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MEDIUM-TERM DETERMINANTS OF OECD PRODUCTIVITY

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INTRODUCTION

This paper provides a summary of recent developments in the "new growth economics" literature and assesses the contribution of this literature to understanding OECD productivity performance. It replicates some of the empirical results found in the recent growth literature in order to evaluate both the overall robustness of the key empirical relationships and their applicability to the OECD which, in the context of this literature, represents a sub-set of relatively rich and industrialised countries with better quality data. Finally it attempts to explain the evolution of productivity growth both over time and across OECD countries. Throughout, the policy implications of the analyses are emphasised.

A large part of the literature on "new growth theories" emphasises the endogenous determination of growth rates. In a formal sense endogenous growth means that the equilibrium growth rate of the economy is determined within the economy, rather than by exogenous technological progress, and that this growth rate is consistent with a competitive equilibrium. If there are diminishing returns to capital formation (where capital is defined broadly, including human, physical, and infrastructure capital), there will be an equilibrium level of productivity, but growth rates will be determined by exogenous technical progress as in the Solow model. Intuitively, if private returns do not fall as saving and (broadly defined) investment increase, there is nothing to impose a stop to accumulation. Endogenous growth models assume that some portion of the return to accumulation is public rather than private, and the limits to private returns determine the limits to accumulation. The conditions for growth rates being completely endogenous are relatively strict and the empirical side of the new growth literature (as well as this paper) has tended to emphasize an expanded set of variables and their qualitative importance, rather than testing literally the hypotheses generated by the endogenous growth literature.

I. RECENT PERSPECTIVES ON PRODUCTIVITY GROWTH

Recent analyses have emphasised human and physical capital accumulation, including infrastructure, R&D and knowledge capital, and trade as major forces behind long-term productivity growth. This section summarises the theoretical basis for these hypotheses and comments on their ability to explain both the weak convergence among countries before 1950 and the slowing of productivity growth after 1973 – two striking stylised facts.

Although convergence is treated as an exogenous force in much of the literature, the convergence of productivity levels among the OECD countries is a largely post-war phenomenon (Table 1). Between 1820 and 1870 most OECD countries were falling increasingly behind the United Kingdom, the productivity leader of that period, and from 1870 to 1950 most were falling further behind the

Table 1. Comparative levels of productivity

GDP per man-hour relative to leading country

	1820'	1870	1890	1913	1929	1938	1950	1960	1973	1987
	United Kingdom = 100			United States = 100						
United States	83	96	99	100	100	100[2]	100	100	100	100
Japan	31	18	20	18	22	23	15	20	46	61
Germany	62	48	53	50	42[4]	46	30[3]	46	64	80
France	80	54	53	48	48	542	403	49	70	94
Italy	58	39	35	37	35	40	31[3]	38	64	79
United Kingdom	100	100	100	78	67[4]	64	57[3]	56	67	80
Canada	..	62	63	75	66	58[2]	75	79	83	92
Austria	66	49	53	48	374	332	27[3]	38	59	74
Belgium	72	79	80	61	554	532	42[3]	45	64	86
Denmark	66	57	59	58	59	54	43	46	63	68
Finland	49	33	32	33	32	33	31	36	57	67
Netherlands	99	85	87	69	74	64[2]	46	54	77	92
Norway	59	46	48	43	45	50	43	52	64	90
Sweden	58	45	46	44	38	43	49	54	76	82
Switzerland	..	60	61	51	57	552	56	59	67	68
Australia	90	127	99	93	774	75	67	69	70	78

1. Extrapolated backwards from 1870 using owth of real GDP per head.
2. Countries with 1929-38 GDP growth of le than 5 per cent.
3. Countries with 1913-50 averaae GDP grc h of less than 1½ per cent per year.
4. Countries with 1913-29 average GDP growth of less than 1½ per cent per year.

Note: The United Kingdom was the productivity leader until 1890; afterwards it was the United States.

Source: Maddison (1991).

United States. Even countries that were not directly involved in the two world wars, such as Sweden and Switzerland, showed minimal tendency to catch-up, and their 1950 productivity levels relative to the United States were about the same as in 1870. Hence, explanations of long-term productivity performance should ideally be able to explain both the catch-up during the second half of the 20th century and the falling behind during the preceding 120 years. Moreover, with the post-1973 productivity slowdown now twenty years old, explanations of long-term productivity growth must in part be judged by their ability to explain the slowdown.

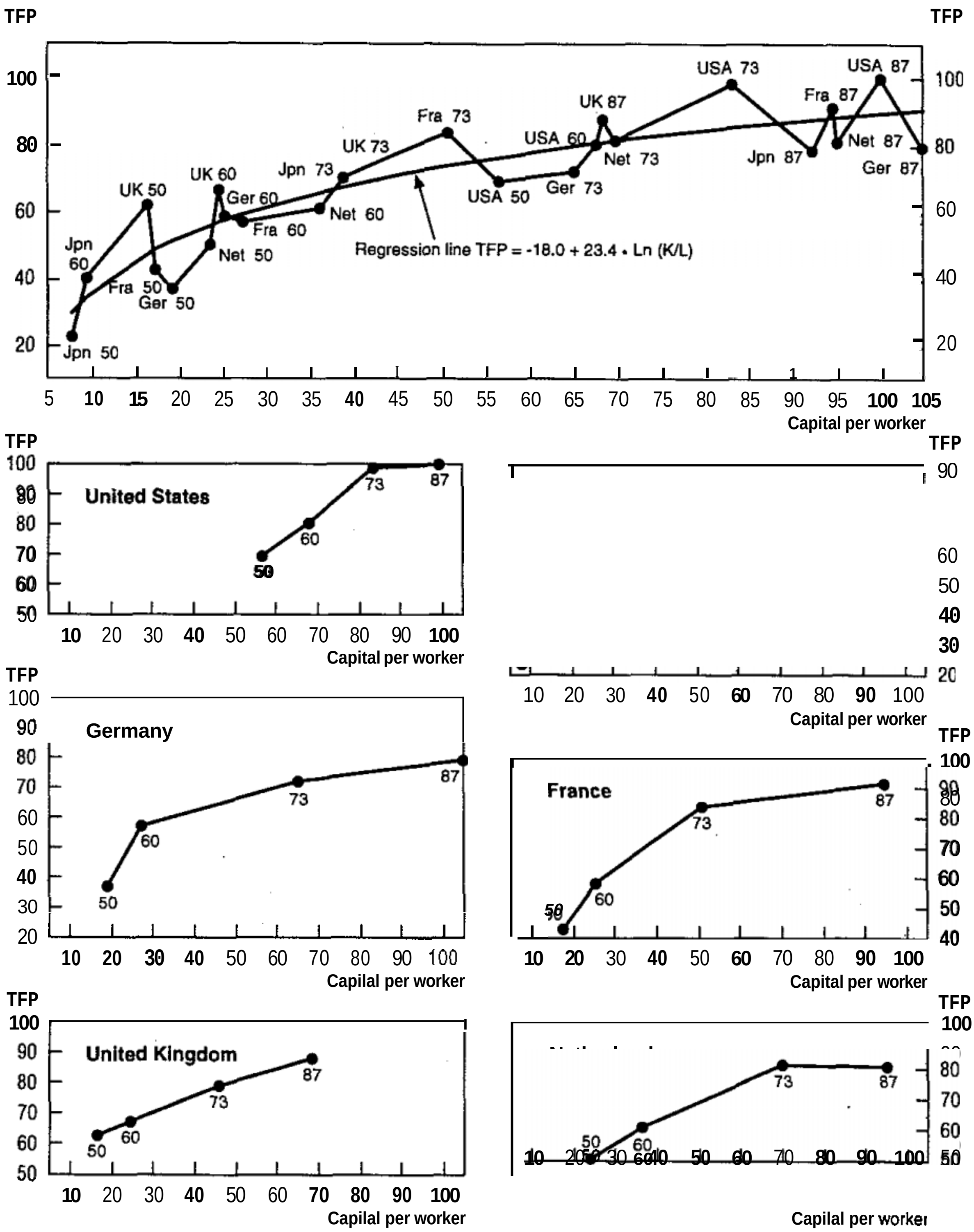
To summarise the conclusions of the review that follows:

- **Education** probably provides a 5-10 per cent increase in productivity **levels** per additional average year of education, but there are probably very small long-term effects on **growth** rates from an additional year of education.
- There is little evidence of large positive externalities of **physical investment.**
- Severe econometric problems in estimating the productivity effects of **infrastructure** make the empirical results that find very large returns suspect.
- While there is evidence of high returns to, and substantial spillovers from, **R&D,** its behaviour over the last two decades provides no explanation for the post-1973 productivity slowdown.
- **Trade and competition,** and their stimulating effects on innovation present an appealing explanation for long-term productivity growth and can help explain rapid post-war catch-up; but supporting empirical evidence is limited.
- Some support emerges for the view that **cyclical** downturns may weaken productivity growth over the medium term, but the evidence is limited.
- Anecdotal evidence suggests that **rent-seeking** has become far more prevalent than in the immediate post-war period, but quantification of these effects is difficult.

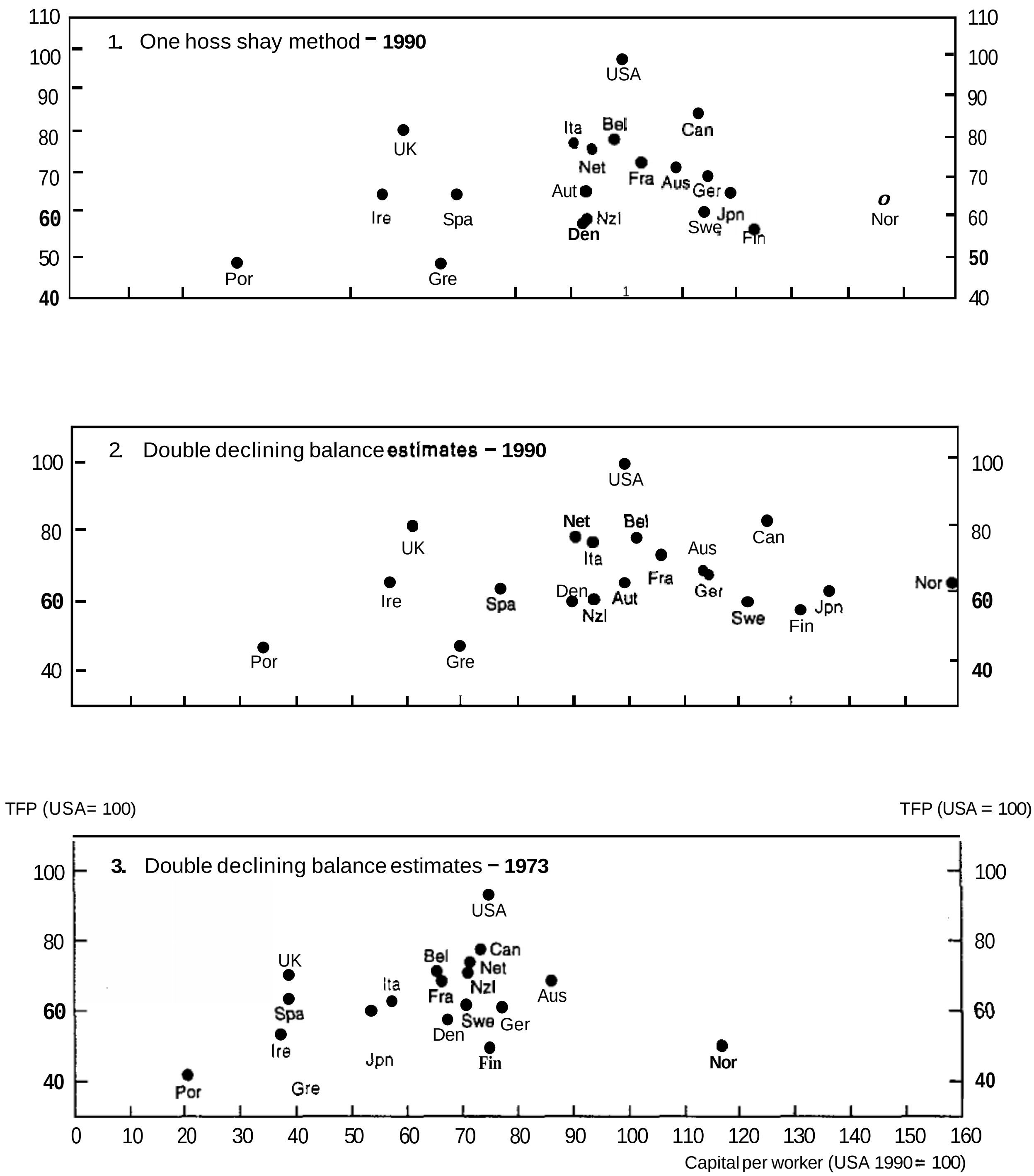
A. Investment and physical capital

Capital and TFP: evidence for the link. The key role assigned to fixed investment in several new growth models is based on the empirical observation that higher levels of capital per worker have been correlated with high TFP levels both over time and across countries (Figure **1).** However, a closer look at the data suggests that the links between capital accumulation and TFP have become substantially weaker over time. Figure 1 indicates that the United States has had a higher level of TFP relative to its level of capital intensity than Japan, Germany or the Netherlands in recent years. This is corroborated by the estimates of Summers and Heston (1993) presented in Figure 2.[1] While there is a moderate

Figure 1. Capital per worker and TFP
USA= 100 in 1987



1. Reporting years are 1950, 1960, 1973 and 1987, as indicated at data points in the figures.
Source: Maddison (1991).



Note: Two different methods were used to arrive at capilal stock estimates. The one hoss shay approach keeps past investments fully in the capital stock till the end of their service lives, at which point they are scrapped. Double declining balance depreciation is analogous to geometric depreciation; capital is assumed to be withdrawn gradually from the use over its service life.

Source: Heston (1993).

upward slope in the relationship between TFP and capital intensity, it is clear that capital deepening does not guarantee higher TFP levels. Data for 1973, as well as 1990, based on double-declining balances, both indicate clearly that the relationship between TFP and capital to labour ratios was quite flat after 1973.[2] While a positive relationship can still be seen in 1973, by 1990 none was apparent. Although the United States remains the TFP leader, it no longer has the highest capital to labour ratio. This suggests that factors other than capital intensity, embodiment or a capital-using bias to technological progress are hindering catch-up outside the United States and suggests that policy should focus on the efficiency with which capital is used as well as the quantities that are available.[3]

The strong association between higher TFP and greater capital intensity during past periods of catching-up may also represent a transition to better technology.[4] For example, better technology may require more intensive use of capital, so countries developing rapidly may simultaneously be shifting to more advanced capital and higher TFP levels. In this view, the flat slope at higher levels of capital intensity in Figure 2 is the norm for advanced countries, and the steep

Table 2. Gross fixed non-residential capital formation

Per cent of GDP

	1953	1955	1957	Mean re-73[1]	1974-79	1980-90
United States	11.5	11.8	13.1	13.4	13.2	13.2
Japan	18.8	16.5	22.9	26.5	24.2	23.7
Germany	14.8	17.3	16.7	17.6	14.7	14.5
France	12.5	13.1	14.4	16.2	15.6	14.7
Italy	15.2	15.1	15.5	16.6	17.0	15.3
United Kingdom	10.3	11.5	12.7	14.6	15.2	14.0
Canada	18.0	17.2	22.1	16.9	16.8	15.4
Austria	13.5	18.7	17.8	21.1	21.1	18.7
Belgium	12.0	12.8	12.9	–	15.4	14.1
Denmark	13.8	13.1	13.8	16.2	15.3	13.6
Finland	20.2	19.3	18.3	20.0	19.8	18.4
Greece	–	–	10.5	15.7	16.0	14.6
Iceland	15.1	14.9	17.8	19.8	21.1	16.3
Ireland	–	–	12.0	19.0	19.9	16.5
Netherlands	16.8	19.1	20.5	19.9	15.7	14.8
Noway	24.2	25.2	24.3	23.6	27.6	21.3
Portugal	11.6	11.2	11.6	–	19.9	21.2
Spain	–	–	–	17.9	17.9	16.4
Sweden	15.8	15.1	15.3	16.3	15.9	14.7
Switzerland	13.1	13.6	16.6	10.3	7.5	8.2
Turkey	–	–	–	13.1	17.1	16.4
Australia	–	–	–	20.4	18.1	19.0
New Zealand	–	–	–	18.3	19.5	18.0

1. Beginning dates vary. See notes to Table 1 of the following article.
Note: National accounts conventions may vary within countries over time, particulary within the 1950s.
Source: National accounts.

slope at low capital intensity represents the special circumstances of post-war OECD catch-up.

Although investment rates are not the theoretically preferred measure of capital accumulation, they are less dependent on assumptions with respect to obsolescence and scrapping, and as such, may be more robust in international comparisons. US investment rates appear to have been very high relative to other countries and relative to subsequent periods between 1870 and 1930, a period during which the United States was pulling ahead of other countries. During the post-war productivity boom enjoyed by most other countries, investment rates were quite strong relative to the past; in some countries the investment share almost doubled (Maddison, 1991). However, while investment shares have fallen off somewhat from the levels of the 1960s and early 1970s, they remain quite a bit higher than in the 1950s when productivity growth in Europe and Japan was very rapid (Table 2.).

Finally, the empirical new growth literature itself does not provide clear evidence for an extraordinary bonus to investment. For example, Scott (1989) estimates that in a country with little or no potential for "catching up" such as the United States productivity growth increases by 0.13 percentage point for every percentage point increase in the investment share, while Levine and Renelt (1992) present estimated output responses ranging from 0.09 to 0.17. These are quite close to what standard neo-classical models would predict.[5]

B. infrastructure capital

High pay-offs to infrastructure capital have been reported by Aschauer (1989) and Munnell (1993), among others. However, the extraordinary returns to infrastructure that are found in some studies can be interpreted in several ways. As the income elasticity of demand for broad classes of infrastructure is likely to be high, estimates of output responses that do not correct carefully for the simultaneous demand-driven expansion of infrastructure are likely to be greatly distorted. If demand for infrastructure increases more or less proportionately to income, then the ratio of infrastructure to private inputs will be a good indicator of TFP levels, even if additional infrastructure has no effect on output growth. Regression analyses will then "reveal" high correlation between infrastructure and TFP, but the causality will run from income to infrastructure rather than from infrastructure to output.[6] Appendix A analyses the simple case of a unitary elasticity of demand for infrastructure. As a generalisation, the overstatement of the productivity response to infrastructure will get higher as the link between infrastructure and output gets tighter and the more that TFP contributes to output growth, so that a tight **demand** side link between infrastructure and output in a country where TFP contributes significantly to output could emerge as a high output response in production function estimates. The coefficient on infrastructure will tend to get smaller if there is a stronger link between private inputs and output growth, *i.e.* if TFP represents only a small portion of output growth.'

C. Education and human capital

In the basic productivity growth data, no adjustment is made for human capital acquisition. To the extent that such human capital contributes to output growth, its earnings are imputed to labour measured in physical units (persons or hours worked), raising estimates of both labour and total factor productivity. Virtually all studies find that there is a substantial private return to education in the form of higher wages, and there may be positive externalities to education as well. The higher wages of educated individuals in turn are viewed as reflecting their relative productivity levels, although in some countries, the wage-skill profile has been deliberately flattened in pursuit of distributional objectives.

Human capital formation encompasses at least three dimensions – years of formal education, vocational education (in school and in the transition to employment) and on-the-job training. Empirical estimates of the return to schooling are generally based on years of formal schooling or enrolment rates, although some effort has been devoted to identifying the qualitative importance of the other two categories.

Education and Productivity Levels. OECD citizens have become better educated over time, with average years of education about two to three years more now than in 1960 (Table 3). The labour economics literature has generally found an increase in private earnings of 5-10 per cent for each additional year of schooling. If these annual returns correspond to additional output as measured in national accounts, an additional two and a half years of schooling will raise productivity levels by about 12-25 per cent. Averaged over 30 years this would contribute about 0.4-0.7 percentage point to average annual productivity growth. Average education levels in the United States still are about 1-2 years above those of other OECD countries. Ignoring educational quality differences and other forms of human capital acquisition, this might explain about 5-20 per cent of the gap in productivity as between the United States and other OECD countries.[8]

However, the big differences in estimates of educational attainment from different sources permit only limited inferences to be drawn from such data.[9] Various methods can produce very different results. For the United States, estimates of average length of formal education for persons in the work force in the 1960s range from 9.8 to 12.2 years. For Japan, the range is 7.2 to 10.5 years. Barro (1992) estimates that the work force's average (unweighted) years of schooling in the OECD were 6.2 years in 1960, rising to 8.2 in 1985, while Benhabib and Spiegal (1992) estimate about 6.9 years for 1965 and 9.3 years for 1985.

Growth in education levels appears to have been at least as fast after 1973 as before. This is consistent with the big increase in enrolment rates in tertiary education in the late 1960s in many countries, and with most countries approaching full enrolment in secondary education (Table 4).[10] Enrolment rates in tertiary education outside North America increased from about 10 per cent in 1960 to

Table 3. **Average years *of* schooling**

	OECD'		Benhabib and Spiegal		Kim and Lau			Maddison			Psacharopoulis and Ariagada [2]	
	1989	1991	1965	1985	1960	1973	1985	1950	1973	1984	1960s	1980s
United States	12.0	12.3	9.8	12.1	12.2	12.2	12.1	9.5	11.3	12.5	10.6 (69)	13.0 (88)
Japan	11.1	–	7.2	9.5	10.5	11.1	11.7	8.1	10.2	11.2	7.6 (69)	9.8 (79)
Germany	11.2	11.5	9.1	10.3	8.5	8.6	9.0	8.5	9.3	9.5	–	10.4 (82)
France	9.7	9.8	8.7	9.5	9.7	9.5	9.8	8.2	9.6	10.8	–	6.2 (82)
Italy	8.3	0.4	6.6	9.1	–	–	–	–	–	–	–	10.2 (87)
United Kingdom	10.7	10.9	7.0	8.5	9.2	9.4	9.6	9.5	10.2	10.9	–	12.4 (87)
Canada	11.2	11.8	8.0	10.0	–	–	–	–	–	–	9.1 (69)	12.4 (87)
Austria	10.3	10.5	–	8.6	–	–	–	–	–	–	–	12.9 (87)
Belgium	9.2	9.7	–	9.4	–	–	–	–	–	–	8.1 (70)	10.5 (86)
Denmark	10.5	10.9	6.5	6.9	–	–	–	–	–	–	8.6 (81)	10.8 (83)
Finland	10.6	10.6	–	10.8	–	–	–	–	–	–	–	–
Greece	–	–	6.4	8.4	–	–	–	–	–	–	4.3 (71)	7.9 (81)
Iceland	–	–	–	–	–	–	–	–	–	–	–	–
Ireland	9.0	9.3	6.3	8.8	–	–	–	–	–	–	–	–
Luxembourg	–	–	–	–	–	–	–	–	–	–	–	–
Netherlands	10.0	10.1	–	9.5	–	–	–	7.4	8.9	9.9	6.1 (67)	11.0 (87)
Norway	10.9	11.3	–	9.2	–	–	–	–	–	–	11.3 (80)	11.0 (87)
Portugal	6.7	6.7	3.9	6.5	–	–	–	–	–	–	4.5 (81)[3]	9.5 (87)[3]
Spain	7.8	8.0	4.1	9.7	–	–	–	–	–	–	6.2 (81)[3]	10.4 (87)[3]
Sweden	11.1	11.1	6.7	9.6	–	–	–	–	–	–	–	12.4 (87)
Switzerland	11.4	11.1	5.7	–	–	–	–	–	–	–	11.0 (80)	12.7 (88)
Australia	10.6	10.6	6.9	8.7	–	–	–	–	–	–	11.1 (81)	12.3 (87)
New Zealand	10.3	10.0	8.0	9.3	–	–	–	–	–	–	–	11.7 (81)

1. Mean years of schooling calculated from OECD (1992, 19[illegible] , Assumes that average sc[illegible] ling of those educated to pi[illegible] ary level is 6 years, lower secondary level 8 years, upper secondary level 11 years. non-univer[illegible] tertiary 14 years, universi[illegible] evel 17 years.
2. Date of estimate in parenthesks.
3. Psacharopoulis and Ariagada noted that these estimates may not be consistent across countries.

Source: OECD (1992. 1993), Benhabib and Spiegal (1992), Kim and Lau (1992), Maddison (1991) and Psacharopoulis and Ariagada (1992).

Table **4.** **Average educational attainment of emerging graduates**

	Average years of education 01 emerging graduates			Secondary education enrolment rates		Tertiary education enrolment rates	
	1960	1989	Difference	1960	1989	1960	1989
United States	10.9	12.6	1.7	80	98	32	60
Japan	10.0	11.7	1.7	74	96	9	31
France	8.5	11.9	3.4	46	97	7	37
Italy	7.9	10.8	2.8	34	78	7	29
United Kingdom	10.0	10.8	0.8	74	82	9	24
Canada	10.5	12.5	2.0	80	93	16	66
Austria	9.8	11.0	1.2	70	82	8	31
Belgium	9.8	12.0	2.2	69	100	9	33
Denmark	9.1	12.0	2.8	56	100	10	32
Finland	10.0	12.3	2.2	75	100	7	43
Greece	8.2	11.7	3.5	41	97	4	28
Iceland	9.4	11.7	2.3	63	99	7	25
Ireland	9.3	11.6	2.3	60	***97***	9	26
Netherlands	9.3	12.0	2.7	58	100	13	32
Norway	8.9	12.0	3.1	53	98	7	36
Spain	7.8	12.0	4.2	33	100	4	32
Australia	9.0	11.0	2.1	51	82	13	32
New Zealand	10.1	11.6	1.5	73	88	13	41

Note: Data are shown lor countries lor which it was possible to make consistent comparisons between 1960 and 1989. In some countries data lor 1988 were used when 1989 data were unavailable. Secondary enrolments are defined in terms 01 age groups ranging from 11-18 to 13-19 years in different countries, so international comparisons are not completely consistent, although comparability is greater lor the 1989 data. In both 1960 and 1989 the minimum education level of a primary school graduate was assumed to be six years. Among secondary school students 70 per cent were expected to graduate with 12 years 01 education and 30 per cent with 9. Tertiary programmes include non-university programmes which in many cases last less than 4 years. Among those enrolled in tertiary programmes, 70 per cent are assumed to graduate with 15 years of education and 30 per cent with 14.

Source: UNESCO, Statistical Yearbook; various years.

30-40 per cent by 1989. In the United States and Canada enrolment rates of 30 and 16 per cent, respectively, in 1960 increased to over 60 per cent by 1989.

In consequence of this enrolment increase, recent graduates in OECD countries now receive two to three years more of formal education than graduates of 1960 vintage. Equivalent data for 1950 (not shown), which are available for a few countries, suggests that the differential in education of new labour market entrants as between the 1950s and late 1980s was probably close to three years. With 1950s and 1960s vintage graduates leaving the work force, and better educated 1990s vintage graduates entering, the educational qualifications of the work force will continue to rise for some time to come even without further increases in the quantity of education absorbed by younger cohorts.

That being said, it is important to recognise the crudeness of the number of completed school years as an indicator of human capital stock. It takes no account of educational quality, which is affected by pupil-teacher ratios, attitudes at home and in society at large, effective length of school year and numerous other factors. A variety of indicators suggest that achievement levels differ across countries and there are also some indications of variation over time within countries. In addition, the estimates of the return to education can be biased upwards if the returns to education reflect a screening effect, whereby employers separate more from less able workers, rather than a direct productivity gain.

Education and growth. A second strand of thought argues that education **levels** are linked to productivity **growth** (Schultz, 1975; Welch, 1975; Benhabib and Spiegal, 1992). In general, an educated, motivated and flexibie labour force will be able to adapt more easily to new processes and new industries, and hence allow productivity to rise more rapidly. In models such as Romer (1990*b*), a set of highly educated individuals constitute the sector of the economy that creates new technology and is closely related to the share of R&D in GDP. The flow of new technology (and productivity growth) will in turn be linked to this share.

There also may be positive externalities from human capital. Where the average level of human capital is high, the incidence of learning from others will be higher, and it is likely that there will be greater productivity gains to be derived from exchanging ideas (Lucas, 1988). Human capital often flows to countries that already have large amounts of such capital (the "brain drain"), suggesting that the return to such human capital is negatively related to its scarcity rather than positively as might be predicted from standard analysis. Moreover, Kremer and Thompson (1993) suggests that there may be some intergenerational complementarities in human capital – for example, the productivity of a young doctor may be raised by the presence of more experienced doctors – so that the returns to increasing human capital investment may be relatively high in already well endowed countries.

However, if there is a link between education levels and productivity growth rates, it is likely to be small at the margin. Looking at the productivity leaders in different periods, UK productivity growth was about 1.1 per cent per year over 1820-70 with an initial education level of about two years; US productivity growth over 1950-89 was about 1.9 per cent starting from a base of 9.5 years of education in 1950; looking at the post-73 period US productivity growth has been about 1 per cent per year from a base of 11.3 years of education." Even if the entire acceleration in productivity growth in the leading country (1950-89 vs. 1820-70) is allocated to education, ignoring other factors such as capital accumulation, trade, increases in formal R&D, the effect on productivity growth rates is 0.1 percentage point per additional year of education. If the comparison is taken with the post-1973 period, the contribution from education to growth would be zero. Such comparisons are crude, but they help establish bounds for the size and reliability of the link between education and productivity growth.

D. Research and development (R&D)

R&D aims explicitly at pushing outward the production possibility frontier for a given amount of conventional inputs (labour, capital and natural resources). R&D differs from most other investment activities in that the appropriability of returns to R&D is often limited, even when patent protection is available. Spillovers are high and social returns often greatly exceed private returns, probably by as much as 30 to 50 per cent (Griliches, 1991). Consequently, the depreciation of private R&D is related to the loss of quasi-rents as the once-private information generated by R&D becomes widely known.

Countries can benefit to a large degree from foreign R&D without undertaking heavy R&D expenditures through the purchase of patent rights, franchising, and trade of goods in which R&D is embodied. Specialisation in R&D, and higher R&D ratios in high productivity countries, may increase the flow of new technology available for all countries. In 1973, the United States accounted for 56 per cent of manufacturing R&D in major OECD countries (in real terms, adjusted for overall PPPs) as compared with 47.5 per cent in 1990 (Figure 3).

The increase in the contribution of R&D outside the United States to technological improvement is probably understated by such calculations. The wider gap in 1973 between productivity in the United States and elsewhere probably meant that other countries' R&D may have been in part directed to adapting and borrowing US technology. If R&D is weighted by relative productivity levels – as a rough downward adjustment to the contribution of R&D from low productivity countries – the United States accounted for almost 70 per cent of OECD R&D in 1973. By '1990 the US share had dropped to 54 per cent on this basis, suggesting that far more room for a two-way flow of technology exists now than in the past, provided that countries do not inhibit the flow of technology by protectionist policies that inhibit the flow of best practice technology.

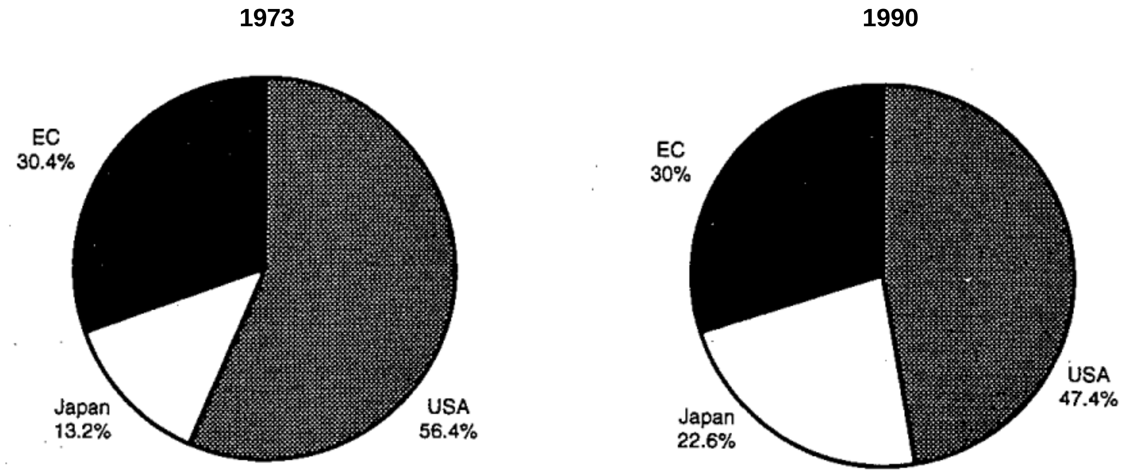
E. Trade and competition

Given the uneven distribution of R&D activity among countries, the focus of recent analysis on the interaction of international trade with innovation and growth is not surprising. In increasing the potential market, international trade raises the prospective returns to a successful innovation. This increase in the size of the market also permits a better exploitation of economies of scale. And last, but not least, trade is likely to produce a more rapid diffusion of new products, processes and research output between national economies.

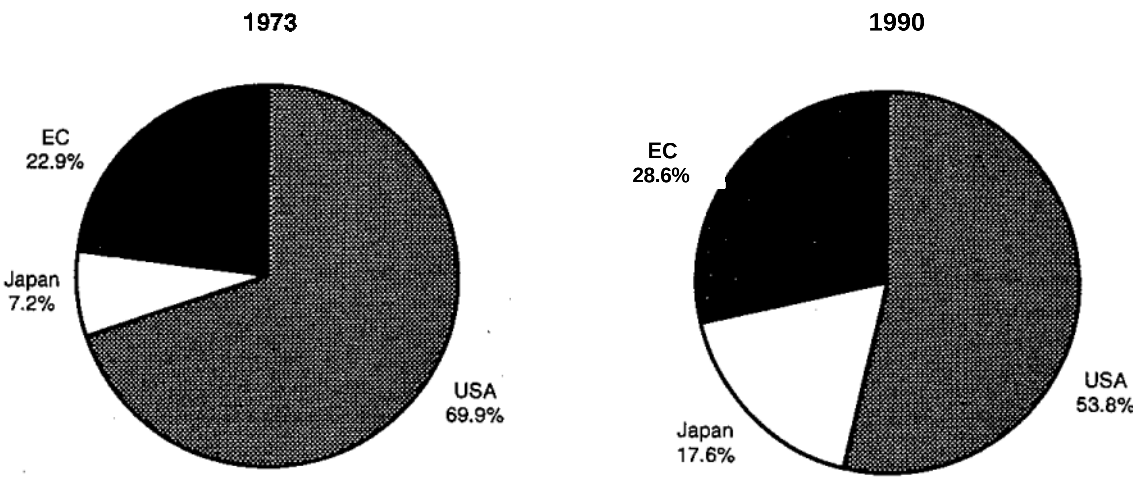
Coe and Helpman (1993) find substantial interaction between import propensities and the ability to benefit from foreign R&D. For a given amount of R&D undertaken abroad, countries with higher import propensities have higher TFP levels. Moreover, they find that while large countries benefit more from domestic R&D, smaller countries benefited more from R&D performed abroad. Similarly,

Figure 3. Manufacturing R&D shares

A. Adjusted for overall PPPs only



B. Adjusted for overall PPPs and proximity to productivity



Note: Panel A divides nominal manufacturing R&D in each country or region by the overall PPP for GDP and calculates each country's or region's share in total manufacturing R&D spending. In panel B, the PPP adjusted R&D expenditures are also multiplied by productivity levels relative *to* the United States, as a crude adjustment for the limited extent to which the R&D of countries far behind the productivity leader pushes out the production possibilities frontier.

Source: OECD, DSTI.

Maddison (991) notes the strong positive correlation of productivity and exports growth across his four "phases" of economic growth. Correlations between labour productivity growth and the growth of exports and between labour productivity growth and the difference between the growth-rates of exports and GDP suggest that periods of increasing trade intensity were also the periods of most rapid labour productivity growth (Table *5)*. The technology content of trade in intermediate and final manufactured goods in the late 20th century is much higher than that of raw materials, suggesting that trade in more technologically advanced goods may carry more significant productivity spillovers now than in the past.

Trade and economic integration may also underlie the very strong catch-up performance of Canada over 1938-50, from 58 to 75 per cent of US productivity levels, representing the most rapid catching-up of the pre-1950 period. Although the sources of this gain are not clear, the rapid expansion of production during the war may have contributed to both integration with and knowledge transfers from the more developed industrial base in the United States, as well as to local experience in producing relatively advanced goods.

Successful entry into international markets has become associated with the rapid improvement in productivity of Japan and the Asian NIEs. There are several alternative interpretations of this success. It is not clear whether the key factor is trade ***per* se** and the resultant gains from specialisation, or competition and the associated pressure for cost minimisation (or both). The most straightforward interpretation of the positive correlation between productivity and export performance is that it reflects the gains from specialisation (exploiting comparative advantage), as in standard trade models, and economies of scale. In this view openness to trade allows countries to benefit from both static and dynamic efficiencies. A second interpretation is that the success reflects domestic policies that have encouraged competition and competitiveness on the world market, as well as domestically. In this case trade (and, in particular, exports) is a consequence of noninterventionist policies that allow resources to be used efficiently.

Table 5. Correlation coefficients between export and labour productivity growth rates

	1870-1913	1913-1950	1950-1973	1973-1987	Pooled sample (64 observations)
Productivity growth and export growth	0.25	0.70	0.87	0.60	0.83
Productivity growth and difference between export and output growth rates	0.03	0.53	0.78	0.35	0.70

Source: **Underlying data are from Maddison (1991).**

A third interpretation is that the apparent export success reflects some neo-mercantilist tendencies, if the performance in the favoured sectors comes at the expense of neglect in other sectors. For example, scarce credit or investment funds may be preferentially allocated to export industries, and limited to other sectors. Such practices would tend to produce disproportionate productivity gains in the favoured tradeable goods sectors relative to nontradeables sectors; the superior measured productivity performance of manufacturing relative to services is characteristic of productivity growth in most countries, but other explanations are possible as well (Baumol ***et** al.* 1989). A fourth interpretation, recently advanced in World Bank (1993), is that international trade represents a testing ground on which the industries and firms with the greatest potential can be revealed and supported.[12] The fittest firms are revealed by their successful participation in world markets. State intervention, directed towards aiding firms that show ability to compete successfully in world markets, thus avoids problems of picking "winners" and the risk that the intervention will primarily benefit rent-seekers.

Recent developments in trade theory have investigated the circumstances in which the benefits from trade may be uneven. In industries where there is imperfect competition, and in industries in which the optimal scale exceeds that of the national economy, it is possible that a "strategic" trade policy may enable a country to specialise in such a way as to maximise its share of the economic rents that arise. Furthermore, if there are positive dynamic externality effects from R&D and innovation, the country that moves first into such areas may acquire a long-term comparative advantage in R&D intensive products where none inherently existed. However, as Grossman and Helpman (1991) point out, even the country that specialises in the non-innovating sector is likely to benefit from the faster pace of global R&D. The question that then arises is whether it is more beneficial to pursue strategic trade policies rather than free trade policies. Krugman (1993) concludes that the gains from strategic trade are small in absolute terms, and much smaller relative to the potential losses that may arise if the pursuit of strategic policies leads countries to abandon the free trading system.[13]

F. Cyclical influences on medium-term growth

Two opposing views have been advanced with respect to the impact of the business cycle on the evolution of productivity. An earlier tradition stressed the role of faster growth in increasing the rate of productivity growth through learning by doing, expansion of markets and economies of scale (Young, 1928; Verdoorn, 1949; Kaldor, 1966). More recently Stiglitz (1993) argues that financing for risky, but high return investments is more likely to be available from internal funds during boom periods than during recessions. Unlike tangible investments, the collateral value of R&D investment from the point of view of a lender is very uncertain, so creditors may not wish to finance such investments during downturns, or they may require a substantial commitment of the firm's own funds along with any borrowed money. Moreover, the behaviour that enables a firm to survive a major downturn is not necessarily that which maximises its long-run rate of productivity growth. Turner *et al.* (1991) conclude that cash-flow (rather than profitability) problems in the early 1980s were the most immediate cause of company failures; hence, downturns or the risk of downturns may lead to more cautious and less innovative behaviour.

Empirically the pro-cyclicality of productivity growth over the very short run is well known. However, this short-term response is not relevant to medium-term productivity performance as it is almost immediately reversed by labour shedding over subsequent quarters. Englander and Mittelstädt (1988) found evidence that productivity growth responded pro-cyclically to medium term shifts in capacity utilisation, even after using instrumental variables techniques in an effort to distinguish between demand and supply shifts. But uncertainty remains as to whether such techniques adequately distinguish between the two types of shocks.

There is clearly a limit to growth-induced productivity gains, however. The acceleration of inflation that comes with "going for growth" points to a limit on the extent to which pump-priming and expansionary demand policy can produce sufficient productivity gains to reduce the upward pressure on costs.

The opposing view emphasises the pressures and opportunities to achieve higher efficiency during downturns. Schumpeter (1939) points to the "cleansing" aspect of recessions that drive inefficient firms out of business and induce cost-savings among surviving firms. Nickell *et al.* (1986) support this interpretation with respect to the U.K. downturn of the early 1980s. Saint-Paul (1992), Hall (1991), Aghion and Saint-Paul (1991) focus on the opportunity costs of cost-savings during downturns – when firms have quasi-fixed labour or physical capital, a period of slack demand can be used for training, maintenance of capital, investment in R&D and so on, activities that might have a lower priority during boom periods.

It would seem that the cost-cutting pressures that emerge during downturns could be largely emulated by encouraging domestic and international competition at full capacity utilisation. The view of recessions as lowering the opportunity cost of productivity would be justified at best for short recessions, when neither the long-run structure of demand nor the survival of firms comes into play, and where access to credit markets is unimpaired. Otherwise, firms may well choose the short-run risk averse strategy of shedding labour and capital wherever possible.

Longer-term historical data presents some limited support for a medium-term link between output growth and productivity. Table 1 identified countries with very weak output growth over two selected historical periods. In the 1913-29 period such countries fell behind the US by an average of 10.2 percentage points (9.0 excluding Australia), whereas other countries averaged a constant relative productivity performance. Over the 1929-38 period, the weakest growing countries fell behind an average of 3.3 percentage points, while the remaining countries converged by 1.0 percentage point. These differences are statistically significant at the 10 per cent level and most often at 5 per cent (Table 6).

Table 6. Catching-up and output growth[1]

	(I) 1913-29, 1929-38	(II) 1913-29	(III) 1929-38	(IV) 1913-29 1929-38; outliers removed[2]
Coefficient on slow growth dummy	-7.12	-10.4	-4.55	-4.83
t-value	3.80	4.24	1.88	2.52
Adj. R^2	0.34	0.58	0.21	0.21
S.E.E.	4.93	4.48	4.60	4.51
Number of observations	30	15	15	27

1. The dependent variable is calculated by substracting the 1913 productivity level relative to the United States from the 1929 level and the 1929 level from the 1938 level. The independent variable is a dummy variable with a value of 1 if growth over the sub-periods averaged less than 1.5 per cent per year. All data are taken from Table 1.
2. The three data points showing slowest relative productivity growth were removed from the data set.

These results are striking because the failure of catch-up can not be viewed as resulting from a slowing of technological progress, as that was determined by the leading country. Rather, it would seem that countries in which output grew slowly over prolonged periods either because of a shock to demand or through a reduction in conventional inputs because of war losses were less able to assimilate the leading country's technology.

G. Energy, demography, labour market unrest, regulation

Energy prices, demographics, labour market unrest and regulation were among the first generation of explanations for the productivity growth slowdown. The slowing of productivity growth in the early 1970s was coincident with the first energy price shock and followed closely upon increases in other raw materials prices. The timing provided a plausible case that prices of energy/raw materials could be a contributing cause of the slowdown. Englander and Mittelstadt (1988) review these hypotheses and provide references to analyses on both sides of the debate. Shigehara (1992) notes that the negative impacts of energy, demographic and labour market unrest were reversed in the 1980s without there being much of a measured productivity impact. OECD (1993*a*) reviews the evidence on the effect of regulation, but it remains difficult to assess the impact of this factor.

H. Rent-seeking and structural rigidities

A number of analysts have raised the importance of providing individuals with incentives to channel their energies to productivity enhancing activities rather than rent-seeking, although not all of these analysts have traced the productivity slowdown to this latter factor (Baumol, 1986; Crafts, 1992; Lindbeck, 1983; Olson, 1982, 1988; Shigehara, 1992). Olson (1988) emphasises the role of special interests which have a strong incentive to seek private advantages to the detriment of society at large, while Lindbeck (1983) emphasises the increase in labour and product market rigidities during the prosperity of the 1960s. Crafts (1992) views rigidities and rent-seeking as major problems confronting the EC, but can not quantify these effects. Strong empirical evidence is difficult to find, and the available studies are difficult to evaluate. Studies (for example, Crafts, 1992) which relate cross-sectional productivity growth to single factors, such as litigations, short-terrnism, industrial subsidies and so on, run a risk that they are picking up one country's mode of rent-seeking, but not another's. The influence of, for example, farmers or small retailers, which is manifest in many countries cannot be captured by focusing on narrow segments of rent-seeking activity.

Nevertheless, despite the difficulties of measurement and the preponderance of anecdotal rather than numerical evidence, there is a strong intuitive appeal *to* the view that there has been an increase over time in rent-seeking and structural rigidities in most OECD economies (Shigehara, 1992). In the empirical work presented below, New Zealand, which undertook perhaps the most radical structural reform in the 1980s, was one of the few countries that is picked up in the statistical analysis of Section IV below as a positive productivity outlier in the 1980s.

I. Review of selected empirical work

Interest in the causes of productivity differences across countries has been reflected in recent empirical efforts to explain observed differences in productivity levels and growth. The relevance for OECD countries of four influential studies – Mankiw, Romer and Weil (1992), De Long and Summers (1992), Barro (1991), and Levine and Renelt (1992) – is assessed in Annex **B.** Although the authors generally stress that they are largely estimating descriptive, rather than structural equations, these studies are often cited in support of specific policy measures to boost productivity. To summarise the results in Annex B, the explanatory variables that appear important in samples which include both OECD and non-OECD countries have much less explanatory power when estimated for the OECD countries alone. This may reflect the fact that the OECD sub-sample is a smaller and considerably more homogeneous group, making it more difficult to identify the individual effects of the various explanatory variables on productivity. However, it may also imply that inferences drawn from the wider sample may be less relevant to the particular situation of OECD countries.

It is of interest to assess whether the proposed explanations can explain the evolution of productivity within countries, given that the primary focus of policy is on improving productivity performance within countries. The specific question asked is how much of slowing in productivity growth between 1960-75 and 1975-90 can be explained by the proposed regressions. Tables 7 and 8 report the results for De Long and Summers and Barro but the results are similar for other studies. For De Long and Summers, the decline in the equipment investment ratio (the variable that they tie to productivity growth) can account for a fall of only 0.2 percentage point, out of an average decline of 2.2 percentage points in the growth-rate of productivity. Moreover, there is very little correlation across countries as between the slowing in productivity growth and the change in the investment share. A similar result obtains when the Barro regressions are used to explain the slowing of productivity growth in different countries. The estimated contributions of changes in school enrolment rates and government spending as a proportion of GDP do not account for much of the productivity slowdown between 1963-75 and 1975-85 (Table 8). The school enrolment variable actually makes a (sometimes substantial) contribution in the opposite direction in most cases.

Table 7. Convergence, investment and the productivity slowdown

Average 1960-75 to average 1975-85

	Change in productivity growth-rate (% p.a.)	Estimated contribution from changes in				
		abour force growth	Productivity gap	Equipment investment share	Non-equip. share	Unexplained
Austria	-3.4	0.0	-0.8	0.1	0.0	-2.7
Belgium	-2.9	0.0	-0.8	-0.2	0.0	-1.9
Canada	-1.3	0.0	-0.3	-0.1	0.0	-0.9
Denmark	-0.7	0.0	-0.2	-0.5	0.1	-0.1
Finland	-1.9	0.0	-0.6	-0.7	0.1	-0.7
France	-3.4	0.0	-0.9	-0.2	0.0	-2.3
Germany	-2.2	0.0	-0.6	-0.5	0.1	-1.2
Ireland	-2.0	0.0	-0.4	0.4	0.0	-2.0
Italy	-2.2	0.0	-0.8	-0.4	0.0	-1.0
Japan	-3.7	0.0	-0.9	0.2	0.0	-3.0
Luxembourg	-1.7	0.0	-0.6	-0.4	0.0	-0.7
Netherlands	-3.3	0.0	-0.8	-0.7	0.1	-1.9
Norway	-0.3	0.0	-0.4	-0.1	0.0	0.2
Spain	-6.0	0.0	-1.0	-0.1	0.0	-4.9
United Kingdom	-0.6	0.0	-0.2	-0.4	0.0	0.0
United States	0.0	0.0	0.0	0.0	0.0	0.0
Average of above	-2.2	0.0	-0.6	-0.2	0.0	-1.4

Note: Productivity is defined as GDP per worker.
Estimated contributions from explanatory variables are derived from De Long and Summers' regression coefficients reported in column 1 of Table B.2 and the actual change in explanatoty variables between the two sub-periods.

Table **8. The productivity slowdown, education, convergence and government spending**

Changes between 1963-75 and 1975-85 period averages

	Chanae in business sector productivity growth	Estimated contribution from changes in			
		Productivity gap	School enrolment	Government spending	Unexplained
Austria	–3.4	–1.3	0.3	0.0	–2.4
Canada	–0.7	–0.6	0.2	0.0	–0.3
Denmark	–1.3	–0.?	0.3	–0.4	–0.6
Finland	–1.4	–0.8	0.6	–0.2	–1.1
France	–1.8	–1.2	–0.1	0.1	–0.6
Germany	–1.8	–1.0	0.1	0.0	–0.9
Greece	–5.6	–0.8	0.5	–0.1	–5.1
Ireland	–0.4	–0.6	0.6	–0.2	–0.1
Italy	–2.2	–1.1	0.4	0.0	–1.5
Japan	–4.1	–1.3	0.1	0.1	–3.0
New Zealand	–0.8	0.0	0.1	–0.1	–0.8
Norway	–2.4	–0.7	0.2	–0.1	–1.8
Portugal	–2.5	–0.4	–0.1	–0.3	–1.7
Spain	–1.8	–1.0	0.7	–0.2	–1.3
Sweden	–1.9	–0.7	0.2	–0.2	–1.2
Switzerland	–1.8	–0.6	–0.3	0.0	–0.8
United Kingdom	–0.3	–0.5	0.3	0.0	–0.1
United States	–0.8	0.0	0.0	0.2	–1.0
Average	–1.9	–0.7	0.2	–0.1	–1.3

Note: Totals may not add up due to rounding. Estimated contributions from explanatory variables are derived from regression shown in the last column of Table B.3.

II. EMPIRICAL ANALYSIS OF OECD PRODUCTIVITY GROWTH

A. Aggregate analysis

The aggregate analysis focuses on the productivity performance of nineteen OECD countries over four time periods (1960s-73, 1973-79, 1979-85 and 1985-90) primarily using as a data source the OECD's Analytical Data Bank (ADB).[14] The analyses were conducted simultaneously on labour productivity (LP) and total factor productivity (TFP), in part for comparability with other studies and in part because the measurement of the contribution of capital to output growth is so uncertain. The variables are measured as mean values over four periods and are defined in Table 9. The focus on OECD countries (and the exclusion of Turkey

Table 9. List of variables and data sources

Variable name	Source	Explanation
CDDUM		Set of country-specific dummy variables
DFIN[1]		Country dummy for Finland
DGRE		Country dummy for Greece
DGRE80		Country dummy for Greece in the 1980s; 0 in other periods
DITA		Country dummy for Italy
DNET		Country dummy for the Netherlands
DNET80		Country dummy for the Netherlands in the 1980s; 0 in other periods
DNZD		Country dummy for New Zealand
DNZD80		Country dummy for New Zealand in the 1980s; 0 in other periods
DUM1		Dummy variable for pre-1973 period; has value of 0 in other periods
DUM2		Dummy variable for 1973-79 period; has value of 0 in other periods
DUM3		Dummy variable for 1980-85 period; has value of 0 in other periods
DUM4		Dummy variable for 1985-90 period; has value of 0 in other periods
EMP	OECD ADB	Growth of business sector employment
ENER	Energy consumption data from International Energy Agency	Average ratio of energy consumption in industry and transport to business sector output
GAP	OECD ADB	Beginning of period ratio of labour productivity to that of the leading country, calculated using 1990 PPPs
GCON	idem	Ratio of government consumption expenditures to GDP
IBSH	idem	Nominal business investment as a share of nominal business output
IBVSH	idem	Real business investment as a share of real business output
INFL	idem	Average inflation rate (GDP deflator)
INFR	Constructed as in Ford and Poret (1991)	Growth of (broadly defined) infrastructure capital stock
K	OECD AD0	Growth of the business sector capital stock
KG7RD	Constructed as in Englander, Evenson and Hanazaki (1988)	Growth in R&D capital stock if G7 country; 0 otherwise
K/L[1]	OECD ADB	Growth in the capital to labour ratio
KRD	Constructed as in Englander, Evenson and Hanazaki (1988)	Growth in R&D capital stock

Table 9. **List of** variables and data sources *(cont.)*

Variable name	Source	Explanation
LF	OECD ADB	Growth in the labour force
LP	idem	Growth in output per employee in business sector
SECEN	Taken from the data set used in Barro (1991)	Beginning of period secondary school enrolment rate
TFP[1]	OECD ADB	Growth in output per weighted average of capital and labour inputs in business sector

1. Only the country dummies for which separate coefficient estimates are presented are listed.

Note: All growth rates are annual averages over the sub-periods, as given in the definitions of **DUM1** to **DUM4.** The starting year of the first period (associated with DUMI) is identified in footnote 1 of Table 1 in the next article.

and Portugal) permits testing hypotheses for a set of countries at relatively similar levels of development. The treatment of four separate productivity epochs provides a stronger test of the various hypothesised relationships – any results obtained are more conclusive if they can explain the evolution of productivity growth over time, as well as over a cross-section of countries. The end points of the time periods selected correspond roughly to business cycle peaks within the OECD, which helps to reduce the cyclical influence on average productivity growth over the periods chosen.

Overview. The first three rows of Tables 10 and 11 use an analysis of variance framework to describe the data. Simple dummies for the four periods account for about **42** per cent of the variance in labour and total factor productivity in the eighteen countries. Country dummies alone account for only 10 per cent of the variance when adjusted for degrees of freedom; jointly the period and country dummies account for about 70 per cent of the variance. In terms of average significance levels, the period dummies are far more significant than the country dummies: the common slowdown in labour and TFP growth after 1973 represents a far more important source of variation in the data than the average difference in growth between countries. The variation in the mean productivity growth rate in the 1980s periods relative to the 1973-79 period is small in magnitude and statistically insignificant. Introduced on their own, country dummies are barely significant at the 20 per cent level in explaining either TFP or labour productivity growth performance, whereas time dummies are highly significant.

Robust results. Three variables are found to be robustly correlated with LP growth: growth in the capital to labour ratio (positive), secondary school enrolment rates (positive) and labour force growth (negative). Estimated coefficients of these variables remain stable and significant irrespective of the (many) regression specifications experimented with. **As** the time dummy for the pre-1973 period remains highly significant, a substantial portion of the productivity slowdown remains unex-

Table 10. **Empirical analysis of labour productivity growth**[1]

Equation	DUM1	DUM3	DUM4	CDDUM	K/L	LF	SECEN	K	EMP	INFL	GAP	ENER	KRD	KG7RD	GCON	INFR	Adj.-R^2	S.E.E.
	Right-hand-side variables																Regression statistics	
	Estimated coefficients (abs. value of t-statistics in parentheses)																	
(1)	2.50	-0.16	[illegible]	–	–	–	–	–	–	–	–	–	–	–	–	–	0.42	1.33
	(5.75)	(0.36)	(0.91)															
(2)	–	–	–	N.L.[2]	–	–	–	–	–	–	–	–	–	–	–	–	0.08	1.69
(3)	2.49	-0.16	-0.40	N.L.[2]	–	–	–	–	–	–	–	–	–	–	–	–	0.65	1.04
	(7.33)	(0.46)	(1.17)															
(4)	2.25	0.16	[illegible]	–	0.39	-0.47	1.62	–	–	–	–	–	–	–	–	–	0.77	0.85
	(7.23)	(0.56)	[illegible]		(6.94)	(3.25)	(2.41)											
(5)	2.18	–	–	–	0.38	-0.49	1.71	–	–	–	–	–	–	–	–	–	0.77	0.84
	(7.53)				(7.30)	(3.58)	(2.60)											
(6)	2.17	–	–	–	–	-0.51	1.78	0.38	-0.36	–	–	–	–	–	–	–	0.77	0.84
	(7.26)					(2.80)	(2.80)	(6.98)	(2.94)									
(7)	1.88	–	–	–	0.34	-0.42	1.52	–	–	-0.06	-1.46	–	–	–	–	–	0.78	0.83
	(5.61)				(5.19)	(2.92)	(2.30)			(-1.61)	(1.54)							
(8)	2.06	–	–	–	0.33	-0.44	1.45	–	–	-0.05	-1.53	-0.08	–	–	–	–	0.78	0.82
	(5.82)				(5.20)	(3.10)	(2.20)			(-1.36)	(1.62)	(1.49)						
(9)	1.87	–	–	–	0.32	-0.44	1.52	–	–	-0.05	-1.06	–	0.05	–	–	–	0.78	0.82
	(5.60)				(4.75)	(3.08)	(2.30)			(1.42)	(1.07)		(1.37)					
(10)	1.83	–	–	–	0.31	-0.48	1.49	–	–	-0.04	-1.55	–		0.08	–	–	0.80	0.79
	(5.74)				(5.04)	(3.50)	(2.37)			(1.23)	(1.72)			(2.93)				
(11)	1.96	–	–	–	0.30	-0.51	1.53	–	–	-0.03	-1.61	-0.06	–	0.07	-2.09	–	0.80	0.79
	(5.70)				(4.55)	(3.65)	(2.38)			(1.00)	(1.79)	(1.07)		(2.44)	(0.78)			
(12)[3]	1.95	–	–	–	0.28	-0.68	1.24	–	–	–	–	–	–	–	–	0.20	0.77	0.84
	(4.65)				(3.09)	(4.25)	(1.03)									(1.81		
(13)[3]	I.84	–	–	–	0.30	-0.50	1.54	–	–	-0.08	-1.77	–	–	–	–	0.08	0.77	0.85
	(4.19)				(3.97)	(2.54)	(1.23)			(1.44)	(1.41)					(0.59		

1. Dependent variable: average growth of labour productivity in nineteen countries over four periods.
2. Individual country coefficients not listed. Joint significance level of 19 per cent and 1 per cent in equations (2) and (3). respectively.
3. Equations (12) and (13) are based on only 40 observations for 10 countries for which infrastructure data are available.

Equation	DUM1	DUM3	DUM4	CDDUM	WL	LF	SECEN	K	EMP	INFL	GAP	ENER	KRD	KG7RD	GCON	INFR	Adj.-R[2]	S.E.E.
	Right-hand-side variables																Regression statistics	
(1)	2.05	0.22	0.28	–	–	–	–	–	–	–	–	–	–	–	–	–	0.42	0.95
	(6.65)	(0.71)	(0.91)															
(2)	–	–	–	N.L.[2]	–	–	–	–	–	–	–	–	–	–	–	–	0.10	1.18
(3)	2.05	0.22	0.28	N.L.[2]	–	–	–	–	–	–	–	–	–	–	–	–	0.66	0.72
	(8.73)	(0.94)	(1.19)															
(4)	2.29	0.12	'0.13'	–	0.03	-0.49	1.72	–	–	–	–	–	–	–	–	–	0.54	0.85
	(7.31)	(0.29)	(0.30)		(0.55)	(3.47)	(7.54)											
(5)	2.13	–	–	–	0.02	-0.51	1.78	–	–	–	–	–	–	–	–	–	0.55	0.84
	(7.68)				(0.42)	(3.72)	(2.70)											
(6)	2.24	–	–	–	–	-0.51'	'1.78	0.02	-0.03	–	–	–	–	–	–	–	0.54	0.84
	(7.45)					(2.80)	(2.68)	(0.39)	(0.21)									
(7)	1.91	–	–	–	0.18	-0.43	'1.58	–	–	-0.06	-1.45	–	–	–	–	–	0.56	0.83
	(5.69)				(0.27)	(3.01)	(2.37)			(1.78)	(–1.52)							
(8)	2.11	–	–	–	-0.02	-0.46	-1.49	–	–	-0.05	-1.53	-0.09	–	–	–	–	0.57	0.82
	(6.01)				(0.32)	(3.23)	(2.27)			(1.50)	(1.63)	(1.71)						
(9)	1.90	–	–	–	-0.04	-0.45	1.57	–	–	-0.06	-1.06	–	0.05	–	–	–	0.56	0.82
	(5.68)				(0.57)	(3.15)	(2.37)			(1.59)	(1.08)		(1.28)					
(10)	1.86	–	–	–	-0.04	-0.50	1.54	–	–	-0.05	-1.54	–	–	0.09	–	–	0.60	0.78
	(5.85)				(0.68)	(3.63)	(2.46)			(1.40)	(1.72)			(3.02)				
(11)	2.01	–	–	–	-0.06	-0.53	1.57	–	–	0.04	1.61	-0.06	–	0.07	-2.18	–	0.60	0.78
	(5.91)				(0.90)	(3.81)	(2.47)			(1.13)	(1.80)	(1.30)		(2.48)	(0.82)			
(12)	2.02	–	–	–	-0.10	-0.72	1.51	–	–	–	–	–	–	–	–	-0.25	0.65	0.78
	(4.81)				(1.13)	(4.49)	(1.25)									(2.29)		
(13)	1.93	–	–	–	-0.09	-0.57	1.77	–	–	-0.07	-1.55	–	–	–	–	0.15	0.65	0.78
	(4.32)				(0.86)	(2.84)	(1.39)			(1.23)	(1.21)					(1.10)		

1. Depe[illegible]nt variable-TFP average growt[illegible] of total factor productivity in nineteen countries over four time periods.
2. Individual country coefficients not listed. Joint significance level for individual country dummies coefficients of 14 per cent in (2) and 1 per cent in (3).

Note: Equations (12) and (13) contain 40 observations for 10 countries for which infrastructure data are available.

plained by economic variables (Tables 10 and 11, row 4). The time period dummies for the 1980-85 and 1985-90 periods are not significant. As this is the case whenever these variables are entered, these dummies are dropped, with little effect on the size and significance of the estimated coefficients of other variables (row 5).[15]

Growth in capital intensity is a standard explanation of labour productivity growth in both neo-classical and "new" growth theories. The magnitude of the coefficient on capital intensity growth is about one-third, which is close to the response expected in neo-classical growth accounting approaches based on capital's one-third share in gross output. The data also support constant returns to scale – the absolute size of coefficients on capital stock and employment growth in the labour productivity equation are close to, and not significantly different from, each other, but of opposite sign (row 6 in Table 10).[16]

If large externalities were generated by capital accumulation ***per se***, TFP regressions would display an output response to capital stock growth that was positive, significant and greater in absolute size than that of employment growth. In the TFP regressions (rows 4-6 in Table 11), coefficients on capital growth, whether entered separately or together with employment growth, are invariably small and insignificant, as neo-classical growth theory would predict. Although not conclusive, this suggests that the increases in the capital to labour ratio that have accompanied productivity growth can be traced to the effect of technological advance on capital productivity, rather than to an extraordinary response of output to capital.

Labour force growth enters the equation with a significant negative coefficient (row 4 in Tables 10 and 11). A more rapid influx of workers will lower the average experience level and productivity of the work force, even if introducing workers who are on average better educated (in terms of years spent at school) than the ones they are replacing. The increase in the participation of women, many of whom with little experience and some with relatively low skills may also explain the result.

The magnitude of the estimated effects of new entrants is far too high *to* be explainable simply by the lower relative productivity of inexperienced workers, however.[17] The size suggests that the new workers in a large entering cohort may not only be less productive because of inexperience, but raises the possibility of additional negative effects due to initial productivity levels that are low for reasons other than inexperience, slower acquisition of on-the-job skills, or induced shifts away from labour saving technological progress. The first two possibilities are consistent with the evidence provided by Mincer (1991) that on-the-job human capital formation in the US became more difficult in the 1970s, when there was a rapid influx *of* (inexperienced) workers into the labour market.[18] Romer (1990*a*) argues that there is a long-run negative correlation between labour force and productivity growth in the United States because an influx of labour tends *to* reduce the pressures on firms to seek out productivity enhancing innovations.

Secondary school enrolment is a standard proxy variable for the educational attainment of the labour force and overall human capital investment (Levine and Renelt, 1992; Barro, 1991). The increase in average OECD enrolment rates from 70 per cent in 1960 to 95 per cent in 1985 is associated with about 0.6 percentage point per year faster productivity growth.[19] This is in the range of possible effects based on micro estimates in section I.C for the effects of increased education. Inclusion of this variable increases the difficulties in explaining the slow-down after 1973, however. Despite the significance, problems of measurement and lack of international comparability make it difficult to attach a strong structural interpretation to this coefficient.

Less robust results. A wide variety of factors have been proposed as being related to productivity growth. In various empirical experiments most of them were found to affect productivity growth in an intuitively plausible way, but their estimated effects were not always robust and their significance levels were low, particularly when all were included simultaneously. This may reflect the multicollinearity that is inevitable when so many regressors are included.

Among these variables the two that are relatively robust are inflation and catch-up (row 7). Both have estimated coefficients of plausible orders of magnitude with t-values not too far below standard levels of statistical significance. The estimated effect of catch-up is to close productivity gaps between the leading country and follower countries at about 1.5 per cent per year, which is at the low end of estimates obtained in most other studies.

The estimated effect of an additional 10 percentage points of inflation is to lower productivity growth by about 0.6 percentage point. This is a stronger effect than is found in a number of studies covering broad cross-sections of countries (Fischer, 1992; Corbo and Rojas, 1992), but smaller than those found using time series methods (for example, Jarrett and Selody, 1983).[20] More recent work by Cozier and Selody (1992) finds an inflation effect close to that found here, although they do not test whether the inflation effect is independent of energy price shocks.

The estimated impact of inflation on productivity should be interpreted with care, however. The straightforward "structural" view is that inflation leads to errors in decision-making, unproductive use of capital due to shifting wealth into inflation-proof assets, and distortions in investment because most contracts and tax rules are based on nominal values.[21] A second possible interpretation relates to structural flexibility, however. Countries which inflated as a way of smoothing the response to various shocks may have done so because rigidities in their economies precluded *a* less accommodative response. The estimated impact of inflation on productivity would thus in part capture the adjustment difficulties of rigid economies, in addition to any direct impact of inflation. However, the introduction of an energy price variable does not greatly affect the estimated inflation response. A 1 percentage point per year fall in the ratio of real energy consumption to real business sector GDP is estimated to reduce productivity growth by about 0.08 (0.09 in the TFP equations) percentage point, while the estimated inflation effect remains at about the same size (row 8).

Research and development spending also has a correctly signed effect when added to the basic equation (row 9) although the coefficient is not significant by conventional standards; a 1 percentage point increase in the growth in the R&D capital stock is estimated to raise productivity growth by about 0.05 percentage point. However, the effect appears stronger and better determined for G-7 countries where the response is about 0.08 percentage point and more significant (row 10).[22] The estimated effect of own R&D for small countries was small and unstable. This is consistent with the results reported in the literature on spillovers, which suggest that large countries benefit to a great extent from their own R&D, while small countries benefit largely from the R&D done elsewhere, interacting perhaps with their domestic R&D (Coe and Helpman, 1993; Cohen and Levinthal, 1991). The share of government consumption expenditures in GDP also was estimated to have a small effect in some regressions, but it was not very large or significant. Barro (1991) found a negative effect in a wider cross-section of countries, possibly because of the distortions that accompany large government claims on income to finance public expenditure.

The various "secondary" effects discussed above are entered simultaneously in row 11. On the whole, the coefficients on these variables remain reasonably stable with neither a big loss nor gain in significance.

Given its policy relevance, the growth of infrastructure capital was included separately in the equation, but there are fewer observations because data are unavailable for seven countries (row 12). The order of magnitude of the estimated coefficient (around 0.2) is on the low end of most estimates and about the same as that obtained by Ford and Poret (1992). It is also unstable, and is reduced by more than half if, for example, catch-up and inflation are also entered (row 13).

Associations not found. Financial deepening variables were not found to have any effect on productivity growth, in contrast to results reported by King and Levine (1993*a*). However, Pagano (1993) points to the need for a disaggregation as between financial market innovations that are oriented to business as opposed to households, while the short-termism discussed in Shigehara (1992) may offset some of the potential benefits of financial market depth. Nor did measures of trade intensity or trade growth, whether or not adjusted for country size turn out to be significant. The share of the work force leaving agriculture had a positive effect in a few regressions but was very unstable. These negative results may just reflect the crudeness of the measures that were available for these factors, rather than the absence of an underlying relationship.[23]

A special role for capital? The results above are consistent with the assumption of constant returns to scale for the aggregate economy, and with returns to capital that were in line with the observed share of capital in income. Possible externalities to capital accumulation and investment have important potential policy implications for improving growth performance. Studies by Scott (1989), Lucas (1988) and Romer (1986) raise the possibility that investment and capital accumulation may have a far greater impact on output and productivity growth than conventional growth accounting calculations would suggest. This section focuses more closely on the evidence that alternatives to standard measures of the growth in the physical capital stock may provide a better explanation of productivity growth, and two such measures – nominal and real gross investment shares – are discussed in detail, given the attention paid to them in the recent literature.

Results that point to an important role for capital – including apparent externalities – are not difficult to obtain, but they turn out to be fragile. Capital accumulation is positively (and strongly) correlated with productivity growth: in a simple bivariate regression capital stock growth accounts for about 73 per cent of the variance in LP growth. A percentage point increase in the average rate of capital accumulation is associated with an acceleration of LP growth of 0.56 percentage point (Table 12, row 2), and about 0.3 percentage point for TFP growth. (The TFP results are available on request.) This is reasonably close to the non-diminishing marginal product of capital that is postulated in some models for endogenous growth and, if robust, would raise the possibility of substantial externalities to capital accumulation that would justify investment and/or saving incentives.

The correlation between capital accumulation and productivity growth slips sharply when either a catch-up variable is introduced or when the time dummy variable is restored (Table 12, rows 3 and 4). In fact, there is little or no apparent productivity bonus to additional capital beyond what is implied by the standard theory, which implies a coefficient of about 0.33. These results are fairly consistent in both LP and TFP equations.

Some studies have suggested that the investment share is closely linked to productivity growth (although in some of these studies it is unclear whether investment ***per se*** is the variable of interest or whether it stands in for unavailable capital stock data). New capital may be better than old capital to a greater extent than is captured by standard quality change adjustment. Scott (1989) argues that investment by its nature creates new profit opportunities; while new investment makes past investment redundant, no output loss results from this induced scrapping. On *a* ***priori*** grounds, he argues that there are non-diminishing returns to investment.

The empirical analysis provides no evidence that investment flows are more closely correlated with labour productivity growth than capital stock growth. Row 1 of Table 12 provides a baseline equation that replicates equation 10 of Table 10 but does not impose equality (in absolute value) on the coefficients of capital and labour. Rows 5 and 6 replace the capital stock with the nominal and real shares of investment, respectively. There is no evidence that the investment shares individually explain more of the variation in productivity growth. When the real and nominal investment ratios are included **in addition** to capital and labour growth (rows 7 and 8), the coefficient of the nominal investment ratio is almost statistically significant, although the estimated coefficients imply very small productivity growth effects from increased investment shares.

Table 12. The role of investment and capital in explaining labour productivity growth'

Equation	Right-hand-side variables										Regression statistics	
	DUM1	LF	SECEN	INFL	GAP	KG7RD	K	EMP	IBVSH	IBSH	Adj.-R^2	S.E.E.
	Estimated coefficients (abs. value of I-statistics in parentheses)											
(1)	1.84 (5.74)	-0.38 (2.03)	1.50 (3.37)	-0.05 (1.40)	–1.64 (1.80)	0.09 (3.00)	0.30 (4.66)	-0.40 (3.11)	–	–	0.80	0.79
(2)	–	–	–	–	–	–	0.56 (4.29)	–	–	–	0.73	1.32
(3)	–	–	–	–	-3.48 (3.46)	–	0.37 (4.29)	–	–	–	0.50	1.24
(4)	1.81 (5.29)	–	–	–	–	–	0.38 (5.29)	–	–	–	0.58	1.18
(5)	1.93 (5.07)	-0.43 (1.97)	1.07 (1.48)	-0.07 (1.76)	-3.93 (4.23)	0.11 (3.31)	–	-0.25 (1.76)	1.10 (0.38)	–	0.73	0.90
(6)	2.04 (5.37)	-0.51 (2.27)	1.17 (1.63)	–0.06 (1.43)	-3.49 (3.64)	0.12 (3.49)	–	-0.24 (1.69)	–	4.63 (1.33)	0.74	0.90
(7)	1.92 (5.80)	-0.42 (2.19)	1.57 (2.45)	-0.04 (0.99)	–1.29 (1.31)	0.09 (3.12)	0.31 (4.73)	0.39 (3.09)	2.46 (0.96)	–	0.80	0.79
(8)	1.99 (6.02)	0.48 (2.73)	1.63 (2.57)	0.03 (0.80)	–1.04 (1.06)	0.09 (3.22)	0.30 (4.72)	-0.38 (3.02)	–	4.77 (1.57)	0.80	0.78

1. Depend t variable-LP: average growth of labour Productivity in nineteen countries over four periods.

Why did productivity growth slow down?

In a typical regression, such as row 10 of Table 10, the dummy variable for the pre-1973 period is the most important variable in explaining the labour productivity growth slowdown. The importance of such period dummies signifies that the productivity growth slowdown was caused by slower exogenous technological progress or other factors unrelated to the variables included in the regressions. Hence, restoring the other explanatory factors to their 1960s levels would not return productivity growth to its former speed.

Table 13 shows how each of the major influences on productivity growth has contributed to its evolution over time, based on simple averages across countries. Growth in the capital to labour ratio slowed from an average of 5.5 per cent per year before 1973 to about 2.2 per cent in 1985-90, contributing about 1 percentage point to the slowing of labour productivity growth between the two periods.[24] For the OECD on average, labour force growth has virtually no trend over the period so it contributes virtually nothing to the slowing of productivity on average, although there was some variation within countries as well as between them. The slowing of R&D capital growth and the catching up of OECD economies contribute 0.1 and 0.4 percentage point, respectively. Inflation was back to 1960s levels by the late 1980s and so does not contribute to the remaining slowdown. Offsetting these various downward effects is the big upward contribution of the rise in secondary school enrolment rates that contributes about 0.4 percentage point to productivity growth.

Taking the combined effects of all explanatory variables, this still leaves a residual post-1973 productivity slowdown of 1.8 percentage points. Whether this represents a genuine slowing of technical progress, as the "technological exhaustion" hypothesis of Evenson (1991) would suggest, rent-seeking and increased rigidity as suggested by Lindbeck (1983) and Olson (1982, 1988), or other unmeasured factors, such as financial-market developments or exchange-rate regimes, remains an open question.

Country-specific effects. The empirical results presented thus far exclude country-specific effects. Identification of such country-specific effects would be helpful for policy analysis by permitting some assessment of relative productivity performance, given the identified determinants of productivity growth.

Residuals from the regression in row 10 of Table 10 were examined because the variables included were found to have reasonably robust effects on productivity growth. Relative to the predicted values only New Zealand and Greece have actual productivity performances on average that are more than a half percentage point below the predicted value for the period as a whole. Italy, Finland, the Netherlands and Spain are at least 0.5 percentage point better than predicted, with Belgium just below this threshold. When separate country dummies were introduced for these outlying countries, the estimated coefficients of the economic variables did not change very much on the whole (Table 14, regression 1 versus regression 2). When the remaining country dummies were added to the column 2 regression as a test of whether the included country-specific effects caught all

Change from	Productivity slowdown due to						Total explained by behavioural vanables	Contnbution of pre-1973 dummy	Residual	Total slowdown
	K/L	LF	GAP	INFL	KG7RD	SECEN				
Pre-1973 to 1985-90	–1.0	0.0	-0.4	0.0	–0.1	0.4	–1.1	–1.8	0.0	–2.9
Pre-1973 to 1973-79	4.4	-0.1	4.2	-0.2	-0.1	0.3	-0.7	–1.8	–0.1	–2.5
1973-79 to 1980-85	-0.3	0	-0.1	0.1	0.0	0.1	-0.2	n.a.	0.1	–0.2
1980-85 to 1985-90	4.3	0	–0.1	0.1	0.0	0.0	-0.3	n.a.	-0.1	-0.2

Table **14. Empirical analysis with country-specific effects**

Right-hand-side variable	Estimated equation					
	(1)		(2)		(3)	
	Estimated coefficient (abs. value of t-statistic in parentheses)					
DUM1	1.83	(5.74)	1.71	(6.19)	1.74	(6.72)
WL	0.31	(5.04)	0.33	(5.65)	0.28	(4.60)
LF	–0.48	(3.50)	-0.33	(2.65)	-0.24	(2.04)
SECEN	1.49	(2.37)	1.65	(2.87)	1.75	(3.30)
INFL	-0.04	(1.23)	-0.05	(1.70)	-0.06	(2.07)
GAP	–1.55	(1.73)	–2.40	(2.89)	–2.77	(3.55)
KG7RD	0.08	(2.93)	0.06	(2.16)	0.06	(2.28)
DITA	–	–	0.96	(2.24)	1.03	(2.53)
DFIN	–	–	0.70	(1.82)	0.70	(1.98)
DGRE	–	–	-0.82	(1.87)	0.01	(0.02)
DGRE80	–	–	–	–	–1.36	(1.83)
DNET	–	–	0.93	(2.55)	1.53	(3.32)
DNET80	–	–	–	–	–1.27	(1.93)
DSPA	–	–	0.57	(1.46)	0.73	(2.00)
DNZD	–	–	-0.96	(2.59)	–1.86	(–3.93)
DNZD80	–	–	–	–	1.68	(2.63)
Adjusted-R^2	0.80		0.86		0.88	
S.E.E.	0.79		0.67		0.61	

Note: The dependent variable is the same as in Table 10.

the relevant variation, these additional country effects were jointly not significant at the 50 per cent level (results available on request). Further examination of whether country-specific effects had changed over time (regression 3) showed shifts in New Zealand, which rebounded sharply in the 1980s from a poor performance previously; the Netherlands, whose productivity performance in 1980s was about average after having been above average before; and Greece, which experienced a sharp fall-off in the 1980s from an average performance before. Again, the magnitudes and significance of the economic variables were not greatly affected.[25]

B. Industry level analysis

Industry-level data are of interest because they provide information on whether convergence has proceeded unevenly across industries due to regulatory or structural problems. However, the quality of industry-level data falls short of that of aggregate data, because of the difficulty in harmonising definitions across countries and the difficulties in properly accounting for intermediate inputs and deflating sectoral value-added within countries.

Notwithstanding this caveat, industry-level data can shed additional light on the factors underlying productivity gains: they can be used as a rough indicator of the relative importance of structural and technological factors in productivity growth. If productivity growth in follower countries depended only on acquisition of modern technology, then catch-up should proceed more or less uniformly across industries within a country and over time. If there is great variation in the pace of sectoral catch-up – and especially if follower countries catch up at different paces in different industries – this suggests that productivity growth in some sectors may be inhibited by structural factors other than the availability of technology.

Manufacturing. Data from several sources suggest that the process of catching-up has been interrupted in many manufacturing sectors and countries since the early 1970s.[26] Table 15 presents the shares of manufacturing output and employment that are accounted for by sectors that did **not** catch-up over the 1970-1990 period. Catch-up did not take place in sectors accounting for close to or more than half of manufacturing production and employment in France, the United Kingdom, Denmark, Sweden and Norway. In Germany and Canada both sets of indicators suggest that the proportion of manufacturing falling behind was far more than one-half. Differences between these countries and Japan in part

Table **15. Share of manufacturing output and employment in lagging industries[1]**

	ISDB		STAN	
	output	Employment	Output	Employment
Japan	13	18	19	26
Germany	84	84	85	84
France	47	54	79[2]	79[2]
Italy	0	0	65[2]	72[2]
United Kingdom	44	53	61	71
Canada	62	63	92	95
Belgium	5	7	–	–
Denmark	52	55	–	–
Finland	0	0	4	8
Netherlands	3	4	–	–
Noway	–	–	75	85
Sweden	69	72	–	–

1. A lagging industry is defined as a sector in which productivity growth over 1970-89 was lower than in the United States.
2. Based on 1980-89.

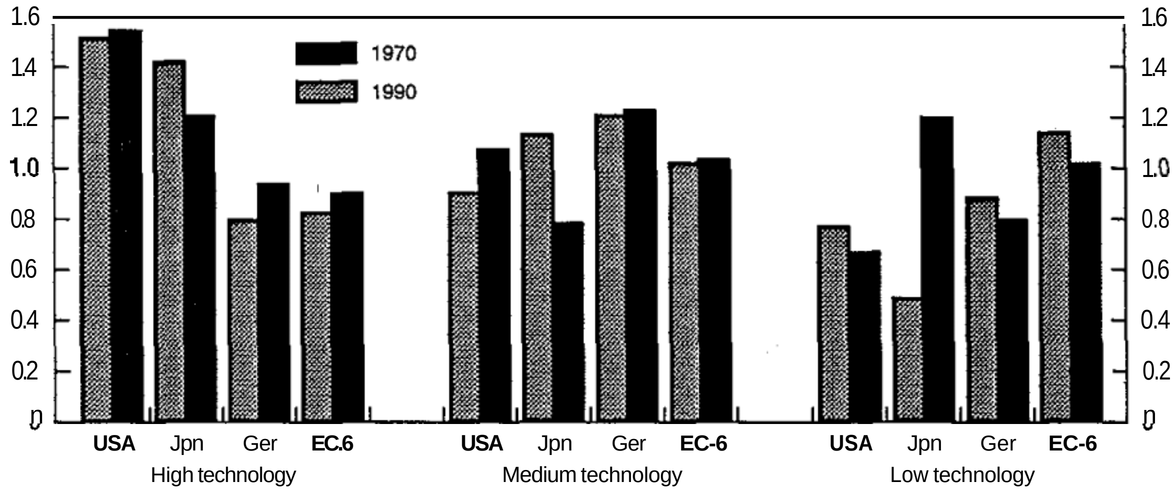
Note: The data are taken from the International Database (ISDB) and Structural Analysis (STAN) industrial database at the OECD. The two databases differ somewhat with respect to data sources and the methods by which sectoral data are reconciled with aggregate totals. The ISDB is described in Meyer-zu-Schlochtern (1993) and STAN in OECD (1992e). Both are available commercially.

reflect the fact that Japan started from a lower level, but it is puzzling that such a large share of manufacturing fell further behind. Although not shown in the table, in each of these countries, the machinery and equipment sector which contains most of the so-called "high-tech" industries is among the lagging sectors. The relatively weak performance of high-tech is also suggested by a comparison of OECD's Directorate of Science, Technology and Industry (DSTI) Revealed Comparative Advantage (RCA) indicator, which slipped in Germany and overall in the EC between 1970 and 1990 (Figure 4).[27]

Van Ark and Pilat (1993) provide sectoral manufacturing productivity **level** data for the United States, Japan, and Germany. In Japan there has been significant and uninterrupted catch-up in aggregate output per hour worked in the post-war period to 1989, but the pace of catch-up in different sectors of the economy has been very uneven (Table 16). In Germany the pace of catch-up has been more modest but also more even across sectors.

In both Japan and Germany, the sectors with the highest relative levels of TFP are no longer necessarily those with the highest relative capital intensity (Figure 5). On the whole in 1990 there was a slight negative correlation between relative TFP levels and capital intensity (bottom panel of Figure 6); the relatively inefficient sectors in the two countries appear to use more capital relative to the United States. However, the additional capital intensity is not enough to bring

Figure 4. Revealed comparative advantage
1970 and 1990



Note: EC-6 include Germany, France, Italy, the United Kingdom, Denmark and the Netherlands. Revealed comparative advantage (RCA) is an indicator developed by the OECD Directorate for Science Technology and Industry. It is the ratio of each sector's share in a country's manufacturing exports divided by its share in manufacturing output. Thus, the weighted average is one. An industry with high exports relative to production would have a RCA greater than one. Annex D presents the industry classification into high, medium and low technology sectors.

Table 16. **Value added per hour worked in manufacturing in Germany and Japan**
United States = 100

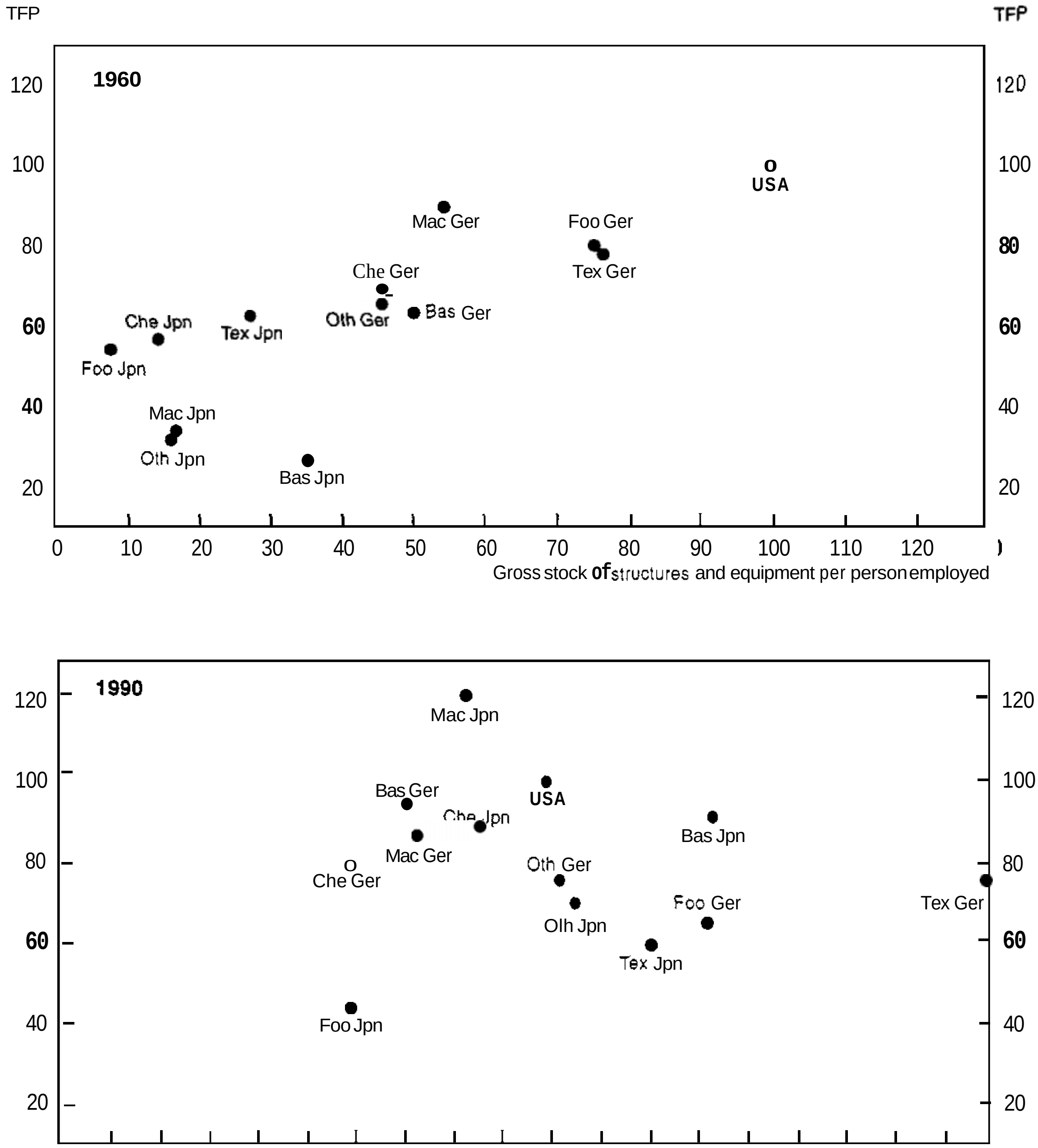
	1950[1]	1965	1973	1979	1990
Germany					
Food, beverages and tobacco	53.1	76.9	68.4	74.1	71.8
Textiles, apparel and leather	44.0	78.1	81.0	85.9	93.0
Chemicals and allied products	32.4	64.3	90.5	106.0	71.2
Basic and fabricated metal products	30.9	53.6	67.2	90.1	91.1
Machinery and equipment	43.7	77.1	90.0	110.7	83.2
Other manufacturing	34.2	56.6	68.8	80.1	78.2
Total manufacturing	38.9	66.7	79.7	95.8	82.1
Japan					
Food, beverages and tobacco	24.5	23.6	40.8	41.0	36.2
Textiles, apparel and leather	41.9	62.9	74.6	76.6	54.9
Chemicals and allied products	17.7	41.4	61.3	81.8	80.2
Basic and fabricated metal products	17.8	32.9	74.3	96.6	100.5
Machinery and equipment	8.6	25.7	52.9	88.2	116.3
Other manufacturing	11.3	21.3	38.9	42.7	63.2
Total manufacturing	18.3	29.3	55.6	69.9	82.1

1. For Japan: 1955.
Source: Van Ark and Pilat (1993).

labour productivity much closer to US levels. This corroborates the observation made above at the aggregate level that the association of TFP and capital intensity is less apparent after 1973 than before.

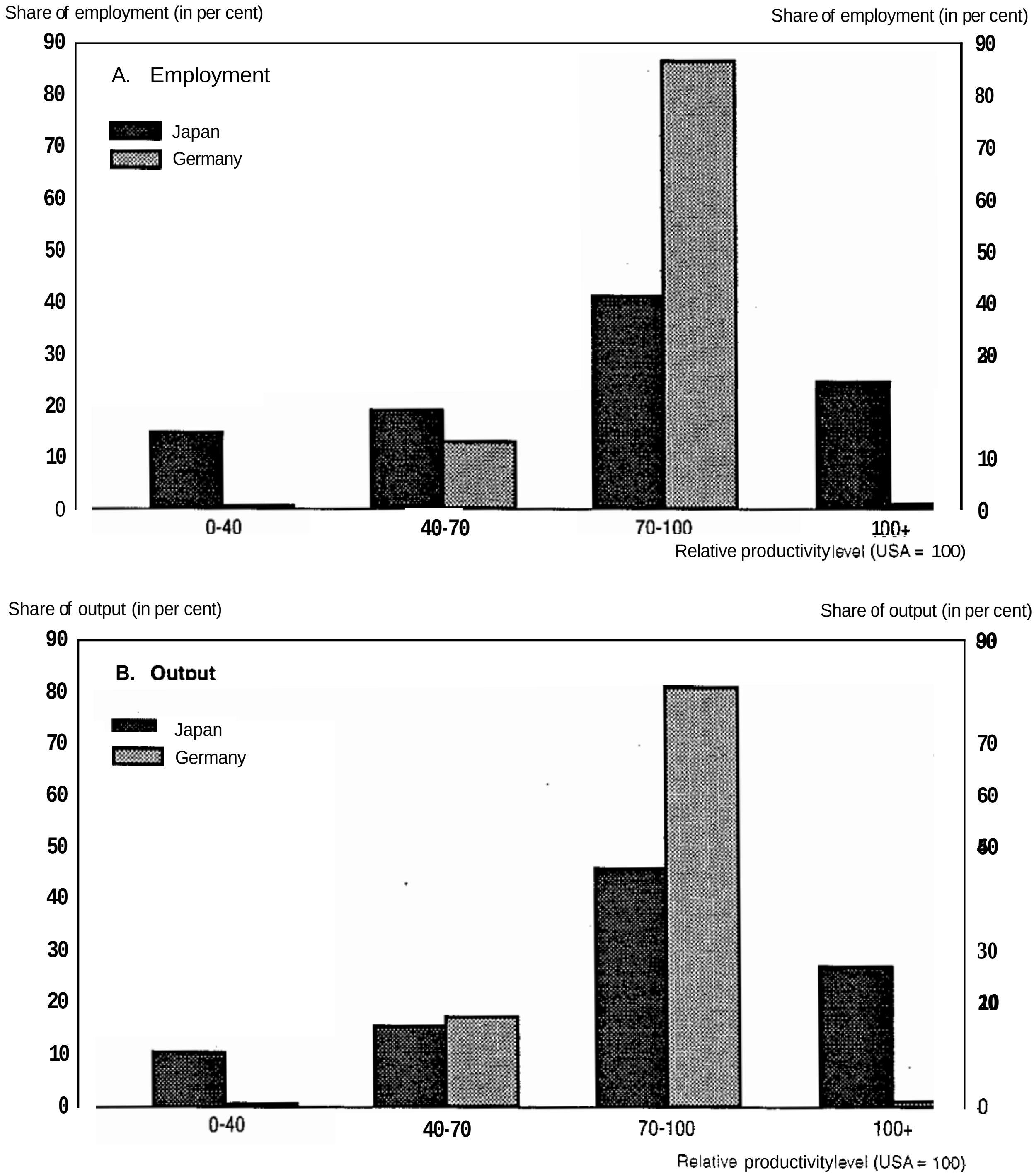
More disaggregated manufacturing sector data show a wide divergence in sectoral labour productivity performance relative to the United States (Figure 6). About 25-30 per cent of Japanese manufacturing employment and production originates in sectors with hourly labour productivity reaching or exceeding that of the United States. However, about 27 per cent of manufacturing output (with 34 per cent of employment) is produced in sectors with relative productivity levels less than 70 per cent of those of the United States. In Germany, only 18 per cent of production (with 13 per cent of employment) occurs in industries with productivity levels less than 70 per cent of those in the United States. (Indeed, more than 50 per cent falls in the 90-100 per cent range, relative to the United States.) However, the data do not suggest that productivity levels in Germany exceed those of the United States in any of the examined sectors. The source of the lag is not a shortage of capital, and given modern communication techniques and foreign trade, it seems unlikely that it is lack of access to state-of-the-art technology. Competition and catch-up to best practice levels can provide substantial scope for rapid productivity growth in these sectors.

Figure 5. Relative TFP and capital intensity in manufacturing sectors in Japan and Germany
USA= 100



Foo = Food, beverages and tobacco.
Tex =Textiles, apparel and leather.
Che = Chemicals and allied products
Bas = Basic and fabricated metal products.
Mac = Machinery and equipment.
Oth = Manufacturing.
Source: Van Ark and Pilat (1993).

Figure 6. **Share of manufacturing employment and output classified by relative productivity levels**



Note: The chart shows the distribution of employment and output in Japanese and German manufacturing industry classified according to the productivity of the industry relative to that in the United States. For example, about 40 per cent of manufacturing employment in Japan and 85 per cent in Germany are found in industries whose productivity levels are 70-100 per cent those of corresponding US industries.

Source: Van Ark and Pilat (1993).

Non-manufacturing. There are less data available on non-manufacturing than on manufacturing. Value-added and productivity comparisons are particularly difficult because the output produced is often intangible and therefore difficult to measure. Hence, all comparisons are extremely tentative, and some inconsistency may be encountered. Baily (1993) and McKinsey Global Institute (1992) provide comparisons of productivity performance in selected service industries. They conclude that service sector productivity is higher in the United States than in Europe and Japan and suggest that the large remaining potential for catch-up can be found in the service sectors. These studies conclude that barriers to competition and regulation (and not access to technology) in transportation and communications – sectors largely characterised by public or quasi-public ownership outside the United States – were responsible for much of the lagging behind in the service sector. In retailing productivity gains have been hindered by limitations on opening hours, store size and choice of location.[28]

III. POLICIES TO PROMOTE PRODUCTIVITY GROWTH

The discussion presented above suggests that there is no simple way to boost productivity growth. This section first provides a discussion of some of the general considerations that relate to the influence of policy on productivity, and then proceeds to a discussion of more specific policy options.

A. General considerations

Historically, there are few episodes of labour productivity growth exceeding 2 per cent per year on average for long periods of time in the technically most advanced country. Aggregate productivity growth exceeded this rate in a number of countries in the post-war period, but this appears largely to have been based on a process of imitation of the technology in use by the leading economy.[29] Gains from such a process diminish as levels of technology approach those in the leading country. However, over the short and medium term the once-off gains in productivity levels in lagging sectors may be substantial.

Market openness. Some empirical evidence was presented that greater openness improves productivity performance. The post- and pre-World War II record also suggests a connection between trade and productivity performance. Indeed, the lack of catch-up between 1913 and 1950 may be related to the barriers that two world wars and the Great Depression put in the way of international integration. The literature provides mixed evidence as to whether such interventionist policies succeed, and even in countries where they have accompanied rapid economic growth, the effectiveness of such policies is debated.[30] On the whole, other than an ultimate criterion of supporting firms that can demonstrate export success, there does not seem to be a reliable policy rule that one could follow to identify and support infant/leading edge industries without running substantial risk of distorted resource allocation.

In most OECD countries trade interventions (as well as subsidies) have largely focused on protecting industries to which few of the infant industry/high-tech externality arguments apply. The importance of high-tech support is relatively small, as compared with the support of agriculture, textiles, automobiles and steel. The protection given to these industries locks resources into areas where their economic value is low at the margin. Moreover, such policies may create some disincentive to future performance, if there is a pervasive sense that the bureaucracy or legislature will routinely bail out failing firms or industries.

Resistance to change. In practice, exploiting catch-up potential often entails changes in the industrial structure and in income distribution that may be strongly resisted. Groups who benefit from the current system and stand to lose from change have an incentive to block regulatory reforms that create both opportunities and pressure to improve productivity. Added spending on education, private and public investment, and R&D is less threatening to individual interest groups than enforcing more reliance on markets and less interference with international trade; given the interaction of institutional set-ups and vested interest, too much reliance on "productivity enhancing" public spending and too little reliance on competitive markets may result.

When productivity gains are rapid and concentrated in some specific sectors, there is a conflict between the visible impact on factors of production in the sectors directly affected and the indirect benefit experienced by society as a whole. Looked over centuries, productivity has advanced without there being a noticeable upward trend in unemployment, and the pre-1973 period of rapid productivity growth and trade penetration was characterised by very low unemployment rates. At the sectoral level, fear of unemployment and lost industry-specific human and physical capital underlie much opposition to productivity-enhancing reforms.[31] When price elasticities of demand for a product are less than one, differential productivity growth rates across sectors will tend to lead to some shedding of labour in the sector experiencing the improvement.

When overall unemployment rates are high the (often justified) fear of being unable to find another job may make workers resist productivity change, often in concert with managers. When there are barriers to entry in product markets, firms may use productivity improvements to widen margins (or share rents with employees) rather than lower prices, so that there is little initial increase in output and capacity in the sector concerned. Social conflicts related to innovation are made more difficult when new technology appears to be biased in favour of employing skilled workers. An unskilled worker who is made redundant may perceive that he has little chance of re-employment at an acceptable wage.

B. Specific policy options

Fixed investment promotion. Available evidence supports the view that technological progress is capital-using and partly embodied in capital goods. Hence, disincentives to saving and investment are likely to have negative effects on the level of productivity. However, there does not seem much basis for intervention to actively encourage additional investment, in the form of generalised or targeted incentives to accumulate capital, beyond what would result in competitive markets. While technical progress will usually stimulate investment, merely adding more capital (without raising its technology content) is far from certain to improve efficiency.

Expanding infrastructure. The possibility of boosting productivity through an accelerated build-up of public infrastructure has received increased attention by policy makers recently. However, the empirical methods used in many of the studies that find a very high return to infrastructure seem biased towards overstating the productivity impact of infrastructure.[32] Case-by-case analysis of individual infrastructure projects is likely to remain necessary to assure an efficient allocation of resources. Better pricing of congested facilities would be an important step to achieve greater efficiency. It would also provide more reliable information as to which facilities are in short supply, and thus provide signals as to where to expand infrastructure most profitably.

Improving education. Empirical evidence of high correlation between educational attainment and productivity levels and growth was found. But as in the case of infrastructure capital, the question of the direction of causality is important. While basic scholastic skills are obviously a necessary condition to implement technology, the incremental value of additional schooling in countries where average length of schooling is already high is less obvious, and probably greatly depends on the type and quality of education. The rising relative wages of skilled labour that is observed in some countries in the presence of an increasing supply of educated workers nevertheless suggests rapidly expanding demand for human capital and skills.

The empirical results presented in this paper (and elsewhere) also suggest that faster labour force growth is strongly associated with slower productivity growth, well beyond its moderating effect on capital deepening. This is possibly due to the difficulties of absorbing and training an influx of new workers. Countries in which labour force growth is high (in the sample of OECD countries the mean is about 1 per cent of the labour force per year) may require policies that improve job matching and enhance the on-the-job skill acquisition of new entrants.

Promotion of R&D. R&D seems to have high social as well as private returns, partly reflecting high risk. Estimated ratios of social to private returns to R&D range from about 1.5 to 3 on average. Given the implied large externalities, favoured treatment via full expensing or other tax incentives seem justified. However, such tax-based provisions favour firms that are making profits against which deductions or credits can be written off. Even if tax write-offs can be carried forward, they do not greatly help venture capital or start-up companies, as their discounted value may be low and firms may be cash-constrained in the early years of product development. Some favourable treatment of capital gains is probably justified for the risk incurred.

It should be noted, however, that R&D is an aggregate of very heterogeneous components, making generalised policy recommendations difficult. There is no *a priori* reason to provide special fiscal incentives to those types of R&D whose benefits can be fully appropriated by the firm. Only where R&D clearly has positive external effects are such incentives justified. Such a distinction is difficult to make in practice, and the existence of fiscal incentives for R&D also creates potentially important tax loopholes.

The role of government research in raising productivity is unclear. Studies, such as Lichtenberg (1992) and Cohen and Noll (1991), show limited productivity benefit to directly funded government R&D, although it should be kept in mind that improvement of business sector productivity has not been the primary objective of much government-funded research. However, this work suggests that spin-off benefits from government funded research may not be as great as once thought, the well-documented cases of commercial aircraft notwithstanding.

Macroeconomic policy. This paper focused largely on structural determinants of productivity growth on the grounds that such structural factors are likely to be the major determinants of medium-and long-term productivity trends. On the whole, the view that the upside of the business cycle was most conducive to more rapid productivity growth seemed the most compelling, although the magnitude of such effects is unclear. The cyclical experience of the post-war period does suggests that policy-induced expansions do not generate sufficient productivity gains to prevent inflation from emerging subsequently.

This paper also found that higher inflation levels tended to be associated with lower productivity growth. This corroborates results found in other studies, but it remains to be determined whether the association reflects primarily direct causal effects from inflation to productivity, or other structural problems that lead to both lower productivity and higher inflation.

From a practical side, there is likely to be less resistance to reform at full or rising resource utilisation because the risk of long spells of unemployment will be reduced. Workers may be less resistant to productivity increasing reforms if they have better prospects of employment elsewhere in case their job is eliminated.

NOTES

1. Their recently available data also make it possible to correct, albeit crudely, for compositional differences in the capital stock: attaching a higher rental rate to machinery and equipment, relative to construction capital, does not greatly alter the picture provided by the figures.
2. The capital stocks are calculated under two different assumptions on capital depreciation – "one-hoss shay" in which capital retains its effectiveness throughout its useful life and then is scrapped; and double declining balance – in which the production capacity of a unit of capital declines roughly geometrically over time. Both methods provide similar results, but one-hoss shay requires a long time series of data in order to be valid, so only data for 1990 are presented.
3. Of course, standard neo-classical growth theory and its empirical implementation in growth accounting treat TFP and capital intensity as being independent. In this framework, increased capital to labour ratios would not raise TFP levels. A simple interpretation of the observed data is that TFP growth has slowed, but capital accumulation has not slowed to the same degree.
4. For example, in many areas the TFP increase associated with the "Green Revolution" could materialise only with additional investment in irrigation and mechanisation.
5. A standard growth accounting exercise, using OECD gross capital to output ratios of about 2.5 and capital shares of about 33 per cent, would predict that output growth would rise initially by about 0.13 percentage point for each percentage point increase in investment share (*i.e.* 0.4 x 0.33; the output to capital ratio multiplied by the share of capital). This would raise the growth rate of the capital stock and output for at least 13 years, the assumed life of equipment. After 29 years, growth would fall back to the original rate as the higher investment levels just offset the plant that is assumed to go out of service.
6. For example, the Congressional Budget Office (1991) reports that classes of infrastructure that are closely linked to demand often have higher correlations with output growth than the infrastructure thought most likely to improve productivity growth.
7. Although the procedure adopted by Lynde and Richmond (1993) corrects for some endogeneity problems, there appears to be nothing in their approach which can identify whether the estimated coefficients represent underlying supply or demand relationships.
8. The bottom end of this range is based on a 5 per cent return to one extra year of education, the top end on a 10 per cent return to an extra two years.
9. The standard methodology is derived from Psacharopoulis and Ariagada (1992), who use census data on the educational achievement of the labour force to construct

estimates of average schooling levels at various points in time. An alternative approach is taken by Kim and Lau (1992), who track enrolment rates back in time and use a perpetual inventory method to assess the average educational level of the adult population. However, there are many ambiguities and inconsistencies in the census and enrolment data that make international comparisons difficult.

10. Note that tertiary education includes both university and non-university programmes.
11. Productivity (output per hour) and education data are taken from Maddison (1982, 1989, 1991).
12. The domestic equivalent, put forward by Baumol *et al.* (1989) as a "fail-safe" productivity enhancing policy, would be to reduce marginal taxes on more productive firms.
13. Conceptually, strategic trade considerations can apply equally well to internal trade as well as international trade, but here too empirical evidence suggests that the net impact may be small. In the United States, there has been no marked long-run divergence of productivity levels in different parts of the country (Barro and Sala-i-Martin, 1992). This suggests that either centres of innovation have emerged in different parts of this country or the benefits from innovation have spread more quickly and evenly than such strategic models would suggest. Either way the possibility that "free-trade" can produce large differences in income growth or levels because of specialisation does not seem to have materialised. In a world of liberalised capital markets, it is relatively easy to buy into the quasi-rents of innovating companies either in other parts of the country or in other countries. However, there remains the possibility that labour mobility within countries may be the mechanism by which the benefits of new technology are transferred, but highly skilled labour is relatively transferable internationally and it appears unlikely that unskilled labour is the mechanism by which productivity advances spill over.
14. Iceland, Ireland, Luxembourg, Portugal and Turkey are not included in the formal statistical work because reliable capital stock data were not available for these countries.
15. In none of the subsequent specifications did these time period dummies prove significant.
16. Intuitively, this means that increasing capital and labour growth simultaneously by an equal percentage point amount, thereby preserving a constant capital to labour ratio, has no effect on labour productivity. If the two coefficients summed to a value significantly greater than zero, an equal percentage point increase would increase labour productivity growth. In the TFP regressions the small value of the coefficients on the two inputs means that increasing their growth rates jointly or independently has no effects on TFP growth, again consistent with aggregate constant returns to scale and the neo-classical growth model in general.
17. The effects of an influx of new workers depends on a number of parameters including the rate of productivity growth and its distribution among workers of different experience levels. However, as a sample calculation, if the workforce and productivity of each worker is growing at 2 per cent per year, and the average length of career is 35 years, the productivity level of a new worker will be about 70 per cent of average. An influx of new workers that accelerates workforce growth to 3 per cent per year will temporarily lower productivity growth by about 0.2 – 0.3 per cent per year.
18. Similar justifications apply to population growth as an explanatory variable (with an expected negative effect on productivity growth), if more resources are diverted to the

young – however, this is more likely to show up as a reduction in business sector capital accumulation than as a slowdown in productivity growth.

19. The variable is probably capturing effects from increased enrolment in tertiary education as well.

20. The time series studies are often difficult to interpret because they focus on high frequency, bivariate relationships that exclude all other potential impacts on productivity growth. For example, Fischer argues that the main path by which inflation seems to matter is indirectly through its effect on lowering investment ratios, so that the estimated inflation impact would include the effect of all other correlated effects. Also, the factors that explain medium-term trends in productivity growth may well be unrelated to the variables that are correlated with the high-frequency movements in productivity.

21. During the period of estimation, financial assets and tax/depreciation schedules in OECD economies were not indexed in general, so rising inflation might well have introduced significant distortions and increased inefficiencies. It would not be surprising if these results did not extend to countries with more persistent high inflation and elaborate indexation mechanisms.

22. The R&D term equals the growth in the R&D capital stock in G7 countries and has a value of 0 for smaller countries. A separate dummy variable for G7 countries, when added, proved insignificant.

23. For example, there is no reason to believe that reducing the share of agricultural workers in the labour force will have the same productivity effect in all countries. Moreover, since productivity growth reflects national relative prices, a country whose agricultural sector is relatively unproductive, but where prices are high, may experience a small measured benefit from a worker leaving that sector. Similarly Levine and King's financial deepening measures amount to various money and credit velocities, which may be adequate for comparing developed countries and LDCs, but not for capturing differences among developed countries. However, this raises the question concerning Levine and King's work whether their financial variables are indicators of the level of development rather than of the effects of financial deepening on productivity.

24. Based on the low coefficients on capital to labour growth in the TFP equation, this factor has contributed very little to the evolution of TFP growth.

25. It would be preferable to include individual country-specific dummies and shift terms simultaneously, but this would use up one-half of the degrees of freedom in the data. However, whenever the country-specific dummies were selected from looking at the residuals of the earlier estimated equation, the remaining country terms proved insignificant at the 50 per cent level or more.

26. The data don't lend themselves to productivity **level** calculations. The assumption is made that the US was the productivity leader in all sectors in 1970. The industries that don't catch-up are those in which US productivity growth over this period exceeded productivity growth in other countries.

27. The RCA is defined as the ratio of an industry's share in a country's exports to that industry's share in output. Note, however, that this indicator can be misleading to the extent that exports are distorted by voluntary export restrictions or other trade measures.

28. OECD Economics Department Working Papers Nos. 135-141 (various authors) provide detailed analyses of the distribution systems of seven OECD countries.

29. The US performance from the end of the war until 1973 stands out as an exception.

30. Young (1992) argues (and provides evidence) that the interventionist policies pursued by Singapore failed to raise TFP. More generally, Young as well as Kim and Lau (1993), argue that faulty input measurement in many NIEs tends to entail a heavy upward bias to measured TFP growth in these economies. Analysis in OECD (1988, and 1992a) points to strong reservations about the effectiveness of interventionist policies.

31. Brown, *et al.* (1993) discuss how the macroeconomic environment affects firms and worker willingness to accept productivity-enhancing organisational changes.

32. This would apply especially to estimates that show low output responses to private inputs and very large output responses *to* public infrastructure.

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Annex *1*

SIMULTANEITY **BIAS** IN ESTIMATING THE CONTRIBUTION OF INFRASTRUCTURE TO PRODUCTIVITY GROWTH

The easiest case to analyse is one where the income elasticity of demand for infrastructure equals one and infrastructure growth contributes nothing to measured output growth. Assuming a Cobb-Douglas production function in private inputs, then:

$$y = \alpha k + (1 - \alpha) l + \lambda$$

where y, k, l, λ are growth rates of output, private capital, labour and TFP respectively. If for simplicity infrastructure demand is modelled with a unitary elasticity, *i.e.*

$$i^d = y + \mu$$

where i^d is the growth in infrastructure demand and μ is a stochastic error term. Incorrectly including infrastructure growth as an explanatory variable in an estimated production function would yield a coefficient on infrastructure equal to:

$$(1 - \Upsilon^2 py)/(\eta - \Upsilon^2 py)$$

where $\Upsilon^2 py$ is the squared correlation between private inputs and output while η is the variance of infrastructure demand relative to income.’ Note that this coefficient approaches one as the link between infrastructure and output gets tighter (as η approaches 1), so that a tight demand side link between infrastructure and output could emerge as a high output response in production function estimates. The coefficient on infrastructure will tend to get smaller if there is a stronger link between private inputs and output growth, *i.e.* if TFP represents only a small portion of output growth. However, in most time-series or cross-section studies the share of output growth attributable to TFP is high, so these are precisely the instances when infrastructure will provide a misleading indication.

• **The assumption is also made that there is no correlation between μ and growth *of* private inputs.**

Annex 2

APPLYING NEW GROWTH REGRESSIONS TO THE OECD

A number of recent studies have attempted to find the determinants of medium term productivity growth. The relevance to the OECD growth experience of four of the more influential studies – Mankiw, Romer and Weil (MRW, 1992), De Long and Summers (DLS, 1992), Barro (B, 1991) and Levine and Renelt (LR, 1992) – is assessed below. There is considerable overlap in the data sets and specifications of estimated equations used in these studies, with much of the data being provided by the International Comparisons Project as discussed in Summers and Heston (1991). The measure of productivity (the dependent variable) is often aggregate GDP per capita, although DLS use GDP per worker, and MRW use GDP per working-age person. The factors explaining productivity growth generally include proxy measures for the stock of human capital, estimates of the stock of physical capital, and the initial productivity gap vis-a-vis the United States (catch-up potential).

In general, when these empirical analyses are applied to the OECD, the only robust variables are “catch-up” and educational attainment. Catch-up is a descriptive variable, not a policy tool, while the association of education and productivity growth may reflect demand for education, as well as its supply effects. Importantly, apart from catch-up, none of the variables contribute to an understanding of why productivity growth slowed down after 1973.

Human capital and investment

Mankiw, Romer and Weil (1992) estimate a production function in which the long-run log-level of output per working-age person depends on the rate of labour force growth and the rate of investment. They also include the proportion of the working-age population enrolled in secondary school education as a measure of the rate of accumulation of human capital.' The results of this study are reproduced in the first two regressions of Table B.1. The first regression explains almost 80 per cent of the cross-country variation in the dependent variable in the authors' 98 country sample, with the coefficients statistically well-determined. However, the authors note that the estimates for the OECD alone (regression 2) are less precise. In this sample, the coefficients on investment and population growth are not statistically significant. In regressions of this type there is also a potential reverse causality problem as rich countries will have a tendency to educate a higher percentage of their young persons, and the regressions may be capturing an education demand effect.

	Log GDP per working-age person, 1985 [1] 98 countries[1]		Log GDP per working-age person. 1985 [2] 22 OECD countries		Log business sector labour productivity, 1985 [3] 22 OECD countries	
	Estimated coefficients labs. value of 1-statistic in parentheses)					
Constant	**6.89**	**(5.9)**	**8.78**	**(4.7)**	**10.64**	(5.1)
Log (I/GDP)	**0.69**	(5.3)	**0.28**	(0.7)	–0.04	(0.1)
Log (n + g + d)	**-1.73**	(4.2)	**-1.07**	(1.4)	**-1.09**	(1.3)
Log (SCHOOL)	**0.66**	**(9.4)**	**0.77**	**(2.6)**	**0.74**	**(2.3)**
Adjusted R^2	**0.78**		**0.24**		**0.13**	
Regression standard error	**0.51**		**0.33**		**0.37**	

1. Excluding countries in which per capita income is dominated by oil rents.

Note:

I/GDP = Share of gross investment in GDP, 1960-85 average.
n = Rate of growth of working-age population, 1960-85 average.
g = Rate of growth of labour augmenting technological progress (imposed at 2 per cent per annum).
d = Rate of depreciation of gross capital stock (imposed at 3 per cent per annum).
SCHOOL = Average percentage of working-age population enrolled in secondary schools, 1960-85 average.

Source: Regressions 1 and 2 are those reported in Table II of Mankiw, Romer and Weii (1992). Column 3 reports results of regressions run by the Secretariat.

In the final regression of Table B.I, the (log) level of business sector labour productivity in 22 OECD countries is regressed on the MRW explanatory variables. This is a more appropriate dependent variable than GDP per working-age person and a better fit would be expected. The regression coefficients are similar to those obtained when GDP per working-age person was used as the dependent variable, with the exception of the investment ratio coefficient which is virtually zero. However, this regression is only able to account for 13 per cent of the cross-country variation in productivity. The reverse causality problems with education and insignificance of any variable related to capital accumulation make it difficult to draw any policy inferences from this result.[2]

Equipment investment

De Long and Summers (1991, 1992) investigate the relationship between investment in physical capital and productivity growth. Their results indicate that countries which devote a higher proportion of GDP to investment in machinery and equipment tend to have a higher rate of productivity growth.[3] In contrast, they were unable to find a significant effect from the proportion of GDP that was invested in structures and transport on productivity growth. They interpret their results as indicating that the social return to investment in machinery and equipment exceeds the private return, by perhaps as much as 30 per cent.

Table B.2. Productivity growth and investment in physical capital

	Dependent variable											
	Growth-rate of GDP per worker 25 "high-productivity" countries DLS repression results						Growth-rate of business sector output per worker 15 OECD countries Secretariat repression results					
	1960-85		1960-75		1975-85		1963-85		1963-75		1975-85	
Constant	–0.0116	(1.4)	0.0004	(0.0)	–0.0273	(1.9)	–0.0072	(0.9)	0.0058	(0.4)	0.0137	(1.4)
Growth in labour force	–0.0005	(0.0)	–0.0807	(0.4)	–0.1764	(0.7)	–0.2365	(0.7)	–0.2462	(0.6)	–0.2221	(0.5)
Productivity gap	0.0305	(3.5)	0.0485	(3.8)	0.0141	(0.9)	0.0437	(3.8)	0.0500	(2.9)	0.0446	(3.0)
Equipment investment share	0.3373	(6.3)	0.2950	(3.9)	0.4256	(4.0)	0.0933	(1.0)	0.1023	(0.7)	0.0000	(0.0)
Structure and transport investment share	–0.0147	(0.4)	–0.0564	(1.3)	0.0472	(0.8)	–0.0153	(0.3)	0.0122	(0.2)	–0.0254	(0.4)
Adjusted R^2	0.662		0.492		0.428		0.715		0.547		0.409	
Regression standard error	0.0077		0.0111		0.0131		0.0055		0.0089		0.0066	

Table B.2 reports the main DLS regression result for a sample of twenty-five "high productivity" countries, which includes sixteen OECD countries.[4] The coefficient on the share of machinery and equipment investment in GDP is significant and of the order of 0.3 to 0.4 over the period 1960-85, and the two sub-periods 1960-75 and 1975-85. **DLS** test a large number of alternative specifications, and find that this core result is robust.

The share of investment in machinery and equipment in GOP is not, however, significantly correlated with the growth-rate of business sector labour productivity in OECD countries (second set of results reported in Table B.2). The coefficients obtained when growth of labour productivity is regressed on the DLS explanatory variables are both smaller in magnitude, and not significantly different from zero. These regressions suggest that initial productivity differences ("catch-up potential") have been the main determinant of differences in productivity growth-rates among OECD countries. Heston (1993) also finds that higher ratios of investment in machinery and equipment to GDP do not appear to raise productivity growth rates significantly in OECD countries.

Explanation of growth: the Barro framework

Barro (1991) allows for the effects of a number of variables that account for the role of government, both in terms of providing political stability and in terms of its economic role. A version of Barro's principal regression[5] is reported in Table 6.3, first column. The average growth rate of real GDP per capita between 1960 and 1985 is explained by: the potential for catch-up, as measured by the relative 1960 productivity levels ***vis-a-vis*** the United States (GDP60); two concepts of the human capital stock (PRIM60 and SEC60), proxied by 1960 enrolment rates in primary and secondary education respectively; the average share of government spending in total GDP during the period 1970-85 (GOV); two measures of political stability (REVCOUP and **ASSASS),** presented by the number of revolutions and coups per year and the number of assassinations per year); the deviation of the purchasing power parity investment deflator in 1960 from the sample (98 countries) average (PPI60DEV) and the share of total investment in GDP 1960-85 (INV).

For the sample of 98 countries (OECD and non-OECD), the regression produces coefficients of the expected sign on all these variables, most of them significant at customary levels. For the sample of 24 OECD countries, the **two** variables that represent political instability and the variable measuring the deviation of investment good prices from world levels are either incorrectly signed or insignificant. In addition, the coefficients on the shares of both government spending and investment in GDP have low statistical significance, so that the main explanatory power is provided by the catch-up and human capital variables. Nevertheless the **OECD** regressions account for a higher proportion of the (much smaller) variation in productivity growth rates than the regressions for the 98 country sample.

The last two sets of results reported in Table 8.3 show that the correlations between Barro's explanatory variables and the growth of business-sector labour productivity in OECD countries are generally weak, except for the catch-up variable. The productivity gap with the United States remains by far the most significant variable. School enrolment rates are weakly correlated with productivity growth, and a larger share of government spending on GDP is associated with lower productivity growth, but the relevant coefficient is not statistically significant: nor is that of the share of investment in GDP.

Table 8.3. Explanation of productivity growth in the Barro framework

	Growth-rate of real GDP per capita 1960-85 average				Growth-rate of business sector labour productivity, 1963-85 average			
	98 countries		24 OECD countries		23 OECD countries		23 OECD countries	
Constant	0.0187	(2.5)	0.0140	(0.7)	-0.0163	(0.7)	-0.0181	(1.0)
1960 GDP per capita (GDP60)	-0.0069	(5.4)	-0.0050	(4.8)	–	–	–	–
1963 labour productivity gap	–	–	–	–	0.0591	(5.2)	0.0540	(6.0)
Secondary school enrolment in 1960 (SEC60)	0.0253	(2.1)	0.0151	(1.7)	0.0184	(1.7)	0.0145	(1.6)
Primary school enrolment in 1960 (PRIM60)	0.0161	(2.3)	0.0168	(1.8)	0.0168	(1.5)	0.0185	(1.7)
Government spending share (GOV)	-0.0875	(3.5)	-0.0248	(0.8)	-0.0484	(1.2)	-0.0598	(1.7)
Investment share (INV)	0.0903	(3.2)	0.0587	(1.4)	-0.0273	(0.5)	–	–
Revolutions and coups (REVCOUP)	-0.0206	(2.8)	-0.0057	(0.3)	-0.0282	(1.3)	–	–
Assassinations (ASSASS)	-0.0015	(0.5)	0.0037	(1.0)	0.0061	(1.5)	–	–
Investment deflator deviation from PPP (PP160DEV)	-0.0010	(0.2)	0.0112	(1.0)	-0.0118	(0.8)	–	–
Standard deviation of productivity growth	0.0185		0.0092		0.0112		0.0112	
Standard error of regression	0.0135		0.0057		0.0066		0.0069	
Adjusted R^2	0.47		0.61		0.66		0.62	

Note: Columns 1-2 use data from Barro (1991).
Columns 3-4 exclude Luxembourg. First year is 1963. except for Spain (1964), Canada (1966). Australia, Netheflands. Belgium (all 1970). Turkey (1972) and Iceland (1973).

Table B.4. **Explanation of productivity growth in the Levine/Renelt framework**

	Dependent variable							
	Growth-rate of real GDP per capita, 1960-85 average				Growth-rate of business sector labour productivity. 1963-85 average			
	98 countries [1]		24 OECD countries [2]		23 OECD countries [3]		23 OECD countries [4]	
Constant	-0.8591	(0.9)	1.8620	(0.6)	0.0527	(2.8)	0.0050	(0.2)
1960 GDP per capita	-0.4328	(3.5)	-0.3725	(2.8)	–	–	–	–
1963 labour productivity gap	–	–	–	–	0.0742	(8.0)	0.0510	(4.6)
Secondary school enrolment	3.087	(2.4)	0.9051	(0.9)	0.047	(0.7)	0.0038	(0.4)
Primary school enrolment	1.752	(2.7)	0.7808	(0.7)	0.0129	(1.5)	0.0054	(0.4)
Government spending	–1.289	(0.4)	-0.3751	(0.1)	-0.1415	(3.5)	-0.0358	(0.8)
Investment	9.042	(3.1)	7.773	(1.5)	-0.1785	(4.1)	–	–
Revolutions and coups	-0.1122	(0.2)	-0.8413	(0.4)	-0.0690	(4.1)	-0.0166	(0.8)
Population growth	-0.1241	(0.6)	0.2158	(0.5)	-0.0057	(2.0)	-0.0031	(0.7)
Trade share	0.7450	(1.5)	-0.1489	(0.3)	-0.0117	(2.6)	–	–
Inflation	-0.0037	(1.4)	0.0043	(0.1)	-0.0003	(1.2)	-0.0003	(0.9)
Standard deviation of productivity growth	0.0175		0.0089		0.0107		0.0107	
Standard error of regression	0.0132		0.0064		0.0042		0.0066	
Adjusted R^2	0.44		0.49		0.84		0.62	

Are growth regressions robust?

Levine and Renelt (1992) assess the robustness of growth regressions to the inclusion or exclusion of a range of alternative explanatory variables. These include catch-up effects, school enrolment rates, the shares of investment and government spending in GDP, Barro's proxy variables for political stability, the rate of inflation and the share of trade in GDP.[6]

The dependent variable for the regressions in this study is the average growth rate of real GDP per capita over the period 1960-89, for a sample of 104 countries. The study concludes that there are positive and robust correlations between average growth rates and the share of investment in GDP, and between average growth-rates and the 1960 secondary school enrolment rate. The authors find "qualified support" for the conditional convergence hypothesis, that is to say that productivity levels have tended to converge, once allowance has been made for the effects of secondary school enrolment and investment shares. However, the support is qualified since such conditional convergence can be found for the 1960-89 period as a whole, but not for the 1974-89 sub-period. Trade policy variables, fiscal indicators, and other economic and political indicators (including the rate of inflation) were found to be not robustly correlated with GDP growth.

The results from a regression in which OECD business sector labour productivity growth-rates were regressed on Levine and Renelt's explanatory variables are reported in Table B.4. When all the explanatory variables are included, the explanatory power of the regression is high (third set of results). However, the significant negative coefficients on the share of investment and trade do not have a plausible economic interpretation. If these two variables are excluded, the only significant variable is catch-up potential. Hence, their estimated effects from school enrolment and government spending reported in Table 15 do not appear to be robust for the OECD sub-sample.

NOTES

1. In steady state the stock of human capital would be proportional to the investment rate.
2. Replacing enrolment rates by measures of adult educational attainment from OECD (1992*b*) increases the explanatory power of the equation slightly, but does not otherwise improve the results.
3. Note that the standard neo-classical ("Solow") growth model implies no positive steady-state relation between the investment ratio and the growth of output per worker. A once and for all increase in the investment ratio would produce a temporary increase in the productivity growth rate during the transition to the new steady-state equilibrium.
4. High productivity" reflects relative productivity levels in 1960. The 16 OECD countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Spain, the United Kingdom and the United States. The nine non-OECD countries are Argentina, Chile, Costa Rica, Hong Kong, Israel, Mexico, Peru, Uruguay and Venezuela.
5. Barro's reported regression could not be replicated exactly. However, the coefficients and standard errors we obtained are similar to those reported by Barro, with the main difference appearing to be the size and significance of the coefficient on the deviation of the PPP investment deflator from the sample mean.
6. This last variable has been used as a measure of the openness to foreign trade in a number of studies, although as De Long and Summers note, it is a better indicator of a country's size than of its openness to trade. Levine and Renelt also consider alternative measures of openness that attempt to measure the degree to which each country's foreign trade is affected by protectionist policies.

Annex 3

INDUSTRY AGGREGATIONS: TECHNOLOGY-BASED INDUSTRY GROUPS

The standard OECD definition of high, medium and low-technology industries has been used in this report. This definition was established in **1986** using **1980** data, and is scheduled to be updated in the very near future. Nevertheless, analysis conducted last year using different databases (STAN and ANBERD) and a different selection of countries than the **1986** work, reconfirmed the **1970** and **1980** rankings of technological sophistication based on R&D intensities and did a preliminary update for **1989**. This work indicated that the ranking of the industries is relatively stable over time and would not change significantly if more recent data was used.

High-technology

3522	Drugs and medicines
383 - 3832	Electrical machines excluding comm. equip.
3832	Radio, TV and communication equipment
3845	Aircraft
3850	Professional goods and instruments
3825	Office and computing equipment

Medium-technology

351 + 352 - 3522	Chemicals excluding drugs
355 + 356	Rubber and plastic products
372	Non-ferrous metals
382 - 3825	Non-electrical machinery
3842 + 3844 + 3849	Other transport equipment
3843	Motor vehicles
3900	Other manufacturing

Low-technology Industries

3100	Food, beverages and tobacco
3200	Textiles, apparel and leather
3300	Wood products and furniture
3400	Paper products and printing
353 + 354	Petroleum refineries and products
3600	Non-metallic mineral products
3710	Iron and steel
3810	Metal products
3841	Shipbuilding and repairing

Source: OECD (1992*c*).