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Productivity Growth: The Effect of Market Regulations

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Abstract

This paper explores the effects of product and labour market regulation on growth in total factor productivity (TFP) using panel data from 1974–2003 for 18 OECD countries. Our regressions are specified so that labour and product market regulations can affect productivity both individually and in combination. While noting that the results are sensitive to the measure of labour market regulation used, we find some support for the hypothesis that lower initial levels of regulation are associated with higher TFP growth over subsequent years, and that labour and product market deregulation have more of an effect in combination. It also appears that product market deregulation has a larger positive effect on productivity growth the further a country is from the technological frontier.

JEL Classification Numbers: C33, J01, L50, O43, O57
Keywords: structural reform, TFP growth, OECD, panel regression

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PRODUCTIVITY GROWTH: THE EFFECT OF MARKET REGULATIONS

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1. Introduction

During the late 1990s some countries experienced a productivity surge that many suggested was driven by information technology. Despite the attention it received, this productivity revolution was relatively limited in geographical scope. A small group of OECD countries (including Australia, Canada, Sweden and the US) experienced a sizeable step-up in their productivity growth in the 1990s (Figure 1).[1] For these countries, average total factor productivity (TFP) growth within the business sector rose by between 0.4 and 1.2 percentage points compared with the previous decade. However, at the same time, TFP growth rates declined across much of Europe.

Explanations for the productivity surge have focused on the production of, or investment in, information and communications technology (ICT).[2] Looking across a sample of OECD countries, there is clearly a positive correlation between expenditure on ICT (relative to GDP) over the 1990s and the change in TFP growth from the late 1980s to the late 1990s (Figure 2). Importantly, the Australian experience demonstrates that it was not necessary to produce ICT, as had been thought, in order to reap some of its productivity benefits. Unlike the United States and most of the other 'high-tech' countries, Australia had no significant ICT production sector.

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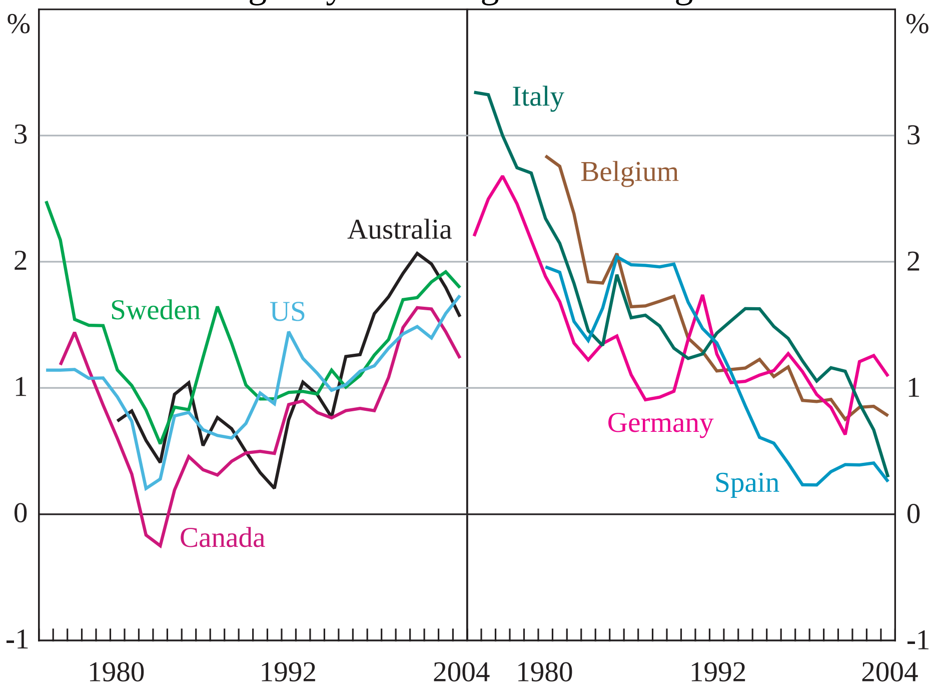
1 This paper focuses on the 18 OECD countries for which relevant data are readily available: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. For a description of data and sources see Section 3 and Appendix A.

2 An influential paper by Oliner and Sichel (2000) attributed around two-thirds of the step-up in labour productivity growth in the US over the 1990s to the use or production of ICT. In Australia, Simon and Wardrop (2002) estimated that IT-related capital deepening added over 1 per cent per annum to output growth in the 1990s or about one-third of the step-up in labour productivity growth over the period.

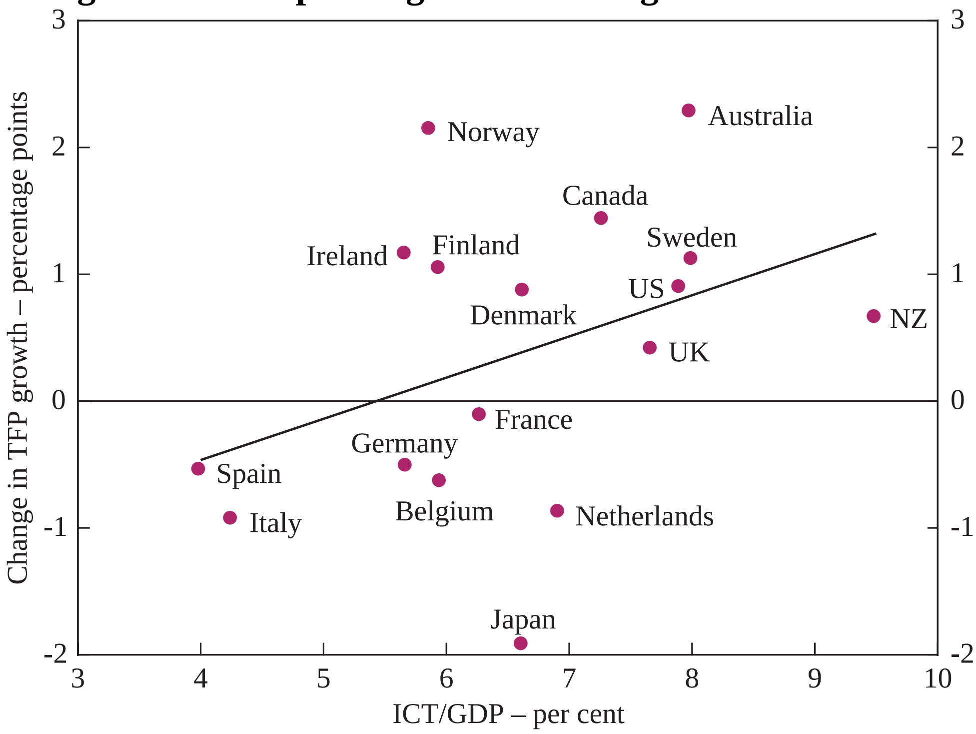
Figure 1: TFP – Business Sector

Rolling 10-year average of annual growth



Sources: OECD; Thomson Financial; authors' calculations

Figure 2: ICT Spending Versus Change in TFP Growth



Note: ICT spending (as a ratio to GDP) is the average for 1992–2000; TFP is the difference in five-year averages of annual growth ending in 1990 and 2000

Sources: OECD; Thomson Financial; World Information Technology and Services Alliance; authors' calculations

Even if we accept that differences in ICT investment have contributed to recent differences in TFP growth, a critical question remains unanswered. What led some countries to invest so heavily in ICT while others did not? One suggested answer is that those countries that did not invest heavily in ICT were hamstrung by rigid regulation of their labour and product markets. For example, Figure 3 shows that countries with higher levels of product market regulation (PMR) in the early 1990s tended to have lower levels of ICT investment over the 1990s. Consistent with this, Gust and Marquez (2004) estimate an econometric model of productivity growth where labour and product market regulation explain ICT investment which, in turn, explains higher growth in labour productivity.[3]

This 'two-step' approach – from regulation to ICT investment to productivity – ignores the potential *direct* link between reforms in product and labour markets and productivity growth. Ignoring this direct link has two potential shortcomings. The first is that market flexibility (or efficiency) might accelerate TFP growth regardless of whether a country has invested heavily in ICT or not. Nicoletti and Scarpetta (2003, 2005b) and Scarpetta and Tressel (2002, 2004) argue that more flexible labour and product markets are critical for more rapid reorganisation of productive resources, thereby allowing countries to move towards the production frontier with greater speed. We argue that, in addition, the *interaction* of product and labour market flexibility might also be important for TFP growth. Ignoring the possibility that labour and product market regulation directly affect TFP growth also precludes an investigation of this possible interaction.

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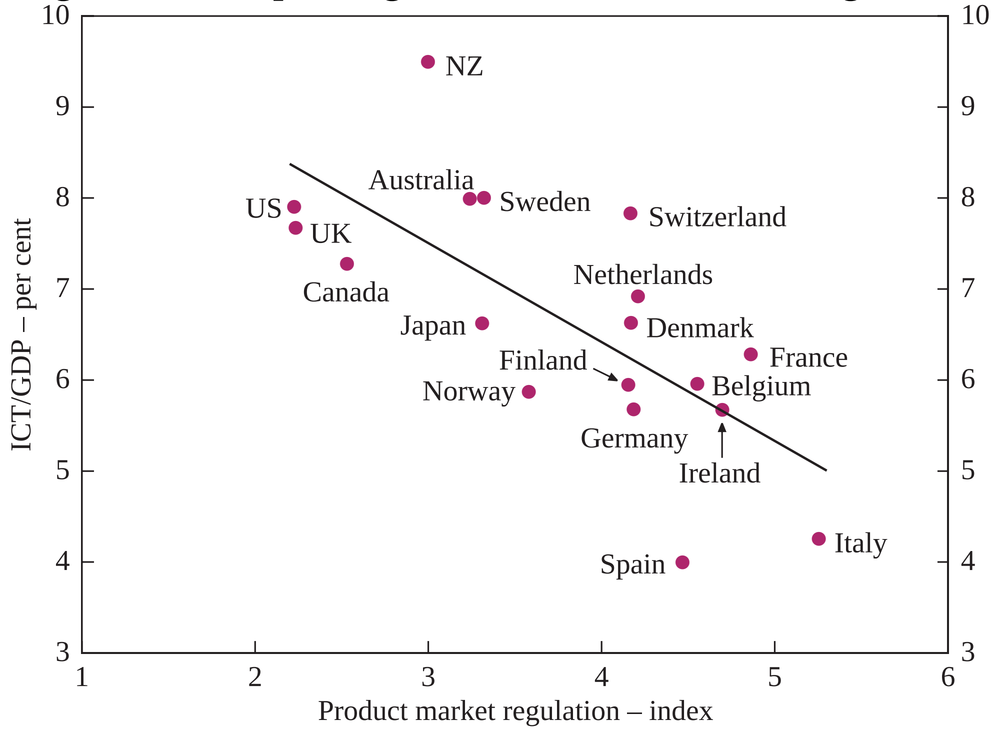
3 Conway *et al* (2006) estimate a related but different set of models which estimate the direct effects of product market regulations on productivity, but omit the effects of labour market regulation. Their first regression explains labour productivity as a function of distance from the technological frontier, product market regulation, and the interaction between these two terms. Their second regression has ICT as the dependent variable and includes various measures of product market regulation as explanatory variables. While the authors feel that the effects of product market regulation would be better identified in a framework where the productivity and ICT models were estimated jointly, they are reluctant to do this without a theoretical model of how ICT affects productivity.

Figure 3: ICT Spending Versus Product Market Regulation



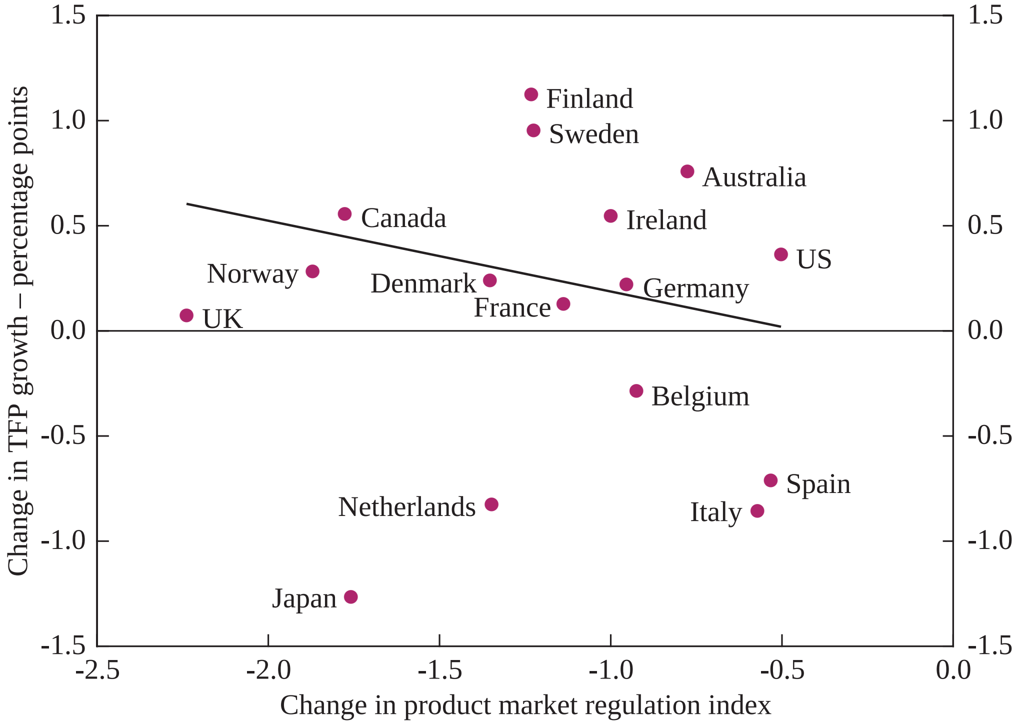
Notes: ICT spending (as a ratio to GDP) is the average for 1992–2000. PMR is an index ranging from 0 (least) to 6 (most) restrictive regulations; data shown are for 1993.

Sources: Conway and Nicoletti (2006); World Information Technology and Services Alliance

A second shortcoming of ignoring possible direct effects of regulation is that changes in TFP growth have been apparent as part of a longer-term trend that pre-dates the 1990s 'tech boom'. As shown in Figure 1, the pattern of rising TFP growth in some countries but falling TFP growth in others has been evident in rolling 10-year averages of annual TFP growth for periods ending around the early 1980s onwards. Evidence in support of a direct link between flexible markets and TFP growth is provided in Figure 4. This shows data for the change in annual average TFP growth versus the change in product market regulation. The trend shown suggests that a single index point reduction in the regulation index is associated with a rise in annual average TFP growth of about 0.3 percentage points.

This paper attempts to address both of the above shortcomings. First, we use data spanning the past 30 years to investigate the direct effects of product and labour market regulation on TFP growth. Second, we specify our regressions so that regulations can affect productivity, both individually and in combination, through

Figure 4: Changes in TFP Growth and Product Market Regulation



Notes: This figure compares the change in PMR from 1983 to 1993 to the change in TFP growth over the 10 years ending in 1993 to the 10 years ending in 2003. The trend shown includes all observations except that for Japan and the Netherlands.

Sources: Conway and Nicoletti (2006); OECD; Thomson Financial; authors' calculations

the interaction of product and labour market reforms. We find tentative support for the hypothesis that lower initial levels of regulation are associated with higher TFP growth over subsequent years, and that labour and product market deregulation have more of an effect in combination, although the significance and magnitude of these effects depends on the measure of labour market regulation used in the regressions. Also, as with any econometric modelling exercise, the presence of a relationship in the past does not guarantee that this same relationship will necessarily continue into the future. In the case of regulation and productivity, the relationship is likely to depend in part on the specific types of labour and product market deregulation pursued. Moreover, the general and relatively imprecise nature of most of those measures of labour market regulation that are both readily available and able to be used to compare developments across countries and over time, makes it difficult to attempt to link our estimates to any specific types of labour market reforms.

Before proceeding, it is important to clarify the kinds of product and labour market regulations that we are dealing with in this paper, and the relationship between these regulations and what we describe as market flexibility or efficiency. We understand a flexible labour market as one in which there are relatively few obstacles to efficiently matching jobs with employees. In the labour market, many types of regulation can affect the rate of job matching and hence labour market flexibility.[4] An efficient product market is one in which price signals encourage movement of resources into profitable opportunities and out of unprofitable ones. In product markets, some regulations (such as those acting as barriers to entry in inherently competitive markets) can restrict competition, while others (such as anti-monopoly laws) are necessary pre-conditions for a competitive system. Our interest is in product market regulations that restrict competition where competition is feasible.

The rest of the paper is structured as follows. Section 2 provides a brief review of the literature, noting the ways in which the paper extends the existing line of research. Section 3 discusses the data and methodological issues and Section 4 presents the results. Section 5 investigates the effects of using alternative measures of labour market regulation and Section 6 concludes.

2. Literature Review

Investigations of the reasons for divergent growth between countries have been around since the *Wealth of Nations*. More recent studies have been motivated by the phenomenon of 'eurosclerosis'.[5] For example, Drèze and Bean (1990) found that the effect of unemployment on wage settlements in Europe is generally weak and that productivity gains were quickly absorbed in higher wages. Blanchard (1997) found that European countries responded to labour shocks in very different ways than Anglo-Saxon countries, and that this difference led to generally higher unemployment in Europe. The common explanation for these

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4 While there are many aspects of the employer/employee relationship that can impede job matching, many things external to this relationship can also impede matching (for example, how likely people are to relocate to fill a vacancy). While there has been a tendency for labour market deregulation to shift bargaining power in favour of employers, there is no *necessary* link between regulation and the relative bargaining power of different agents.

5 For example, Bruno and Sachs (1985), Drèze and Bean (1990) and Blanchard (1997).

different behaviours was differences in labour market institutions. However, while the role of institutions was thought to be qualitatively well understood, these earlier papers did not directly quantify the role of institutions.

More recent papers have directly addressed the influence of institutions on macroeconomic variables including productivity. In particular, papers such as those by Blanchard and Wolfers (1999), Hornstein, Krusell and Violante (2002) and Nicoletti and Scarpetta (2003) have examined whether indices of product or labour market regulation can explain various measures of macroeconomic performance. In general, they find that overly restrictive institutions can have a deleterious effect on some macroeconomic outcomes, including productivity. Blanchard and Wolfers suggest that rigid institutions can entrench the effect of negative shocks. Hornstein *et al* show that differences in labour market institutions affect the changes in unemployment and wage inequality arising from a technology shock. Nicoletti and Scarpetta examine panel data across countries and across industries and show that an index of product market regulation has significant explanatory power for TFP growth. They argue that the ability of firms to innovate, adopt new technologies and reorganise productive processes depends on the extent of restrictive regulations in product markets, and present evidence that countries with fewer regulations move toward the technological frontier more quickly. However, they only make use of variation in the extent and speed of reforms in a limited way (ignoring, for example, significant changes in labour market regulations over time), nor does their industry-level data allow for the possibility that reforms matter for aggregate productivity growth via a reorganisation of productive activities.[6]

This paper adds to the literature exploring the link between productivity growth and labour and product market institutions, exploring similar questions to those posed by Nicoletti and Scarpetta (2003) and Scarpetta and Tressel (2002, 2004), but extending these analyses in two key respects.

First, we use data pre-dating the 'tech boom' to examine the direct effects of product and labour market flexibility on TFP growth, both independently and in

6 For further discussion of this paper and an overview of the theoretical and empirical literature on the relationship between competition and economic growth and productivity, see Aghion and Griffith (2005).

combination. Specifying our regressions this way captures an idea formalised in Nicoletti and Scarpetta's (2005a) analysis of the effect of product and labour market regulation on employment: that the changes in employment arising from deregulation in one market might depend on regulation in another. Applying this concept to productivity, the idea is that while reforms that are limited to (say) product markets may enhance competitive pressures and encourage innovation, without flexible labour markets the ability of firms to restructure may be restricted, and the entry of new firms may be limited. Similarly, labour market reforms may be less potent in the face of only limited product market reforms, which would potentially impede innovation, reorganisation and new entrants.

Second, this paper focuses on aggregate TFP growth. As noted in Conway *et al* (2006), studies that focus on industry-level data may underestimate the effects of regulatory changes on aggregate productivity. This is because they ignore the fact that institutional changes may encourage reallocation of resources across industries in a way that encourages aggregate productivity growth. Conway *et al* (2006) note that the reallocation of resources across industries has to date played a relatively small role in explaining cross-country differences in aggregate productivity growth in the OECD. Even so, using aggregate data also allows us to capture the fact that reforms which help to spur productivity in some industries could have important spill-over effects for all industries by reducing the costs of business inputs, thereby lowering costs for new entrants.[7]

3. Data and Method

This paper uses fixed-effects panel data regressions with growth in TFP as the dependent variable. We examine the effects of product and labour market regulation on TFP growth in 18 OECD countries from 1974 to 2003.[8] Appendix A provides detailed descriptions of our data and its sources while Table 1 summarises the key data.

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7 The OECD's indices of the 'knock-on' effects of regulation in the non-manufacturing sector (Conway and Nicoletti 2006) are designed to capture these effects at a sectoral level.

8 As discussed below, we exclude observations for Japan and the Netherlands in the 1990s from most of the regression analysis.

We run the regression with observations over three 10-year blocks. While the data are annual, estimating the regression over 10-year periods lets us better capture any relationship between TFP growth, which is quite volatile from one year to the next, and changes in the structure of product and labour markets, which are likely to have a delayed and more gradual impact on TFP growth. This is also one way to attempt to control for any influence of the business cycle on measured TFP growth (discussed further below).

The dependent variable in our regressions is growth in TFP in the business sector. We calculate TFP from OECD data converted to US dollars using purchasing power parity exchange rates to increase cross-country comparability. Restricting our analysis to the business sector avoids the problems of measuring output and productivity in the government sector, and using an hours-based measure of labour inputs avoids the well-known problems with time series comparisons of heads-based productivity estimates. An important difference between our measure of TFP and some others is our measure of labour's share of income (LSI): we include an approximation of labour's share of gross mixed income (GMI) in our estimate of LSI.[9]

The general specification we use for our regression analysis is a modified version of that in Griffith, Redding and Van Reenan (2000) and is based on a 'catch-up' theory of TFP growth. This theory suggests that, other things equal, countries further from the technological frontier will experience more rapid TFP growth, given their opportunities to adopt more advanced productive practices of those countries at the frontier. Following Griffith *et al*, we assume that TFP growth is an auto-regressive distributed lag (1,1) process in which the level of TFP in each country is co-integrated with that in the technological leader. This specification allows for the possibility that TFP growth rates may converge in the long run, but that differences in the level of TFP can persist. If we also assume long-run homogeneity, TFP growth in a given country at time t will be a function of TFP

[9] Specifically, we assume that all self-employed are paid average wages. The conceptually correct method for calculating LSI is to sum compensation of employees (CoE), labour's share of GMI and net taxes on labour. Of course, labour's share of GMI is positive, and net taxes on labour are also likely to be positive (and relatively small). Hence the standard technique of approximating the numerator of LSI solely with CoE yields LSI estimates that are biased downwards. As LSI is the weight on labour inputs in calculations of TFP, bias in the level will affect estimates of TFP growth.

Table 1: Summary Statistics *(continued next page)*

	TFP growth[a]			Product market regulation[b]				TFP gap[c]		
	1983	1993	2003	1975	1983	1993	2003	1973	1983	1993
Australia	0.41	1.05	1.80	4.0	4.0	3.2	1.5	–31.9	–30.1	–32.3
Belgium	1.84	1.15	0.85	5.5	5.5	4.6	2.1	–34.2	–17.5	–21.1
Canada	–0.25	0.90	1.45	4.3	4.3	2.5	1.9	–3.1	–7.6	–12.9
Denmark	0.80	0.69	0.92	5.5	5.5	4.2	1.6	–39.5	–33.0	–40.1
Finland	2.05	1.85	2.97	5.5	5.4	4.2	2.4	–63.9	–53.6	–51.4
France	0.73	0.79	0.92	6.0	6.0	4.9	3.0	–4.2	–0.8	–5.9
Germany	1.22	1.04	1.26	5.2	5.1	4.2	1.7	–28.6	–19.5	–23.5
Ireland	3.59	3.91	4.44	5.7	5.7	4.7	3.2	–80.9	–51.1	–25.5
Italy	1.45	1.53	0.67	5.8	5.8	5.3	2.6	–24.8	–17.1	–19.0
Japan	1.11	1.68	0.41	5.1	5.1	3.3	2.2	–38.9	–38.0	–35.4
Netherlands	1.65	1.51	0.67	5.6	5.6	4.2	1.6	–22.2	–9.2	–8.2
NZ	–	–	1.11	4.9	4.5	3.0	2.1	–	–	–36.1
Norway	2.41	2.01	2.28	5.5	5.5	3.6	2.3	–22.0	–6.8	0.0
Spain	1.38	1.12	0.41	5.1	5.0	4.5	2.0	–24.9	–15.1	–16.8
Sweden	0.56	0.97	1.92	4.5	4.5	3.3	1.9	–33.6	–31.9	–37.1
Switzerland	–	–	0.58	4.1	4.2	4.2	2.8	–	–	–42.3
UK	1.54	1.22	1.28	4.8	4.5	2.2	1.0	–26.4	–14.6	–17.2
US	0.28	1.23	1.59	3.7	2.7	2.2	1.4	0.0	0.0	–1.5
Average	**1.30**	**1.41**	**1.42**	**5.0**	**4.9**	**3.8**	**2.1**	**–28.1**	**–21.6**	**–23.7**

Notes: (a) Ten-year average of annual growth ending in the year shown. Average for Finland and Norway begins in 1976.
(b) Averages of indicators of regulatory and market environment for seven energy and service industries, see Conway and Nicoletti (2006); index from 0 (least) to 6 (most) restrictive regulations.
(c) Difference between the log level of TFP in country *i* and that of the technological leader (multiplied by 100). The 1973 figure for Finland and Norway is from 1976.

Table 1: Summary Statistics *(continued)*

	Days lost to labour disputes[(d)]				Employment protection legislation[(e)]			Union density[(f)]		
	1973	1983	1993	2003	1973	1983	1993	1973	1983	1993
Australia	450.8	413.0	137.3	39.0	0.0	0.0	1.1	50.2	47.2	37.5
Belgium	216.9	56.8	27.4	21.0	3.0	3.0	2.6	47.6	51.9	55.0
Canada	570.9	563.4	159.7	151.0	–	0.6	0.6	34.6	36.6	32.8
Denmark	550.4	114.4	31.6	37.7	0.0	0.0	1.9	62.2	80.8	77.3
Finland	888.8	223.7	78.9	28.5	–	2.2	2.2	61.4	68.8	78.8
France	189.7	87.5	37.6	73.8	2.7	2.7	2.9	22.1	16.0	10.1
Germany	67.4	1.5	16.6	4.3	3.6	3.6	3.2	32.4	35.0	31.8
Ireland	213.4	341.0	94.7	32.8	0.8	1.0	1.0	53.3	57.2	50.0
Italy	1 001.9	699.3	146.5	121.0	0.0	4.2	3.8	43.3	45.5	39.2
Japan	101.9	9.4	2.3	0.3	2.6	2.6	2.6	33.5	29.8	24.3
Netherlands	45.9	20.2	11.0	21.5	3.1	3.1	2.8	36.2	31.3	25.9
NZ	140.5	236.4	51.7	21.8	0.0	1.0	1.0	56.3	64.5	34.5
Norway	6.6	54.1	66.8	22.2	1.6	3.1	3.0	53.2	58.1	58.0
Spain	67.0	359.2	338.5	157.4	0.0	3.7	3.5	–	8.9	18.0
Sweden	74.4	19.6	19.8	50.4	0.0	3.4	2.9	72.5	79.6	83.9
Switzerland	1.0	0.5	0.1	3.8	1.3	1.3	1.3	27.8	29.6	22.9
UK	609.2	186.3	25.2	28.0	0.4	0.5	0.5	45.5	48.0	36.1
US	419.3	144.2	35.2	14.3	0.0	0.0	0.2	26.3	21.7	16.9
Average	**312.0**	**196.1**	**71.2**	**46.0**	**1.2**	**2.0**	**2.1**	**44.7**	**45.0**	**40.7**

Notes: (d) Number of working days lost due to industrial disputes per 1 000 employees, three-year-ended average.
(e) Interpolated index of employment protection legislation (EPL) from Nicoletti *et al* (2001) backcast following Blanchard and Wolfers (1999); index from 0 (least) to 6 (most) restrictive regulations.
(f) Proportion of employees who are members of a trade union expressed as a percentage. The 1973 figure for Australia is from 1976.

Source: See Appendix A

growth in the technological leader and the technological ‘gap’ for each country, which is the difference between the logged levels of TFP in country *i* and the technological leader (see Equation (1) below).

To test the effects of regulation on TFP growth we add measures of product and labour market regulation on their own, in combination, and (following Nicoletti and Scarpetta 2003) in combination with the technology gap.[10] The products of regulatory terms with the technology gap allow for the possibility that the effects of labour and product market regulations on productivity may depend on a country’s distance from the productive frontier.

Our measure of product market regulation is an OECD index, which provides an internationally comparable measure of the degree to which government policies inhibit competition. This index is based on a number of sub-indices covering regulations related to barriers to entry (including legal and administrative barriers to entrepreneurship), public ownership, market structure, vertical integration and price controls in seven non-manufacturing industries (for more details see Appendix A and Conway and Nicoletti 2006). The index ranges from most restrictive (6) to least restrictive (0), and is an annual time series available from 1975–2003. We can think of this index as a ‘direct’ measure of a country’s economic structure, in the sense that it is directly related to a country’s economic regime, rather than being a consequence of that structure.

Like most proxies, direct measures of product market competition such as these have both advantages and disadvantages. A significant advantage of direct measures of the regulatory structure is that (provided regulators do not deregulate opportunistically) they are more exogenous to the macroeconomic variables under investigation than traditional proxies such as firms’ mark-ups. Two potential disadvantages are that proxies based on statutes cannot adjust for the way that the statutes are enforced in practice, and that the regulations might be a poor proxy for competition because, even if enforced, they do not actually affect competition. The

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[10] Griffith *et al* (2000) use an endogenous growth framework to derive a model of productivity growth incorporating R&D. Scarpetta and Tressel (2002) and Nicoletti and Scarpetta (2003) adapt this specification, replacing R&D in the original equation with PMR. While Griffith and Harrison (2004) criticise this replacement as being *ad hoc*, Scarpetta and Tressel and Nicoletti and Scarpetta do suggest mechanisms through which product market competition can affect the adoption of new technologies.

OECD indices attempt to adjust for enforcement by including some data on actual market structures. Also, the few direct tests of the OECD indices conducted to date suggest that they are correlated with traditional indicators of competition such as firm entry rates and sectoral mark-ups (Conway and Nicoletti 2006).

Our preferred measure of labour market regulation (LMR) is a proxy based on the number of days lost in labour disputes, but we test the sensitivity of our results to alternative measures in Section 5. While the annual data are quite volatile, a three-year moving average shows a trend decline across most countries, and this trend appears to be consistent with the variation in the extent of labour market reforms across countries.[11] Because the approach to industrial relations reform has been quite different across countries, an outcome-based measure such as this may be better than a direct measure. For example, Wooden and Sloan (1998) show that while Australia and the UK adopted different approaches to labour market reform, they have resulted in very similar labour market outcomes.

Both the PMR and LMR variables enter our regressions in levels rather than changes. With this specification, the literal interpretation of a significant negative relationship between a regulatory variable and TFP growth is that deregulating the relevant market causes a *permanent* increase in the growth rate of TFP. Although we do find such significant econometric relationships, we would caution against this literal interpretation. This is because it may be difficult to distinguish between lower levels of regulation leading to higher *levels* or higher *growth rates* of TFP over our sample period.

To avoid attributing changes in the quality of labour to changes in TFP growth, we include two controls for changes in labour quality in our regressions. The first is average years of schooling, a proxy for human capital. Clearly this is imperfect as it measures a process (education) rather than an outcome (human capital formation) and does not capture post-school human capital formation. However,

[11] It is possible that there is a mechanical relationship between the days lost to labour disputes in one year and TFP growth in the next. Whether or not such a relationship exists depends on: (i) how the labour input of striking employees is measured in each country in our sample; and (if measured hours worked *do* fall as a result of industrial action) (ii) the extent to which this decrease in labour inputs results in a fall in output, TFP, or some combination of the two. Even if such a mechanical relationship does exist, its effect will be negligible as our dependent variable is average TFP growth over 10- or 5-year periods.

Bassanini, Scarpetta and Hemmings (2001) note that the specific series used in their paper represents an improvement upon those generally used in the literature.[12]

The second control is an employment-to-population ratio. This should capture variation in the quality of labour inputs arising from the employment of more or less productive employees over time. Various versions of this measure have been found to be significant in related studies.[13] The choice of both the denominator and numerator are potentially important here. The choice of the denominator (total population, population aged 15 and older or population aged 15–64) affects the extent to which changes in an employment-to-population ratio reflect changes in the age structure of the population (which are not necessarily related to labour productivity). We choose the denominator (population aged 15–64) that is likely to be least susceptible to demographic changes, given our sample period. For the numerator we choose business sector rather than total employment, although there are potential problems with either measure. Total employment would fall if public sector employment fell with unchanged business sector employment, which we would expect to have only a tenuous relationship with the marginal productivity of employees in the business sector, our sector of interest. Conversely, we might expect the marginal productivity of new entrants into private sector employment to differ depending on whether they came from outside the labour force, unemployment, or the public sector, but our measure will only register an increase in the employment rate regardless of the origin of the entrants.

Measured TFP growth may be influenced by the state of the business cycle, and business cycles are not perfectly synchronised across countries. It follows that international comparisons of productivity growth may be distorted unless one controls for the business cycle in each country. This can be done by including an indicator of the cycle as an independent variable. Alternatively, the dependent variable could be smoothed to remove its cyclical component. Skoczylas and

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[12] For an examination of the importance of human capital in closing Australia's labour productivity gap with the US, see Dolman, Parham and Zheng (2007).

[13] For example, Belorgey, Lecat and Maury (2004) find a negative association between labour productivity and the change in the employment rate, where the denominator of the latter is the total population. Gust and Marquez (2004) find a negative association between business sector labour productivity growth and the change in the ratio of total employment to the population aged 15 and older.

Tissot's (2005) analysis of cross-country labour and multifactor productivity compares these methods. While they favour the former, the authors note that for most countries in their sample the results of each method are broadly similar. We make use of both approaches in this paper. When using data over 5- or 10-year blocks, much of the effect of the cycle is controlled for indirectly. We also include an output gap as an indicator of the cycle in our regressions. Our gap is the difference between the natural logarithms of actual and trend business sector output, where trend is constructed with an HP filter. The standard endpoint problem is partially mitigated by including three years of OECD forecasts for business sector output when smoothing these series.[14]

In summary, we estimate regressions based on the following general formulation:

$$\begin{aligned}\Delta tfp_{it} = {} & \beta_1 PMR_{it-1} + \beta_2 LMR_{it-1} + \beta_3 PMR_{it-1} * LMR_{it-1} + \beta_4 \Delta tfp_{Lt} \\ & + \beta_5 tfpgap_{it-1} + \beta_6 tfpgap_{it-1} * PMR_{it-1} + \beta_7 tfpgap_{it-1} * LMR_{it-1} \\ & + \beta_8 tfpgap_{it-1} * PMR_{it-1} * LMR_{it-1} + \beta_9 hk_{it-1} + \beta_{10} epop_{it-1} \\ & + \beta_{11} outputgap_{it} + T + \alpha_i + \varepsilon_{it}\end{aligned} \tag{1}$$

where: Δtfp_{it} and Δtfp_{Lt} are average annual growth in TFP for country *i* and the leading country *L* over the time period, *t*, in question; PMR_{it-1} is the lagged level of the product market regulations index; LMR_{it-1} is the lagged level of working days lost to labour disputes (smoothed by taking averages over three-year periods); $tfpgap_{it-1}$ is the level of the gap between TFP in country *i* and the leading country; hk_{it-1} is the lagged level of average years of schooling; $epop_{it-1}$ is the lagged level of the ratio of employment to the working-age population; $outputgap_{it}$ is the average annual value of the output gap over the period *t*; and *T* is a time trend. The time periods are the three 10-year blocks ending in 1983, 1993 and 2003. The regulation variables, TFP gap, human capital and employment-to-population ratio are all measured on a period-ended basis, that is, the year just prior to the start of the 10-year block *t*; the exception to this is for the first 10-year period for which the PMR index is only available for 1975.

[14] We also estimated regressions below using output gaps from the OECD's *Economic Outlook* No 78 database. Their results were very similar.

4. Results

The first point to note is that regressions based on the full sample (results not reported) show that residuals for Japan and the Netherlands in the 10-year period ending in 2003 stand out as being particularly large.[15] This is because these countries experienced sizeable declines in PMR from 1983 to 1993, but also experienced among the largest declines in average TFP growth from the 10 years ending in 1993 to the 10 years ending in 2003. In what follows we exclude observations for the Japan and the Netherlands in the 1990s. The exclusion of outlying observations is fairly common in the literature, in part reflecting problems with errors in variables and omitted variables that may be especially relevant to some observations (see, for example, Nicoletti and Scarpetta 2003). For Japan, the after-effects of the financial bubble are likely to have played an important role. For the Netherlands, wage moderation enabled a very large rise in participation through the 1990s (without a commensurate increase in labour market flexibility), which was associated with a sharp decline in labour and total factor productivity (for a discussion of the Dutch case, see Naastepad and Kleinknecht 2002 and Bell 2004).

The key results of estimating a number of variants of Equation (1) using OLS appear in Table 2. Model 1 is a basic regression with only the PMR and LMR measures (and their interactive term) included. The coefficients on the LMR and interactive terms are significant by themselves. The coefficient on PMR is not – its p-value is 0.108, but excluding it from the model leads to a drop in the fit of the model of around 20 per cent. The PMR variable is significant in the absence of the LMR and interactive terms (results not shown), and its coefficient is of a similar order of magnitude as per Model 1.

Because of the interactive term, the interpretation of the marginal contributions of reforms in labour and product markets depends on the level of the other regulatory variable. This can be seen in Figure 5, where changes in the vertical height of the surface show the estimated changes in TFP growth for given changes in LMR and PMR. From the initial to the most recent observations of PMR and LMR included in our panel, most countries moved from points near the front and left of the

[15] The residual for Canada in the 1970s is also large, but exclusion of this observation makes no substantial difference to the following results.

surface, to points towards the right and rear of the surface. Within much of the region of reforms actually observed, the shape of the surface shows that deregulation in labour and product markets had large effects when undertaken in combination.[16]

Table 2: Panel Regression Results for Growth in TFP – Equation (1)

Fixed-effects estimation, three 10-year blocks ending in 1983, 1993 and 2003

Variables	Lag	Model 1	Model 2	Model 3	Model 4[(a)]
PMR	*t*-1	–0.22	0.12		–0.23**
LMR	*t*-1	–0.009***	–0.016***	–0.010***	–0.008***
PMR*LMR	*t*-1	0.0016***	0.0030***	0.0019***	0.0016***
Human capital	*t*-1		0.068		
Employment/population	*t*-1		–0.070		
TFP growth leader	*t*		0.042		
TFP gap	*t*-1		–0.087**	–0.085***	
TFP gap*PMR	*t*-1		0.015*	0.015***	
TFP gap*LMR	*t*-1		–0.0003		
TFP gap*PMR*LMR	*t*-1		$6.4\text{x}10^{-5}$		
Output gap	*t*				–0.21***
Number of observations		48	48	48	82
R^2 within[(b)]		0.34	0.57	0.49	0.30
p-value for rejecting F-test of overall significance		0.025	0.000	0.000	0.000

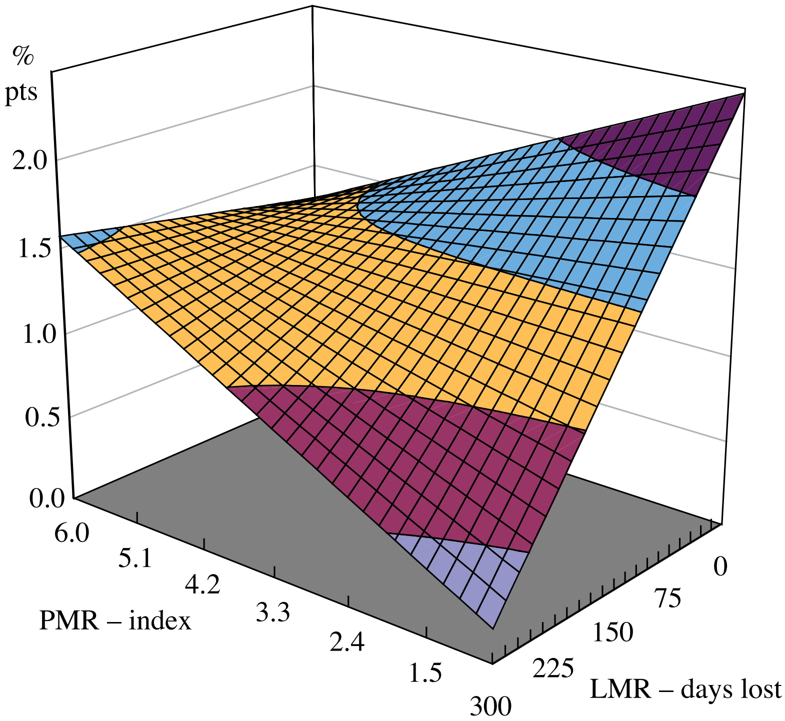
Notes: ***, ** and * indicate that coefficients are significant at the 1, 5 and 10 per cent significance levels, respectively, using robust standard errors. All models exclude observations from 1994 to 2003 for Japan and the Netherlands. PMR – index from 0 (least) to 6 (most) restrictive. LMR – days lost to labour disputes per 1 000 employees.

(a) Based on five 5-year blocks, ending in 1983, 1988, 1993, 1998 and 2003.

(b) The R^2 within does not take account of the explanatory power from the constant.

16 The estimated marginal effect of labour market deregulation on TFP growth is positive for values of PMR below 5.4. Between 1975 and 1993, average PMR fell from 5.0 to 3.8, so the estimated marginal contribution of changes in LMR has been positive for most countries over the sample period. The estimated marginal effect of product market deregulation is positive for values of LMR below 138 days lost per 1 000 employees. Over 1973–1993, average working days lost fell from 312 to 71, so that the marginal effect of product market deregulation is estimated to have become positive for most countries during the sample period.

Figure 5: Estimated Contribution to TFP Growth – Model 1



Notes: This figure shows the percentage point contributions of changes in regulatory variables to TFP growth. Only the *change* in the level of TFP growth is meaningful in this case.

Source: authors' calculations

Model 2 is the more comprehensive specification, with human capital, the employment-to-population ratio, the TFP gap and related interactive terms with the regulatory variables all included.[17] The TFP gap by itself is significant and enters with a negative coefficient. As all TFP gaps are negative or zero, this implies that the further a country is behind the lead country, the faster will be its average TFP growth over the next decade. While PMR is not significant on its own, its interactions with both LMR and the TFP gap variables are both significant. The coefficient on the interactive term between PMR and TFP gaps is positive, implying that the technology gap tends to have closed more quickly when product market regulations were less restrictive. Because of the interactive terms, the

[17] Although the time series was too short for inclusion in the 10-year regression, we estimated the regression based on 5-year blocks (see below) with an indicator of R&D expenditure, which was insignificant (results not shown). Econometric research into the effects of R&D expenditure on TFP growth (for example, Scarpetta and Tressel 2004) suggests that the effects depend on the type of technology in a given industry and hence may be difficult to detect in an aggregate analysis.

interpretation of the marginal contributions of reforms in labour and product markets depends on the level of the other regulatory variable, and the level of the technology gap. To interpret these interactions, we remove the insignificant variables from Model 2 to obtain the parsimonious Model 3.

The estimated contribution to TFP growth of changes in the regulatory environment can be illustrated with a surface similar to that of Figure 5 for each of three different TFP gaps: large; intermediate; and small. These surfaces are shown in Figure 6, where changes in the height of the surfaces show the estimated changes in TFP growth for given changes in LMR and PMR, conditional on the TFP gap.

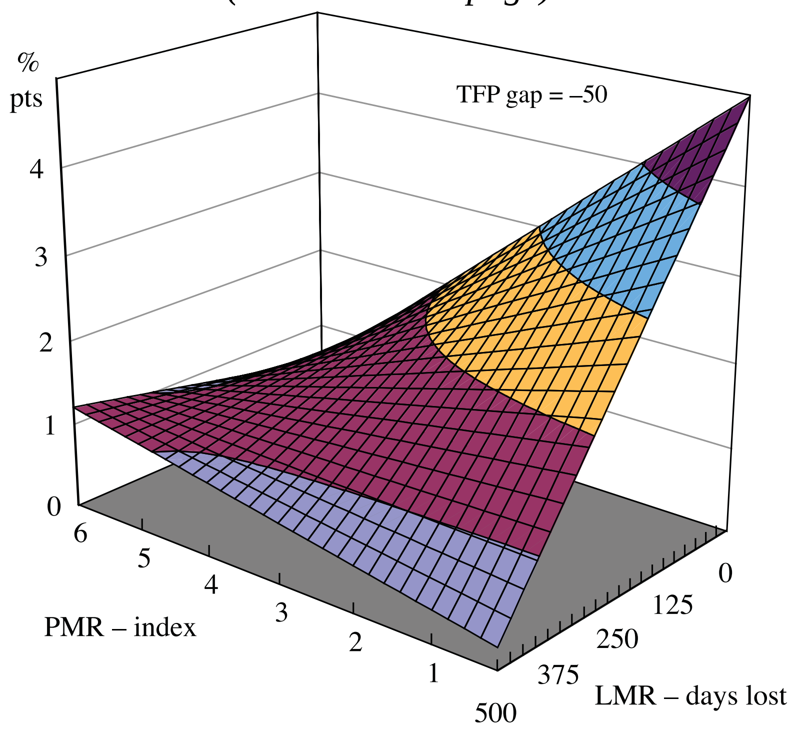
For all three TFP gaps, the contribution of labour market deregulation is positive so long as the product market is not too heavily regulated (a PMR index of less than about 5.3), and the contribution is larger at lower levels of product market regulation. The contribution of product market deregulation depends on the levels of both LMR and the technology gap. For each gap, the estimated marginal contribution of product market deregulation is negative for higher levels of labour market regulation; the level of LMR needed to make a marginal change in PMR positive falls as the technology gap closes. For moderate to low levels of labour market regulation, product market reforms are estimated to make a positive contribution to TFP growth. This contribution is larger the lower is labour market regulation, and the larger is the TFP gap.

Model 1 is fairly robust to the inclusion of an output gap or the exclusion of each individual country from the sample, although the coefficient on PMR is not as stable as the others. While the coefficients on LMR and the interactive term are quite robust, adding a time trend or time dummies roughly halves the coefficient on PMR. The same tests[18] for Model 2 reveal that the coefficients on PMR, human capital and TFP growth in the leading country are generally rather unstable. This is probably driven in part by the high correlation between some of the variables in the

[18] With the exception of adding time dummies or trends. Because the average TFP growth of the leader is constant across countries, it can be expressed as a function of the time dummies, giving a near-perfect dependence between a subset of the explanatory variables. Also, the correlation between the time trend and average TFP growth of the leader is extremely high, so including a time trend risks generating spurious results and introducing yet more collinearity into Model 2.

Figure 6: Estimated Contribution to TFP Growth – Model 3

(continued next page)



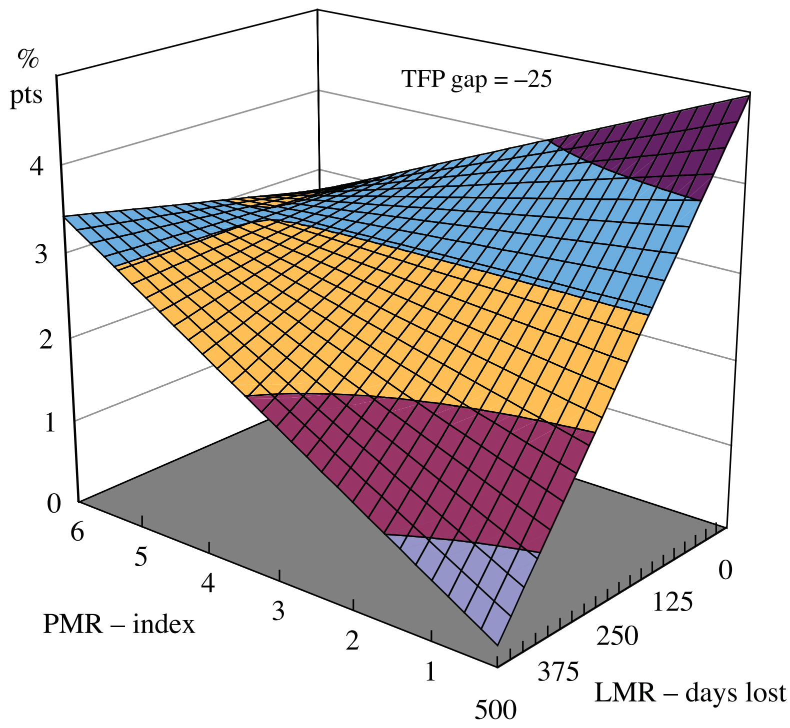
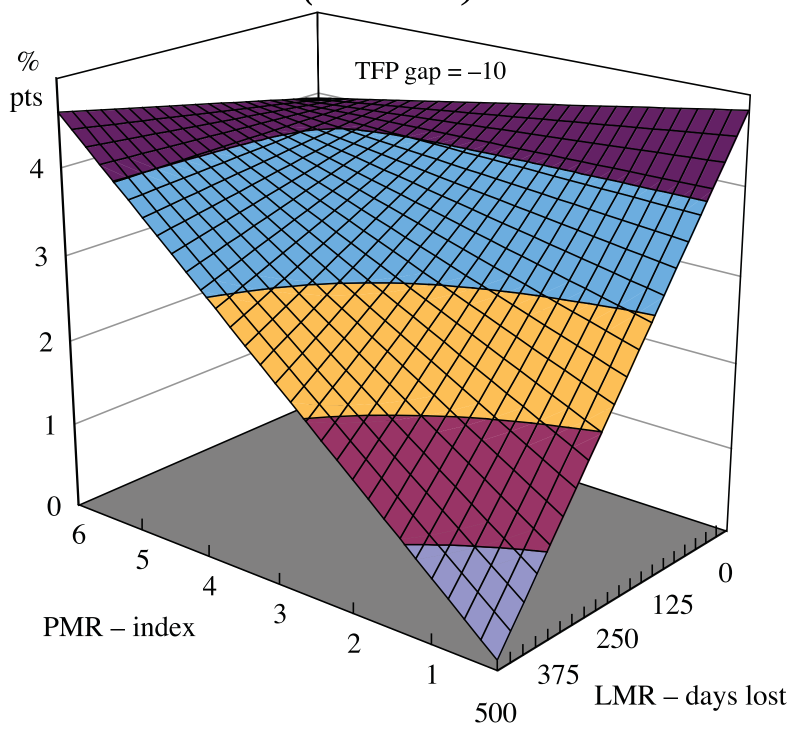


Figure 6: Estimated Contribution to TFP Growth – Model 3
(continued)



Notes: These figures show the percentage point contributions of changes in regulatory variables to TFP growth. Only the *change* in the level of TFP growth is meaningful in this case.

Source: authors' calculations

model (in particular between PMR and human capital) which makes their coefficient estimates sensitive to small changes in the sample. The parsimonious Model 3 is robust to the inclusion of an output gap, the inclusion of time trends or time dummies, and to the exclusion of individual countries from the sample. The coefficient on the output gap was not itself significant in any of the models.

Our specification of Equation (1) suggests two further robustness checks. Strictly speaking, when Equation (1) includes the technology gap terms it is only relevant for countries that are not the technological leader. We therefore follow Griffith *et al* (2000) and re-estimate Models 2 and 3 excluding Norway and the US (results not shown). Model 3 is completely robust to their exclusion and Model 2 is generally robust. If our sample were larger, we would include one further check: re-estimating Models 2 and 3 with instrumental variables (IV) to confirm that any downward bias arising from the inclusion of the technology gap in the fixed-effects specification is small as theory suggests. Unfortunately, given the instruments available to us, IV reduces our sample size so much as to make estimation unreliable.[19]

We also examined results based on using data in 5-year blocks (Model 4 in Table 2). This has the advantage of more degrees of freedom by greater use of the time dimension, but at the expense of a potential increase in measurement error. To account for the impact of the business cycle on measured TFP growth we included the output gap in regressions. The main difference between these and the 10-year block regressions is that the TFP gap and its interactive terms were no longer significant. The results for the parsimonious Model 4 is very much like that of Model 1 (based on 10-year blocks), though with PMR now significant in its own right. This was not the case in the presence of time trends or time dummies, though the time trend was not significant in the presence of the PMR variable and the inclusion of the trend added only marginally to the explanatory power of the model.

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[19] Nickell (1981) showed that a fixed-effects model with a lagged dependent variable generates estimates that are biased downwards when the number of time periods (T) is small. Judson and Owen (1999) showed that, for the kinds of panels commonly found in macroeconomics (relatively more time periods and fewer cross-sections than in the typical microeconomic panel), the size of this bias can be between 3 and 20 per cent of the true size of the coefficient even when T is as big as 30. While it would still be desirable to check that the bias is small in our case, Equation (1) is a non-standard example of this type of bias problem because, rather than being a lagged dependent variable, the technology gap that appears on the RHS of Equation (1) is related to the lagged dependent variable by construction. This means that it is not feasible to use existing methods such as bias correction (Bruno 2005) or the generalised method of moments to generate unbiased estimates for Equation (1). Hence IV is the only technique open to us, but, given the available instruments, it reduces our sample size so much as to make estimation unreliable. Fortunately it is likely that the differences between our model and a standard lagged dependent variable fixed-effect model make any potential bias even smaller. For example, like Scarpetta and Tressel (2004) and Griffith *et al* (2000), we use different indices of TFP on the LHS and RHS of Equation (1); the index on the RHS is a superlative index that permits comparison of the levels of TFP across countries. Although the underlying data are the same, the indices are constructed differently so any correlations and bias would probably be smaller than would be the case in a more standard regression with a lagged dependent variable, other things equal.

5. Alternative Measures of Labour Market Regulation

This section discusses some alternative measures of labour market regulations and presents regression results where these are used in place of the working days lost (WDL) measure. A measure of labour market regulations is included to capture the degree of flexibility of a country's labour market at a given point in time, where we understand a 'flexible' labour market as one in which employees can be matched with jobs in an efficient manner. The rationale for using working days lost per 1 000 employees as a measure of labour market regulation is that there is likely to be an indirect, though perhaps imprecise, link between this variable and labour market flexibility.

There are several alternative measures, but each has its own problems. One alternative is union density, which measures the proportion of employees who are union members (Table 1). Again, while there may be an indirect relationship between union density and the rate of job matching, the linkages may be somewhat tenuous. This is partly because, regardless of the proportion of employees who are union members, it is the structure of wage bargaining prevailing in a given country that determines the proportion of employees actually covered by union-negotiated wage bargains (this proportion is called 'union coverage'). Furthermore, because the gap between union density and union coverage differs across countries, union density is not a good proxy for coverage.[20]

Both WDL and union density measure an outcome of the regulatory structure of the labour market rather than measuring that regulatory structure directly. While outcomes-based measures might reflect a broader range of structural features affecting the labour market than more direct measures do, measuring outcomes can lead to problems of endogeneity. Of course we have tried to address these, at least in part, by an appropriate lag structure in the regression analysis.

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[20] For example, in France in 1990, about 10 per cent of employees were union members but union coverage was around 90 per cent. The figures for the US were 16 and 18 per cent, respectively (Nickell and Nunziata 2000). While data for union coverage are too sparse to be useful, the summary indicator of wage bargaining presented in Elmeskov, Martin and Scarpetta (1998) does measure a related concept for some countries over most of the 1980s and 1990s.

In contrast to these outcomes-based measures, the summary indicator of employment protection legislation (EPL) produced by the OECD measures one aspect of labour market regulation – the procedural and monetary costs associated with legislation governing dismissals. This index is comparable across countries and time,[21] with a higher number indicating stricter legislation. To date, the indices are only available for three time periods: the late 1980s, the late 1990s and 2003. We therefore follow Blanchard and Wolfers' (1999) method of backcasting and interpolating an EPL to create a long time series for this indicator (see Appendix A for further details).

The theory that stricter EPL makes employment adjustment more costly for firms (and hence impedes matching) is fairly robust across the literature.[22] However, as a proxy for labour market regulation more generally, EPL suffers from the fact that it may not be the most significant determinant of flexibility, so that changes in EPL strictness might not reflect changes in the overall degree of flexibility. For example, employment protection can be strengthened as other key features of the labour market – such as the structure of wage bargaining – are made more flexible. If the increased flexibility arising from the other changes more than offsets the fall in flexibility from increased EPL, using EPL as a proxy for labour market flexibility would mistakenly suggest flexibility had decreased.[23] From an empirical perspective, there is less within-country variation in this EPL than in WDL (the average within-country coefficients of variation are 0.53 and 0.87 respectively), although this is only problematic if variation in the EPL understates the 'true' variation in the flexibility of the labour market.

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[21] The statistical techniques used to combine the raw data also yield cardinal indices. See Annex 2.A1 in OECD (2004) for a detailed description of the construction method.

[22] The existence and magnitude of these effects in practice has been a far more contentious issue. See OECD (2004) for a recent cross-country analysis of the effects of EPL on labour market outcomes.

[23] Indeed, for Australia, the EPL measure we use suggests that the labour market was more regulated in recent years compared with the 1980s, despite the significant reform over this period (see Dawkins 2000 for a discussion of these labour market reforms).

The results of re-estimating Models 1 and 2 with union density and EPL appear in Table 3.[24] When Model 1 is re-estimated using EPL as the LMR variable, the model is not significant overall and the p-value on EPL is very high (0.984). The model is generally robust to excluding individual countries, with the exception of the UK and the US. When EPL is replaced with union density (UD), the coefficient on UD is not significant; the model itself is also not significant overall, while the coefficient on PMR is not particularly robust to the exclusion of individual countries from the sample. The fit of the EPL and UD models is poorer than that based on WDL (as indicated by much lower R^2 values).

Model 2 with EPL is significant overall (at the 10 per cent level) but few coefficients are significant by themselves. The effects of product and labour market regulation on TFP are evident in the parsimonious specifications (Model 3) based on these alternative labour market variables. However, Model 3 based on EPL suggests that the net effect of a one unit decrease in EPL on TFP growth is positive only for countries that are closer to the technological frontier (that is, once TFP gaps are smaller than about –24). Model 3 based on UD implies that, for a country with an intermediate technology gap, a simultaneous move from a PMR of 5 and UD of 50 per cent to a PMR of 3 and UD of 20 per cent is associated with a rise in TFP growth of 1.2 percentage points, other things equal.

Overall, these results suggest that conclusions about the effects of product and labour market regulation on TFP growth are somewhat sensitive to the measure of labour market regulation included in the regression analysis.

[24] We do not show results based on a fourth measure of LMR, the Economic Freedom of the World (EFW) Index of overall labour market regulation. While some of the individual components of this index may be useful, the composition of the index changes over time and yet the overall index for any year seems to be merely a simple average of that year's components. This means that within-country variation can reflect the addition of new components rather than a change in flexibility.

Table 3: Panel Regression Results for Growth in TFP – Equation (1)
Alternative Measures of Labour Market Regulation
Fixed-effects estimation, three 10-year blocks ending in 1983, 1993 and 2003

Variables	**Lag**	**Model**					
		1 EPL	1 UD	2 EPL	2 UD	3 EPL	3 UD
PMR	*t*-1	–0.21	–0.10	–0.62	–0.52		
LMR	*t*-1	0.011	0.006	–1.56	–0.060	–0.37***	
PMR*LMR	*t*-1	–0.006	–0.004	0.25	0.016		
Human capital	*t*-1			–0.36	–0.18		
Employment/ population	*t*-1			0.0011	–0.024		–0.026*
TFP growth leader	*t*			0.25	0.38		
TFP gap	*t*-1			0.14	0.037		–0.081***
TFP gap*PMR	*t*-1			–0.023	–0.031	0.0042***	
TFP gap*LMR	*t*-1			–0.087*	–0.002	–0.015***	
TFP gap*PMR*LMR	*t*-1			0.015	0.0009*		0.00025***
Number of observations		46	47	46	47	46	47
R^2 within[(a)]		0.13	0.19	0.39	0.44	0.23	0.35
p-value for rejecting F-test of overall significance		0.34	0.16	0.069	0.12	0.014	0.005

Notes: ***, ** and * indicate that coefficients are significant at the 1, 5 and 10 per cent significance levels, respectively, using robust standard errors. All models exclude observations from 1994 to 2003 for Japan and the Netherlands. PMR is an index from 0 (least) to 6 (most) restrictive. LMR is either EPL (which is an index from 0 (least) to 6 (most) restrictive) or UD (which is the percentage of employees who are union members).
(a) The R^2 within does not take account of the explanatory power from the constant.

6. Conclusion

This paper has extended the existing literature on institutions and productivity in a number of ways. Using data covering 18 OECD countries over the period 1974–2003, we explore the effects of product and labour market regulations on aggregate TFP growth for the business sector. We find some evidence that lower levels of regulation are associated with higher TFP growth over subsequent years. There is also some evidence that labour and product market deregulation have more of an effect in combination. That is, greater flexibility (or efficiency) in one dimension appears to be more beneficial when the other market is also relatively flexible (efficient). It also appears that product market deregulation has a larger positive effect on productivity growth the further a country is from the production (or technological) frontier. However, these results are sensitive to changing the measure of labour market regulation used in our analysis. Furthermore, as with any econometric modelling exercise, the presence of a relationship in the past does not guarantee that this same relationship will necessarily continue into the future. In the case of regulation and productivity, the relationship is likely to depend in part on the specific *type* of labour and product market deregulation pursued.

Appendix A: Data Description and Sources

TFP growth and technology gap: Construction of these variables mainly follows Griffith *et al* (2000). TFP growth in the business sector in country i at time t is given by the superlative index[25]

$$\Delta tfp_{it} = \ln\left(\frac{Y_{it}}{Y_{it-1}}\right) - \frac{1}{2}(\alpha_{it} + \alpha_{it-1})\ln\left(\frac{L_{it}}{L_{it-1}}\right) - \left(1 - \frac{1}{2}(\alpha_{it} + \alpha_{it-1})\right)\ln\left(\frac{K_{it}}{K_{it-1}}\right) \qquad \text{(A1)}$$

where: Y_{it} is real business sector output; L_{it} is aggregate hours worked, which is the product of business sector employment and average hours per employee; and K_{it} is the real business sector capital stock. Both Y_{it} and K_{it} are rebased where necessary to a common year and then converted to US dollars using purchasing power parity (PPP) exchange rates. The rebasing uses implicit price deflators for aggregate output and private non-residential investment from the OECD *Economic Outlook* No 78 database. Rebased output is converted to US dollars using the 2000 PPPs over GDP from the OECD. The rebased capital stocks are converted to US dollars using 2000 PPPs over investment constructed by multiplying price indices for investment expenditure from Penn World Tables 6.1 by exchange rates from the OECD. The labour share of income is estimated by adding an approximation of labour's share of gross mixed income to compensation of employees:

$$\alpha_{it} = \frac{[CoE_{it} + SE_{it}(CoE_{it}/(E_{it} - SE_{it}))]}{GDP_{it}} \qquad \text{(A2)}$$

where: α_{it} is labour's share of income in country i at time t; CoE_{it} is compensation of employees; SE_{it} is the number of self-employed people; E_{it} is total employment and GDP_{it} is aggregate nominal GDP. We approximate average compensation of employees with $CoE_{it}/(E_{it} - SE_{it})$ because the numbers of wage and salary earners are not available for all countries over a long enough time period. All the data are annual and are sourced from the OECD *Economic Outlook* No 78 database. Exceptions are estimates of New Zealand business sector employment, which are quarterly data from the OECD *Economic Outlook* No 77 database, and components of labour's share of income, which are annual OECD data sourced from Thomson Financial.

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[25] This type of index is desirable because it can be derived directly from a flexible functional form. See OECD (2001) for more details.

The technology gap is calculated as

$$tfpgap_{it} = 100\,[\ln(TFP_{it}) - \ln(TFP_{Lt})] \quad \text{(A3)}$$

where $tfpgap_{it}$ is the technology gap for country i at time t, and TFP_{it} and TFP_{Lt} are the levels of TFP in country i and the technological leader at time t. The level of TFP is given by the index

$$TFP_{it} = \frac{Y_{it}}{\overline{Y}_t}\left(\frac{\overline{L}_t}{L_{it}}\right)^{\sigma_{it}}\left(\frac{\overline{K}_t}{K_{it}}\right)^{1-\sigma_{it}} \quad \text{(A4)}$$

where the output and capital stock have been converted to a common currency as described above. Variables with a bar are geometric means for all countries at time t, and σ_{it} is given by

$$\sigma_{it} = \frac{1}{2}(\alpha_{it} + \overline{\alpha}_t) \quad \text{(A4)}$$

where α_{it} is the LSI for country i at time t. The levels of TFP constructed with this index are comparable across countries, so the TFP leader can be identified and TFP growth in the leader (the variable Δtfp_{Lt} in Equation (1)) calculated using Equation (A1).

Product market regulations: Originally from Nicoletti *et al* (2001); we use the updated version presented in Conway and Nicoletti (2006). Countries are classified on a 0–6 scale from least to most restrictive for each regulatory and market feature of the seven non-manufacturing industries: airlines, railways, road, gas, electricity, post and telecommunications. Depending on the industry, the features covered are: barriers to entry, public ownership, market structure, vertical integration and price controls. Aggregate indicators for each country are simple averages of indicators for the seven industries and the time series run from 1975–2003. These data are different from the commonly cited economy-wide indicators, which are only available for 1998 and 2003 (Nicoletti, Scarpetta and Boylaud 2000; Conway, Janod and Nicoletti 2005). As the time series index is highly correlated with the economy-wide measure of product market regulation for the years where the two overlap, it is arguably a useful time-series proxy for the stance of economy-wide regulation (Conway and Nicoletti 2006).

Working days lost to labour disputes per thousand employed: Constructed from the number of working days lost (from the International Labour Organization) and the level of employment. The exceptions are: Australia – OECD *Main Economic Indicators* (MEI); Belgium – Eurostat; Canada – MEI; France – Eurostat; Germany – data from 1993 onwards from Eurostat; Netherlands – Eurostat; US – MEI. Employment data from OECD *Economic Outlook*, sourced from Datastream. Data are smoothed using a backward-looking three-year-moving average.

Extended employment protection legislation (EPL) index: We follow Blanchard and Wolfers' (1999) method of backcasting the EPL index to create a long time series for this indicator. Briefly, we backcast using the growth rates of a proxy, which is a weighted average of scaled data on severance and notice periods for a blue-collar worker with 10 years service. Except for the following differences, we follow the method outlined in Blanchard and Wolfers' Appendix:

- We backcast the EPL in Nicoletti *et al* (2000) rather than in the OECD *Employment Outlook* (1999). The only difference between the two series is the choice of weights; Nicoletti and Scarpetta use factor analysis to derive the weights while the weights in the *Outlook* are chosen subjectively. The use of statistically derived weights seems preferable *ex ante*, but Nicoletti *et al* show that the two series are broadly similar and differences in the summary indicator are small. When constructing the weighted average of severance and notice periods we use the relevant weights calculated from Table 12 in Nicoletti *et al* rather than those from the *Outlook*.

- We use Addison, Teixeira and Grosso's (2000) corrected and updated version of Lazear's (1990) dataset on severance and notice pay, which has been used in a number of papers by its authors and others. There are few missing values in this updated dataset and we do not attempt to fill them.

- We begin backcasting the EPL using growth rates in the proxy series from 1984 rather than from 1979. There are two countries (Denmark and the US) whose EPL for the 'late 1980s' from Nicoletti *et al* (2000) is positive but whose proxy

EPL from Addison and Grosso is zero for all years 1956–2004. We choose to set the pre-1985 score for these countries as zero in our backcast EPL.

Union density: Proportion of wage and salary earners who are union members expressed as a percentage; both the numerator and denominator from the OECD. Trade union membership can be reported either by trade unions (‘administrative data’) or employees as part of labour force or other surveys (‘survey data’). For all countries in our sample except Australia, Canada, the Netherlands, Sweden, the UK and the US, only administrative data are available. For the remaining countries, survey data become available some time during our estimation period. Although survey data are preferable, we are wary of simply moving from administrative to survey data when the year in which the data source changes corresponds with a historically large change in calculated union density, as seems to be the case for Australia, Canada and the US. For these countries, we combine the two series in a way that avoids a historically large change in union density, for example by back- or forward-casting using the growth rates of administrative or survey data, respectively. For the Netherlands, Sweden and the UK we move from administrative to survey data without adjustment as this has no noticeable effect on calculated union density.

Average years of schooling: Geometric interpolation of the average years of schooling data constructed by de la Fuente and Doménech (2002). These data are a revised and partially extended version of the series in de la Fuente and Doménech (2000). Average years of schooling are observed every five years from 1960–1995, with the exception of France, Japan, Spain and the UK, for which there is no observation for 1995. We construct these observations by assuming that average years of schooling grew at their 1985–1990 rates over 1990–1995.

Employment to working-age population: Business sector employment as a percentage of the population aged 15–64, both from the OECD *Economic Outlook* No 78 database.

ICT expenditure: Total nominal expenditure on information technology (hardware, software and services) and telecommunications (equipment and services) as a percentage of aggregate nominal GDP. Source: WITSA (2000, 2002, 2004).

Output gap: Difference between natural logarithms of actual and trend business sector output, where trend business sector output is real business sector GDP from the OECD *Economic Outlook* No 78 database, smoothed with a Hodrick-Prescott filter using a smoothing parameter of 100. When smoothing we included the forecasts for real business sector output for the years 2005–2007; these forecasts are published in the OECD *Economic Outlook* No 78 database.

Research and development (R&D) expenditure: Nominal expenditure on research and development by the business enterprise sector as a percentage of GDP from the OECD's *Main Science and Technology Indicators (MSTI): 2006/2 edition*.

References

Addison JT, P Teixeira and J-L Grosso (2000), 'The Effect of Dismissals Protection on Employment: More on a Vexed Theme', *Southern Economic Journal*, 67(1), pp 105–122.

Aghion P and R Griffith (2005), *Competition and Growth: Reconciling Theory and Evidence*, MIT Press, Cambridge.

Bassanini A, S Scarpetta and P Hemmings (2001), 'Economic Growth: The Role of Policies and Institutions. Panel Data Evidence from OECD Countries', OECD Economics Department Working Paper No 283.

Bell G (2004), 'Recent Productivity Trends in the Netherlands', in IMF Country Report No 04/301, pp 21–40.

Belorgey N, R Lecat and T-P Maury (2004), 'Determinants of Productivity per Employee: An Empirical Estimation Using Panel Data', Banque de France Working Paper No 110.

Blanchard O (1997), 'The Medium Run', *Brookings Papers on Economic Activity*, 2, pp 89–158.

Blanchard O and J Wolfers (1999), 'The Role of Shocks and Institutions in the Rise of European Unemployment: The Aggregate Evidence', NBER Working Paper No 7282.

Bruno G (2005), 'Estimation and Inference in Dynamic Unbalanced Panel Data Models with a Small Number of Individuals', Centre for Research on Innovation and Internationalization Working Paper No 165.

Bruno M and J Sachs (1985), *Economics of Worldwide Stagflation*, Blackwell, Oxford.

Conway P, D de Rosa, G Nicoletti and F Steiner (2006), 'Regulation, Competition and Productivity Convergence', OECD Economics Department Working Paper No 509.

Conway P, V Janod and G Nicoletti (2005), 'Product Market Regulation in OECD Countries: 1998 to 2003', OECD Economics Department Working Paper No 419.

Conway P and G Nicoletti (2006), 'Product Market Regulation in the Non-Manufacturing Sectors of OECD Countries: Measurement and Highlights', OECD Economics Department Working Paper No 530.

Dawkins P (2000), 'The Australian Labour Market in the 1990s', in D Gruen and S Shrestha (eds), *The Australian Economy in the 1990s*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 316–352.

de la Fuente A and R Doménech (2000), 'Human Capital in Growth Regressions: How Much Difference Does Data Quality Make?', Centre for Economic Policy Research Discussion Paper No 2466.

de la Fuente A and R Doménech (2002), 'Educational Attainment in the OECD, 1960–95', Centre for Economic Policy Research Discussion Paper No 3390.

Dolman B, D Parham and S Zheng (2007), 'Can Australia Match US Productivity Performance?', Productivity Commission Staff Working Paper.

Drèze J and C Bean (1990), 'European Unemployment: Lessons from a Multicountry Econometric Study', *Scandinavian Journal of Economics*, 92(2), pp 135–165.

Elmeskov J, JP Martin and S Scarpetta (1998), 'Key Lessons for Labour Market Reforms: Evidence from OECD Countries' Experience', *Swedish Economic Policy Review*, 5(2), pp 205–252.

Griffith R and R Harrison (2004), 'The Link between Product Market Reform and Macro-economic Performance', European Commission Economic Papers No 209.

Griffith R, S Redding and J Van Reenan (2000), 'Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries', Centre for Economic Policy Research Discussion Paper No 2457.

Gust C and J Marquez (2004), 'International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices', *Labour Economics*, 11(1) pp 33–58.

Hornstein A, P Krusell and GL Violante (2002), 'Vintage Capital as an Origin of Inequalities', Centre for Economic Policy Research Discussion Paper No 3596.

Judson RA and AL Owen (1999), 'Estimating Dynamic Panel Models: A Guide for Macroeconomists', *Economics Letters*, 65(1), pp 9–15.

Lazear EP (1990), 'Job Security Provisions and Employment', *Quarterly Journal of Economics*, 105(3), pp 669–726.

Naastepad CWM and A Kleinknecht (2002), 'The Dutch Productivity Slowdown: The Culprit at Last?', Delft University of Technology, mimeo, available at <http://www.tbm.tudelft.nl/webstaf/ron/>.

Nickell S (1981), 'Biases in Dynamic Models with Fixed Effects', *Econometrica*, 49(6), pp 1417–1426.

Nickell S and L Nunziata (2000), 'Employment Patterns in OECD Countries', Centre for Economic Performance Discussion Paper No 0448.

Nicoletti G, A Bassanini, E Ernst, S Jean, P Santiago and P Swaim (2001), 'Product and Labour Markets Interactions in OECD Countries', OECD Economics Department Working Paper No 312.

Nicoletti G and S Scarpetta (2003), ‘Regulation, Productivity and Growth: OECD Evidence’, *Economic Policy*, 18(36), pp 9–72.

Nicoletti G and S Scarpetta (2005a), ‘Product Market Reforms and Employment in OECD Countries’, OECD Economics Department Working Paper No 472.

Nicoletti G and S Scarpetta (2005b), ‘Regulation and Economic Performance: Product Market Reforms and Productivity in the OECD’, OECD Economics Department Working Paper No 460.

Nicoletti G, S Scarpetta and O Boylaud (2000) (1999), ‘Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation’, OECD Economics Department Working Paper No 226.

OECD (1999), *OECD Employment Outlook: June 1999*, OECD, Paris.

OECD (2001), *Measuring Productivity: OECD Manual*, OECD, Paris.

OECD (2004), *OECD Employment Outlook: 2004*, OECD, Paris.

OECD (2006), *Main Science and Technology Indicators (MSTI): 2006/2 Edition*, OECD, Paris.

Oliner SD and DE Sichel (2000), ‘The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?’, *Journal of Economic Perspectives*, 14(4), pp 3–22.

Scarpetta S and T Tressel (2002), ‘Productivity and Convergence in a Panel of OECD Industries: Do Regulations and Institutions Matter?’, OECD Economics Department Working Paper No 342.

Scarpetta S and T Tressel (2004), ‘Boosting Productivity via Innovation and Adoption of New Technologies: Any Role for Labor Market Institutions?’, World Bank Policy Research Working Paper No 3273.

Simon J and S Wardrop (2002), 'Australian Use of Information Technology and its Contribution to Growth', RBA Research Discussion Paper No 2002-02.

Skoczylas L and B Tissot (2005), 'Revisiting Recent Productivity Developments across OECD Countries', BIS Working Papers No 182.

WITSA (World Information Technology and Services Alliance) (2000), *Digital Planet 2000: The Global Information Economy*, World Information Technology and Services Alliance, Arlington.

WITSA (2002), *Digital Planet 2002: The Global Information Economy*, World Information Technology and Services Alliance, Arlington.

WITSA (2004), *Digital Planet 2004: The Global Information Economy*, World Information Technology and Services Alliance, Arlington.

Wooden M and J Sloan (1998), 'Industrial Relations Reform and Labour Market Outcomes: A Comparison of Australia, New Zealand and the United Kingdom', in G Debelle and J Borland (eds), *Unemployment and the Australian Labour Market*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 169–203.