of R&D Investment on Productivity: New Evidence Using Linked R&D-LRD Data", *Economic Enquiry*, Vol. XXIX, April, pp. 203-28.

MACDONALD, J.M., (1994), "Does Import Competition Force Efficient Production?", *Review of Economics and Statistics*, 76(4), pp.721-727.

MALERBA, F., and L. ORSENIGO (1995), "Schumpeterian Patterns of Innovation", *Cambridge Journal of Economic*s, Vol. 19, pp. 47-65.

MALERBA, F., and L. ORSENIGO (1997), "Technological Regimes and Sectoral Patterns of Innovative Activities", *Industrial and Corporate Chang*e, Vol. 6, pp. 83-117.

McKINSEY Global Institute (1997), *Removing Barriers to Growth and Employment in France and Germany*, McKinsey.

MEYER , M., and J. VICKERS, (1997), "Performance Comparisons and Dynamic Incentives," *Journal of Political Economy* , 105, 3, 547-581.

MOULTON, B.R. (1986), "Random group effects and the precision of regression estimates", *Journal of Econometrics*, 32, pp. 385-397.

NALEBUFF, B., and J. STIGLITZ (1983), "Information, Competition and Markets", *American Economic Revie, Papers and Proceedings 73*, 278-93.

NELSON, R. and S. WINTER (1982) *An Evolutionary Theory of Economic Change,* Cambridge, Mass.: The Belknap Press of Harvard University Press.

NICKELL, S., D. NICOLITSAS and N. DRYDEN (1997), "What makes firms perform well?", *European Economic Revie*w, 41.

NICKELL, S. (1996), "Competition and Corporate Performance", *Journal of Political Economy*, Vol. 104, pp. 724-746.

NICOLETTI, G. A. BASSANINI, E. ERNST, S. JEAN, P. SANTIAGO and P. SWAIM (2001), "Product and Labour Market Interactions in OECD Countries", *OECD Economics Department Working Paper* No. 312, Paris.

NICOLETTI, G., S. SCARPETTA and O. BOYLAUD (1999), "Summary indicators of product market regulation with an extension to employment protection legislation", *OECD Economics Department Working Paper* No. 226, Paris.

OECD (1997), The OECD Report on Regulatory Reform, Paris.

OECD (2001*a*), "The New Economy Beyond the Hype: The OECD Growth Project", Paris.

OECD (2001*b*), The OECD Productivity Manual, Paris.

OLINER, S.D. and D.E. SICHEL (2000), "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?", *FRG Finance and Economic Discussion Paper*, 2000-20, Federal Reserve Board.

OLIVEIRA MARTINS, J., and S. SCARPETTA, (1999), "The levels and cyclical behaviour of mark-ups across countries and market structures," *OECD Economics Department working papers* 213, OECD Economics Department.

PANZAR, J. (1989), "Technological Determinants of Firm and Industry Structure," Ch. 1 in *Handbook of Industrial Organization*, North-Holland.

PORTER, M., (1990) *The Competitive Advantage of Nations*, London: MacMillan Press.

SCARPETTA, S. and T. TRESSEL (2002), "Technological change, productivity growth and labour market institutions: An empirical investigation for OECD countries", mimeo.

SCHARFSTEIN, D. (1988), "Product Market Competition and Managerial Slack", *Rand Journal of Economics* 19,147-155.

SCHREYER, P., and D. PILAT (2001), "Measuring Productivity", OECD Economic Studies No.33, 2001/11.

SØRENSEN, A. (2001), "Comparing Apples and Oranges: Productivity Convergence and Measurement Across Industries and Countries: Comment", American Economic Review, 91, 4, pp. 1160-1167.

SOSKICE, D. (1997), "German Technology Policy, Innovation, and National Institutional Frameworks", *Industry and Innovation*, Vol. 4, pp. 75-96.

SUTTON, J. (1996), "Technology and Market Structure", *European Economic Review,* 40(3-5), April, pp. 511-30.

SUTTON, J. (1998), *Technology and Market Structure*, Cambridge, Mass.: The MIT Press.

SUTTON, J. (2000), "Rich Trade, Scarce Capabilities, Industrial Development Revisited", Keynes Lecture, British Academy, October.

SYMEONIDIS, G. (1996), "Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes", *OECD Economics Department Working Paper* No. 161, Paris.

VAN WINJNBERGEN, S., and A. J. VENABLES (1993). "Trade Liberalization, Productivity, and Competition: The Mexican Experience," *Centre for Economic Performance*, London School of Economics, *mimeo.*

VICKERS, J. (1995), "Entry and Competitive Selection", *Mimeo*.

WINSTON, C. (1993), "Economic deregulation: Days of reckoning for microeconomists", *Journal of Economic Literatur*e, Vol. XXX1, pp. 1263-1289, September.

## Appendix

### *Source of the different data*

Data on **hours worked** are from ILO for the following countries: Australia, Austria, Finland, France, Norway, Portugal, Spain, Greece, Italy, Japan Netherlands and New Zealand. For manufacturing industries, we use the data for total manufacturing. For the sectors 41 and 42 (see Table 1 above), we have data for: Australia, Austria, Finland, France, Portugal, Spain, Greece, Italy and Netherlands. For Norway, Japan and New Zealand we use data of industry 40. For sectors 44, 45, we use data of sector 43 for all countries. For sectors 47 and 51, we have the data for: Australia, Austria, Finland, France, Portugal, Spain, Greece, Italy and Netherlands. We use data of sector 46 for Norway and New Zealand. For the United States, we use the data from the BLS. Data are from CRONOS for the following countries: Belgium, Denmark and Germany. For Canada, we use data from the National Statistics Office.

**Wage data** are country-industry specific observations. They are from the OECD DEELSA database on employment. The primary source of the data is the European Structure of Earnings Survey (Eurostat) for EU countries, OECD calculations on the microdata file of the outgoing rotation group of the Current Population Survey for the US, and Structure of Earnings Surveys or Labour Force Surveys for the other countries. The observation is 1998 for non-EU countries, 1994 for France, 1996 for Sweden, 1995 for other EU countries. Data on wages for Portugal, Netherlands, Finland, Norway, Germany, Australia and Japan are not included. In order not to drop these countries when using skill data, we make the following assumption: we use the relative wages of a neighbour country when available, or the US data otherwise. For Portugal, we use Spain, for Netherlands we use Belgium, for Finland and Norway we use Sweden; for Germany we use Austria; for Canada, Australia and Japan we use the US.

Data on the **skill composition of employment** also have a country, industry and time dimension.[25] These data are from several sources: (1) the DEELSA data described above, (2) the skill data in OECD STI Working Paper No. 1998/4; and (3) ILO data on aggregate employment for the four skill categories. Data from (2) typically have country, industry and time dimension,[26] while those from (3) are panel data at the country level. Our dataset was constructed in the following way: we used (2) as the baseline source; then we complemented these data using (1) and (3) for the following countries: Austria, Belgium, Canada, Denmark, Greece, Netherlands, Norway, Portugal, Spain and Sweden. The procedure was the following: when the industry breakdown was available in (1), we used this single observation to compute, for each skill category, the industry wage relative to the country (weighted) average wage, and used this differential to construct time series from the aggregate source (3) data.

We used **industry-specific PPPs** to convert volume output into a comparable currency (se Sørensen, 2001, for a critics of the use of nation-wide GDP PPPs for the comparison of

25 Except for Canada for which we do not have the manufacturing detail and Norway data do not have the sectoral decomposition.

26 Depending on the country considered, the number of (non necessarily consecutive) observation varies between 2 and 5. We use a linear extrapolation between the two extreme points to obtain a panel dataset.

productivity levels, as in Bernard and Jones, 1986*a,b*). The starting point of these calculations were the PPPs for detailed expenditure headings from the United Nations International Comparisons Project (ICP). These detailed PPPs were mapped into the STAN classification of industries by assigning each basic expenditure heading bought by consumers, firms or the government to its industry of origin. When the basic heading includes products produced in more than one industry, the same price was assigned to all the industries concerned. Within each industry, proxies of the product prices were obtained aggregating the basic headings with the corresponding expenditure shares. However, as suggested by Harrigan (1997), there are a number of problems in using expenditure PPPs for industry productivity comparison. In particular the presence of distribution and transportation margins, indirect taxes and the inclusion/exclusion of the prices of imported/exported goods all tend to create a gap between expenditure prices and production prices. While available data did not allow to account for distribution and transportation margins, corrections for both indirect taxes and international trade were made. In particular, in the above-mentioned Secretariat work, the correction for indirect taxes was made using the following formula :

$$PPP_{i,j}^{adjI} = \frac{1+t_{i,j}}{1+t_{US,j}} \cdot PPP_{i,j}$$

where $t_{i,j}$ is the indirect tax rate of country *i* in industry *j*.

The impact of trade on the differential between expenditure and production prices is larger the more the sectoral expenditure price differs from the exchange rate. Since imports and exports have opposite effects on this differential, only the net trade position is relevant. The following adjustment was made to PPPs:

$$PPP_{i,j}^{adjII} = PPP_{i,j}^{adjI} + \frac{X_{i,j} - M_{i,j}}{Y_{i,j}} \cdot \left(e - PPP_{i,j}^{adjI}\right)$$

where *X* stands for industry exports, *M* for industry imports, *Y* for industry output, and *e* for the exchange rate.

As a final test of robustness, the whole analysis (e.g. for the different measures of labor input) was repeated by using aggregate PPPs for GDP from *STD*, *National Accounts of OECD Countries – Main Aggregates. Vol. I – 2002 Edition.*

In a number of instances, the industry time series of the **capital stock** was not readily available in the original databases. If data on gross fixed capital formation were available, we used the perpetual inventory method to construct a proxy for the capital stock following the OECD ISDB *User Guide:*

$$GCS_t = \sum\nolimits_{j=0}^{2ASL-5} INV_{t-j} \cdot g_{t-j}$$

where: *GCS* is the gross capital stock at constant prices, *INV* is gross fixed capital formation at constant prices; *g* is the survival coefficient; *j* is the vintage of investment; *ASL* is the average service life. The survival coefficient is given by: g = 1 if j<5 and g = 1- ½(ASL-5) if j>4 and j-1<2ASL-5 (depreciation starts at date t-5). Average services lives (ASL) are from ISDB98 – *methods used by OECD countries to measure stocks of fixed capital*, OECD, Paris (1993).

The formula above implies the following recursive relation of the stock of capital for adjacent dates:

$$GCS_t = GCS_{t-1} + INV_t - \frac{1}{2(ASL-5)} \sum_{j=5}^{2ASL-5} INV_{t-j}$$

Gross capital stocks are calculated from this formula.

***Sensitivity Analysis***

The estimates of MFP used in the empirical analysis discussed above are based on the assumption that product markets are competitive. Moreover, these estimates of MFP do not control for changes in composition of the workforce. In order to test for the robustness of the results, we have re-estimated the productivity equations using alternative measures of MFP. In particular, three alternative measures were used in the sensitivity analysis:

- a) a measure of labour input that does not include changes in hours worked (this is the simplest measure of labour input);

- b) a measure of labour input that controls for changes in hours worked and in the composition of employment by skills;

- c) a measure of labour input that controls for hours worked (i.e. the variable used in the analysis above) and a labour share that is adjusted for the presence of a positive mark-up of prices over marginal costs. We used estimates of country-industry specific mark-ups developed by Oliveira Martins and Scarpetta (1998). In particular, in the presence of a mark-up, the labour share parameter $\alpha_{ijt}$ has to be replaced by: $\tilde{\alpha}_{ijt} = \mu_{ij} \cdot \alpha_{ijt}$, where $\mu_{ijt}$ is the country-industry specific mark-up. The mark-up estimates in Oliveira Martins and Scarpetta (1998) are relatively aggregated and do not cover the whole country sample. If mark-ups were not available for a given detailed industry, we used the more aggregated industry's mark-ups.[27] This adjustment for mark-ups is available only for manufacturing industries.

The whole sensitivity analysis has been repeated for the following measures of MFP:

- Cobb-Douglas production function instead of translog production function.

- Aggregate PPPs instead of industry PPPs.

Our main results on convergence, impact of institutions and regulations, significance of human capital variables and impact of R&D - in particular the different estimates between "High-Tech High Concentration" and "High-Tech Low Concentration and greater impact of R&D for leaders in high-tech industries – are robust to these different specifications.

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27 We took the estimated mark-ups for the period 1980-1992. Missing countries are: Austria, Spain, Greece and Portugal.

For the main measure of MFP (translog production function, industry PPPs) the sensitivity analysis yields the following results. Firstly, we checked that the coefficients in the baseline regressions for the entire **business sector**, with or without control for outliers and with and without robust standard errors, are stable while controlling or not for hours worked labour composition. Coefficients of the long-term relation of MFP between countries are remarkably stable and always significant at the 1% level. Moreover, human capital has a positive and significant effect (at 1% or 5% level of confidence) in all specifications, with a coefficient varying between 0.18 and 0.22. Interestingly, the coefficient remains significant even when the composition of labour is incorporated in the calculation of MFP. This is consistent with the existence of externalities linked to the accumulation of human capital.

Secondly, we checked whether the differences in the estimated coefficients for manufacturing and services were robust to different measures of MFP. Indeed, whatever measure of MFP, convergence is stronger in service sectors than in manufacturing sectors: the F-tests reject the equality of the short-run coefficients in all specifications, while the equality of coefficients is rejected in all but one specification for the long-run coefficient. The largest gap in the speed of convergence is obtained when controlling for hours worked and skill composition.

Thirdly, we checked whether the conclusions concerning the impact of product market regulations are robust to the use of different estimates of MFP. More precisely, when both direct and indirect effects of product market institutions are included, we find for all specifications significant direct impact of product market regulations on MFP growth. In addition, the interaction between PMR and the catch-up term remains statistically significant in most cases.

Finally, we checked the results for labour market institutions and EPL. Reassuringly, the baseline results are all confirmed in this sensitivity analysis. In addition, the coefficient for high corporatism countries is significant and negative in several cases, despite the fact that it is not significant in the specification reported in the main text.

Moreover, when adding simultaneously labour market indicators and the indirect effect of product market regulations, results on labour market regulation and institutions are not significantly affected.

We also replicate the sensitivity analysis for the **manufacturing** equations. Firstly, the results for the baseline specification are remarkably robust to different measures of MFP. After correction for outliers[28] for each specification, the long-run coefficient varies between –0.02 and -0.06. In all cases are coefficients significant at the 1% level. Moreover, convergence is always greater in low-tech than in high-tech industries.

Secondly, the impact of R&D – either direct or indirect through the interaction term – is essentially identical in all specifications, *i.e.* the coefficient is positive and significant for the direct effect while the indirect effect is significant (at various levels) for high-tech industries (within high-tech industries it is significant for high concentration industries), with the same sign as in the main analysis.

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28 Not correcting for outliers does not significantly modify the results.

Finally, the conclusions on the impact of product and labour market regulations and institutions are not significantly affected by the measure of MFP considered. First, all specifications support the finding that strict PMR reduces the speed of convergence (interaction term between PMR and catch-up) as in the results discussed above. The evidence concerning the direct impact of PMR on productivity is, however, at best weak, or non-significant.[29] The quantitative impact of PMR, as reported in Table 8, may however vary significantly across specifications: the effect reported in the text reflects the upper bound, while the lower bound gives an impact about five time lower as the one reported in the text. Lastly, the use of alternative estimates of MFP does not influence significantly the impact of EPL on productivity: EPL has a negative and significant impact on MFP in countries with an intermediate bargaining system while it is not significant in other countries.[30] The impact remains quantitatively very close to the one reported in Table 8.

29 We checked that this result is driven by the control for mark-ups, not by the smaller sample size due to the availability of mark-ups. Note that, given the smaller size of the original dataset of industry mark-ups, questionable assumptions had to be made as for the mark-ups in some countries.

30 The only exception is for countries with High Corporatism in the specifications with a control for mark-ups in which the impact of EPL is significant and positive. Again, this contrasting result may be due to the hypothesis

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