TOTAL FACTOR PRODUCTIVITY: MACROECONOMIC AND STRUCTURAL ASPECTS OF THE SLOWDOWN

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INTRODUCTION

For over a decade the productivity performance of most OECD countries has been disappointing judged against earlier postwar trends (Chart A). Although year-to-year productivity growth has recovered somewhat since the recession of the early 1980s, there is little evidence that the slowdown in trend productivity growth, generally dated as beginning in the late 1960s or early 1970s, has been reversed (Table 1). For the OECD area, average output growth since 1979 has exceeded the combined rise in labour and capital inputs by about ½ per cent per *annum*, an extremely small increase in returns per unit of input. Thus low productivity growth is part, and for some countries an important part, of the answer to the policy question of why growth has been lower than before.

Should these productivity trends continue, OECD countries will experience stagnant or only marginal increases in standards of living, with little of the improvement that the active population had come to expect in earlier postwar years. Moreover, should labour or owners of capital attempt .to raise their real incomes above what is justified by the weak productivity performance, the likely results would be increased inflation and social tension. Conversely, should trend productivity increase, this would serve to raise per *capita* income and ease inflationary pressures while also allowing higher real wages and employment. For these reasons, productivity growth is clearly one of the key variables determining long-run economic growth and prosperity.

Judged relative to longer historical trends, the postwar era was clearly unusual, being characterized by reconstruction, technological catch-up, rapid expansion of international trade under the GATT and Bretton Woods system of fixed exchange rates, and perhaps the commercial exploitation of a backlog of technological advances made during the war. This "golden era" had ended by the early 1970s, and more recent productivity developments may at least partly represent a reversion to a lower, more normal, growth path. The 1970s and early 1980s, however, were also an unusual period of supply shocks and high inflation followed by a successful policy-induced disinflation. There may, therefore, be some hope for improved productivity performance in the late 1980s and 1990s. particularly in light of what appear to be significant opportunities for technological advance in a number of important areas such as communications, new materials and biotechnology.

The focus of this paper is on developments in total factor productivity (TFP) in OECD countries since the 1960s. TFP growth is defined here as that portion of real output growth which is not accounted for by increases in inputs of labour and capital, the two most fundamental factors of production. In this sense, TFP growth is a measure of the gains in the efficiency of production, i.e. over the medium and longer term it can be taken as a measure of technological progress, but over shorter periods it is also affected by other factors such as managerial efficiency, capacity utilization, work habits and even the weather (Solow, 1957). As defined here, TFP

CHART A

ANNUAL GROWTH IN OUTPUT, TFP AND LABOUR PRODUCTIVITY

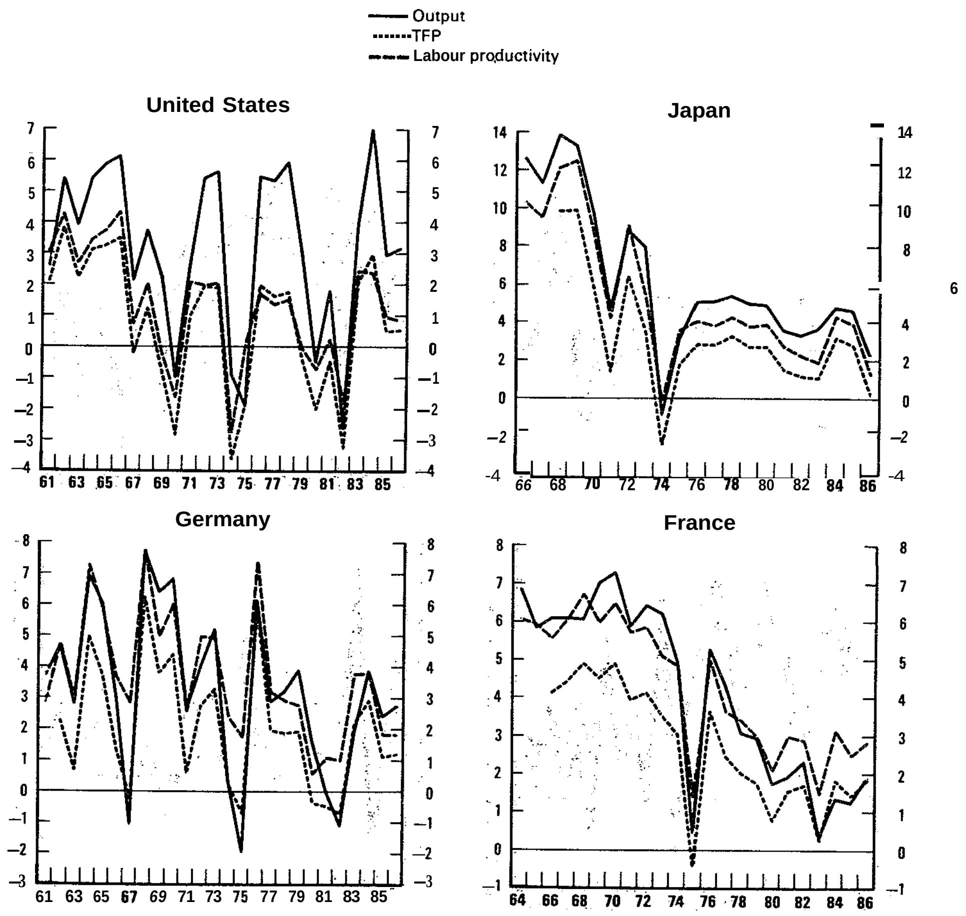
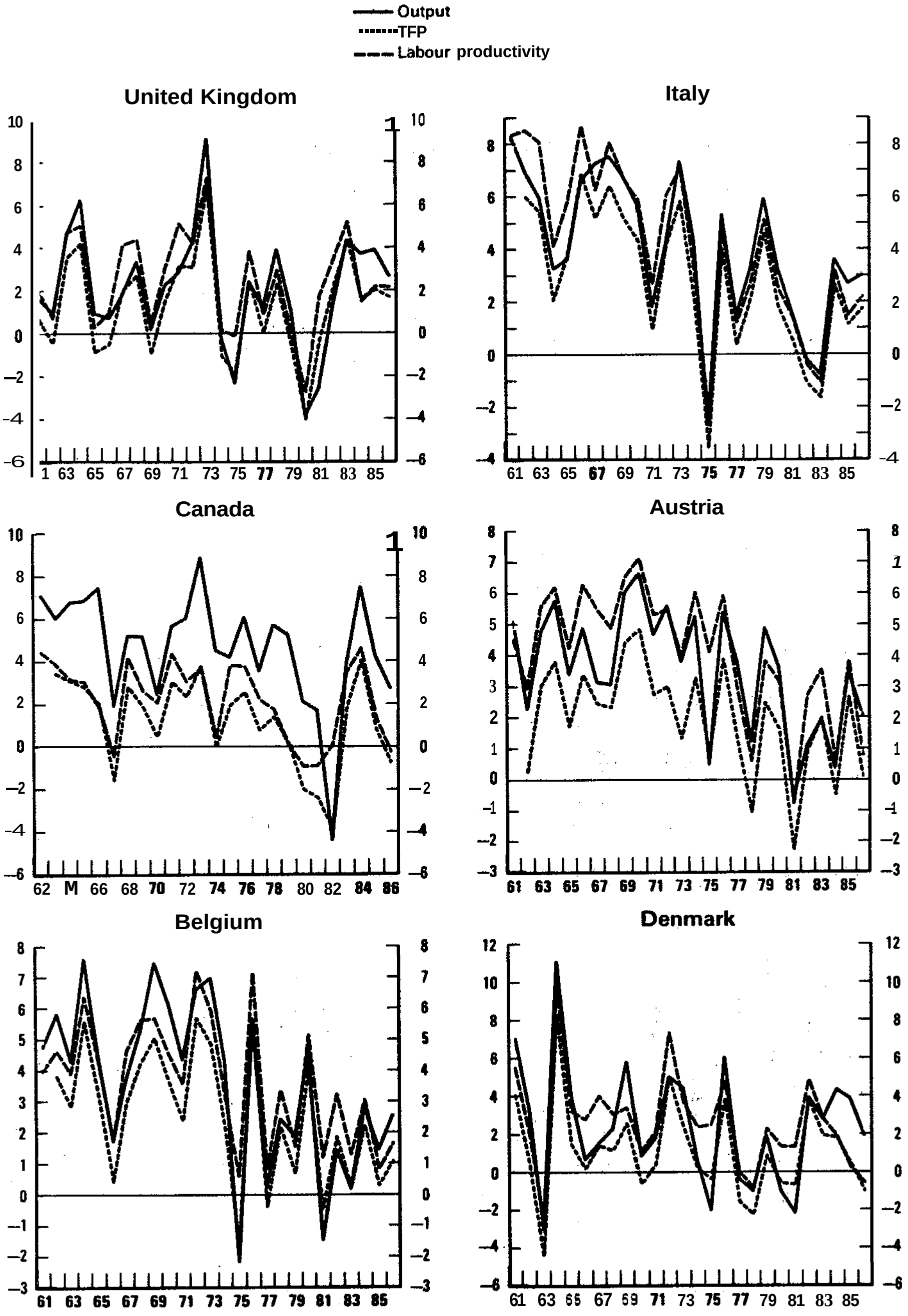


CHART A (continued)

ANNUAL GROWTH IN OUTPUT, TFP AND LABOUR PRODUCTIVITY



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ANNUAL GROWTH IN OUTPUT, TFP AND LABOUR PRODUCTIVITY

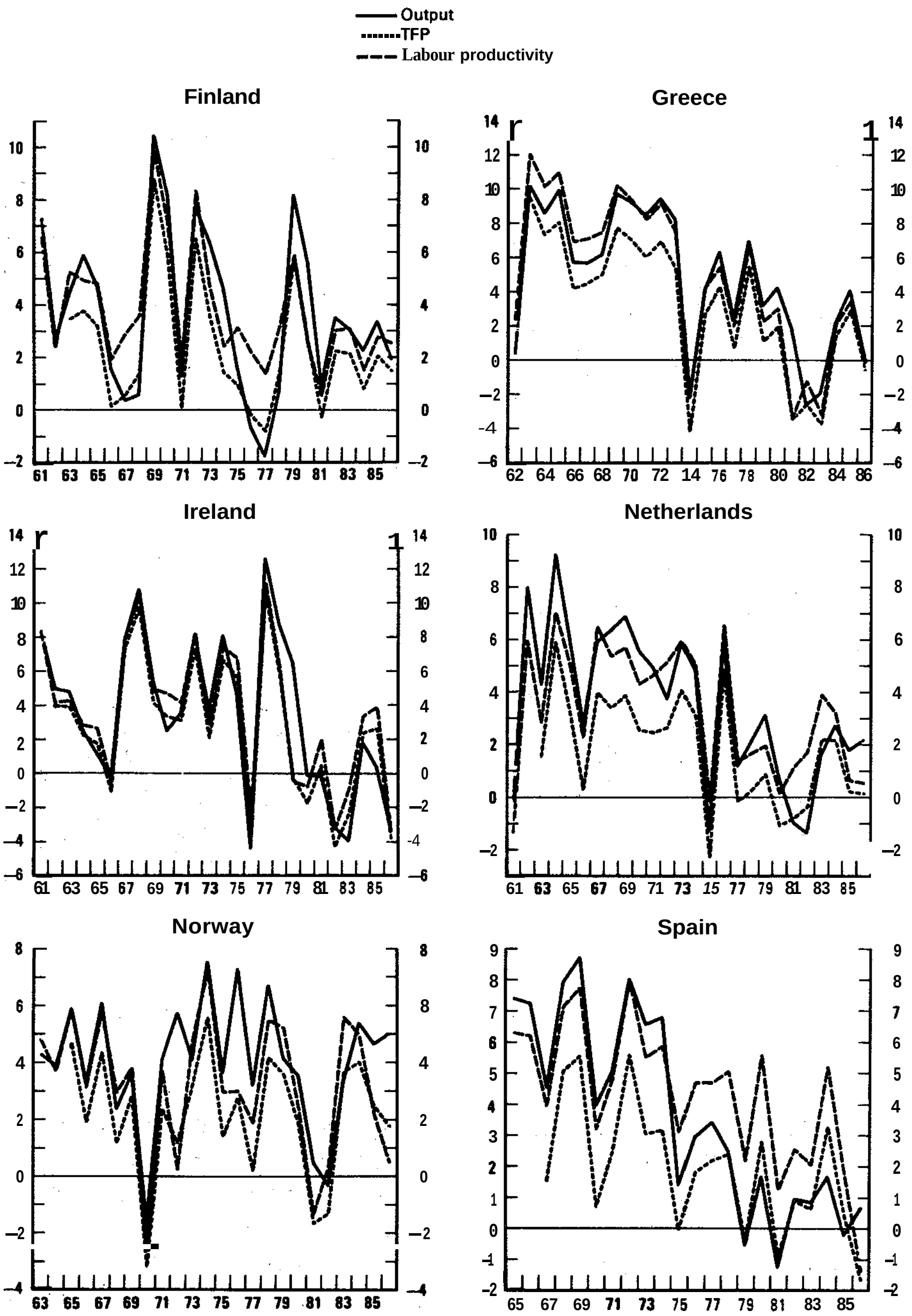
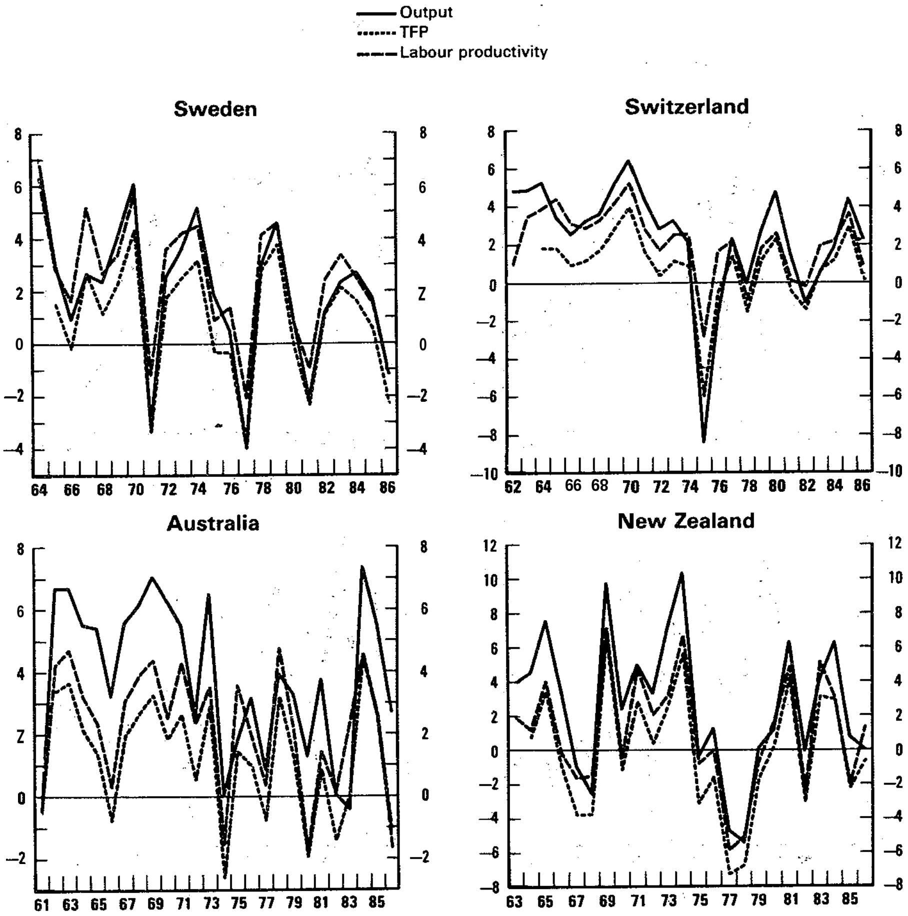


CHART A (continued)

ANNUAL GROWTH IN OUTPUT TFP AND LABOUR PRODUCTIVITY



growth is also equal to the weighted sum of the growths in labour productivity — real output per employed person — and capital productivity — real output per unit of capital — with 1985 factor shares used as weights. Although the data are presented in a growth-accounting framework, the paper is not a full-fledged attempt at growth accounting which would incorporate the estimated influences of managerial ability, regulation and other factors in order to whittle down the size of the residual

(Denison, **1979;** Maddison, **1987** and the references cited therein). Rather this paper tries to combine the growth accounting framework and a statistically based approach.

In this context, it is useful to note that there remains considerable variation in the methods used to measure TFP growth. Various studies have favoured a very disaggregated index number approach, with capital's weight determined by the user cost approach (Diewert, **1976;** U.S. Bureau of Labor Statistics, **1983;** Jorgenson, **1987).** At the economy-wide level, it is impractical to apply this framework to a large number of countries. Hence, a simpler approach, measuring input growth in terms of gross capital stocks and numbers employed and using fixed input weights rather than the theoretically preferable shifting weights is adopted'.

In doing so, explicit attention was paid to the adequacy of the measurement of TFP growth, as reported in Englander **(1988).** A number of tests, based on the expected properties of the TFP data and their components, were made. These tests can not, of course, be conclusive, but they do suggest that the available TFP data, when averaged over a number of years, generally reflect the broader productivity developments in OECD economies. Nevertheless, there is clearly a need for caution in drawing policy implications from the calculated TFP data and from analyses based on that data.

The data used come from the supply block of the OECD INTERLINK model. A data set on aggregate TFP growth and its output and input components at constant prices has been constructed for virtually all OECD countries, as described in Annex **1.** The availability of the cross-country dimension permits a much greater focus on medium-term issues than has been possible in earlier studies, although at the well-known cost of assuming that the economies possess a more-or-less common structure. However, the great advantage is that much of the statistical analysis can be conducted in terms of cross-section regressions with the time series elements consisting of complete business cycles rather than quarterly or annual observation. This greatly reduces the impact on the data of short-term cyclical fluctuations on output and TFP growth, which may not have much bearing on the medium-term issues.

Beyond presenting OECD-wide data on TFP growth over the last 25 years or so, this paper draws the following tentative conclusions on the slowdown:

i) Technological progress is, to some extent, embodied in capital. That is, increases in capital accumulation per worker and a more modern capital stock are associated with improved medium-term TFP trends.

ii) The ability to use technology originating in the United States, the technology leader, contributed to the rapid growth of TFP in Europe and Japan in the late **1960s** and early **1970s.** By the mid- **1970s** the room for countries outside North America to catch-up to the higher productivity levels in North America had substantially narrowed. Differences in

Table 1. **Productivity, output and input growth[a]**

Business sector; average percentage changes at annual rates

	OECD average[b]	United States	Japan	Germany	France	United Kingdom	Italy	Canada	Austria	Belgium	Denmark
1960s to **1973[c]**											
output	5.2	3.8	9.7	4.6	6.4	3.2	5.6	5.7	4.5	5.4	3.4
Factor input	2.4	2.3	3.5	1.8	2.1	1.2	0.9	3.5	1.7	1.6	1.7
TFP	2.8	1.5	6.1	2.8	4.3	2.0	4.7	2.2	2.8	3.7	1.7
Labour productivity	4.1	2.2	8.6	4.9	5.9	3.3	6.5	2.9	5.3	4.8	3.5
Capital productivity	–0.4	0.3	–2.4	–1.1	0.6	–0.7	0.4	1.1	–2.7	1.0	–1.8
1973-79											
output	2.9	2.8	3.8	2.4	3.5	1.1	2.9	4.9	3.5	2.0	0.9
Factor input	2.2	2.9	2.0	0.6	1.4	0.9	1.3	3.7	1.7	0.6	0.7
TFP	0.7	–0.1	1.8	1.8	2.1	0.2	1.6	1.1	1.8	1.4	0.1
Labour productivity	1.6	0.3	3.2	3.4	3.5	1.3	2.4	2.0	3.9	2.8	1.8
Capital productivity	–1.4	–0.9	–3.0	–1.1	–1.2	–1.9	–0.4	–0.3	–2.7	–1.8	–3.3
1979-86[d]											
output	2.3	2.2	3.8	1.6	1.5	1.4	1.9	2.5	1.7	1.6	1.9
Factor input	1.7	2.2	2.1	0.8	0.2	0.3	1.1	2.9	1.1	0.3	1.1
TFP	0.6	0.0	1.7	0.8	1.3	1.1	0.7	–0.3	0.7	1.3	0.8
Labour productivity	1.4	0.6	2.8	2.0	2.5	1.9	1.2	1.1	2.0	2.3	1.7
Capital productivity	–1.3	–1.0	–2.0	–1.3	–1.4	–0.8	–0.7	–2.6	–2.2	–1.2	–0.9
Memorandum:											
1985 capital share	32.2	34.3	22.6	34.8	30.8	32.5	29.9	37.9	32.1	29.2	33.8

	Finland	Greece	Ireland	Netherlands	Norway	Spain	Sweden	Switzerland	Turkey	Australia	New Zealand
1960s to early **1970s[c]**											
output	4.7	8.4	4.6	5.6	3.7	6.4	2.4	4.0	5.2	5.6	3.9
Factor input	1.3	1.8	0.6	2.5	1.7	3.0	1.0	2.3	4.5	3.5	3.3
TFP	3.4	6.6	4.0	3.1	2.0	3.4	1.4	1.7	0.7	2.1	0.6
Labour productivity	5.0	9.1	4.7	5.0	3.0	5.7	3.1	3.4	0.0	3.2	1.8
Capital productivity	–0.3	–3.4	1.1	0.2	0.7	–2.1	–1.7	–1.9	1.2	0.1	–1.0
1973-79											
output	2.2	3.5	6.1	2.7	5.4	2.7	1.8	–0.6	4.8	2.2	0.1
Factor input	0.7	1.8	1.9	1.5	2.5	1.2	1.0	0.2	4.4	1.6	2.7
TFP	1.5	1.7	4.2	1.1	2.9	1.5	0.8	–0.8	0.3	0.6	–2.5
Labour productivity	3.1	3.1	4.8	2.8	4.3	4.2	2.2	0.7	0.4	1.8	–1.0

output	3.0	1.2	–1.2	1.0	3.1	0.6	0.8	2.0	3.5	2.9	2.6
Factor input	1.4	1.7	–0.3	0.6	1.6	–0.2	0.7	1.3	1.6	2.4	2.0
TFP	1.6	–0.5	–0.9	0.4	1.5	0.7	0.1	0.7	1.9	0.5	0.6
Labour productivity	2.3	0.2	0.2	1.6	2.1	2.4	1.2	1.5	2.4	1.1	1.6
Capital productivity	0.0	–3.3	–5.3	–1.5	0.8	–3.2	–1.9	–1.0	1.5	–0.6	–0.8
Memorandum:											
1985 capital share	30.5	20.08	20.08	39.7	43.5	29.6	'35.0	31.9	55.1	35.4	42.4

a) Output is value added in the business sector (GDP at factor cost excluding value added in general government) at constant prices. TFP growth is equal to either *i)* output growth minus factor input growth (a weighted index of capital and labour inputs), or *ii)* a weighted average of the growth of labour and capital productivity. In both cases, 1985 capital and labour shares are used as weights. Differences are due to rounding.

b) Weighted average of above countries based on the 1985 business sector output at 1985 prices and exchange rates.

c) The starting years are as follows: United States 1960, Japan 1967, Germany 1961, France 1965, United Kingdom 1960, Italy 1961, Canada 1962, Austria 1961, Belgium 1961, Denmark 1960, Finland 1962, Greece 1962, Ireland 1961, Netherlands 1962, Norway 1964, Spain 1966. Sweden 1966, Switzerland 1963, Turkey 1972, Australia 1961, New Zealand 1963.

d) 1979-85 for Turkey.

e) Capital share assumed to be 20 per cent.

Source: National source data and OECD estimates, see Annex for sources and definitions.

productivity levels across countries, however, still appear to be substantial.

iii) Expenditure on R&D has important effects on TFP developments in the industries where the R&D is used, and countries investing more in R&D tend to have faster TFP growth. The available evidence suggests, however, that the TFP slowdown may have been less related to a slowing of R&D growth than to a possible reduction in the effectiveness of R&D (Englander, Evenson and Hanazaki, 1988).

iv) Medium-term TFP trends can be affected by macroeconomic developments as well as microeconomic or structural factors. In particular, there appears to be a significant feedback effect running from sustained departures of actual output from its trend to medium-term TFP developments.

No major direct contributions were found from other commonly cited factors:

v) The large rise in energy prices per se probably did not have major direct impacts on TFP. This conclusion is based on the timing of the TFP slowdown in some countries, the weight of energy in OECD economies and estimation results of aggregate production functions; it also appears to receive some indirect support from the apparent failure of recent declines in real energy prices to produce an important reversal of TFP trends. However, the indirect effects of increases in energy prices at a time of rising underlying inflationary pressures, and the subsequent policy responses, as well as possible induced obsolescence in the capital stock, may have been important factors exacerbating the productivity slowdown.

vi) The role of structural rigidities in slowing adjustment of OECD economies to changed economic circumstances has been well documented (OECD, 1987), but rigidities are difficult to quantify and only very limited direct evidence was found of their importance to productivity developments. A gradual accretion of market rigidities and disincentives may have contributed importantly to the TFP slowdown. Moreover, the absence or slow pace of structural adjustments may have intensified the output losses associated with mastering inflation, thus contributing indirectly to the TFP slowdown.

vii) Although the trend decline in average hours worked, the changing labour force composition and the increased importance of some low productivity growth industries or sectors appears to have reduced aggregate productivity growth in a number of countries, the size of their combined effects appears to have been relatively modest. Other studies, particularly at the disaggregated level, find more important effects, however*.

The data also suggest, however, that many of these factors are inter-related. A general description of a high TFP growth country would be one with ample room to catch-up to the technological leader and rapid growth in capital stocks and outlays on R&D. But it is extremely hard to separate out the individual contributions of these factors.

This paper has three parts. The first one presents aggregate and sectoral data on productivity trends since the 1960s, emphasizing both the broad nature of the slowdown across countries and the differences in sectoral performance which have become prominent in recent years. The second part uses the OECD INTERLINK model to identify some of the potential benefits of faster TFP growth, but also provides a cautionary note on risks of demand expansion. The third and final part examines the main sources of the observed slowdown in TFP growth, as discussed above.

I. AGGREGATE AND SECTORAL TFP PERFORMANCE

The stylised facts of the productivity slowdown in the business sector over the last twenty years are:

- TFP growth in the OECD area slowed from an average annual rate of about **3** per cent in the period from the mid- **1960s** to the early **1970s** to about ¾ per cent in the **1973-79** period, and has further declined to about ½ per cent in the **1979-86** period. While for many countries the fall in TFP growth has been continuous, in the period since **1979** TFP growth has stabilized in the United States, Japan, Belgium, Finland and Australia and recovered somewhat the United Kingdom, Denmark, Switzerland, Turkey and New Zealand (Table 1).
- In contrast to widely-held perceptions of **1973** as the watershed year, TFP growth in some countries began to slow in the second half of the **1960s,** notably in the United States and Japan (Chart A). In a number of smaller countries, a significant weakening of TFP gains only became apparent after **1973.**
- The growth rates of both labour productivity and capital productivity fell sharply in **1973-79** compared to the previous period. Given the slower growth in the capital-labour ratio, labour productivity growth declined more sharply than capital productivity or TFP growth (Tables 1 and 2). In most countries, the slowing of labour productivity growth was mostly due to a slowing of TFP growth rather than of growth in capital to labour ratios.

Table 2. **Factor input growth and factor substitution**

Business sector; percentage changes at annual rates

	OECD average[b]	United States	Japan	Germany	France	United Kingdom	Italy	Canada	Austria	Belgium	Denmark
1960s to 1973[a]											
Labour	1.1	1.7	1.0	-0.3	0.5	-0.1	-0.9	2.8	-0.8	0.5	-0.1
Capital	5.6	3.5	12.1	5.6	5.7	3.9	5.2	4.6	7.2	4.4	5.2
Capital-labour ratio	4.5	1.9	11.1	5.9	5.3	4.0	6.1	1.8	8.0	3.8	5.3
Factor substitution[b]	1.3	0.6	2.5	2.1	1.6	1.3	1.8	0.7	2.6	1.1	1.8
1973-79											
Labour	1.3	2.5	0.6	–1.0	0.0	-0.1	0.5	2.9	-0.4	-0.7	–1.0
Capital	4.4	3.7	6.8	3.5	4.7	3.0	3.4	5.2	6.2	3.9	4.1
Capital-labour ratio	3.1	1.2	6.2	4.4	4.8	3.1	2.9	2.3	6.6	4.6	5.1
Factor substitution[b]	0.9	0.4	1.4	1.5	1.5	1.0	0.9	0.9	2.1	1.3	1.7
1979-86											
Labour	0.9	1.6	1.0	-0.4	–1.0	-0.6	0.6	1.5	-0.3	-0.7	0.3
Capital	3.6	3.3	5.8	2.9	3.0	2.1	2.5	5.2	3.9	2.8	2.9
Capital-labour ratio	2.7	1.7	4.8	3.3	4.0	2.7	2.0	3.7	4.1	3.5	2.6
Factor substitution[b]	0.8	0.6	1.1	1.1	1.2	0.9	0.6	1.4	1.3	1.0	0.9

	Finland	Greece	Ireland	Netherlands	Norway	Spain	Sweden	Switzerland	Turkey	Australia	New Zealan
1960s to 1973[a]											
Labour	-0.3	-0.7	-0.1	0.6	0.6	0.6	-0.7	0.6	5.2	2.4	2.1
Capital	5.0	11.8	3.5	5.4	3.0	8.5	4.2	5.9	4.0	5.5	4.9
Capital-labour ratio	5.3	12.5	3.7	4.8	2.4	7.9	4.9	5.2	–1.2	3.1	2.8
Factor substitution[b]	1.6	2.5	0.7	1.9	1.0	2.3	1.7	1.7	-0.6	1.1	1.2
1973-79											
Labour	-0.9	0.4	1.2	–0.1	1.1	–1.5	-0.4	–1.3	4.4	0.3	1.1
Capital	4.3	7.4	4.6	4.0	4.2	7.8	3.6	3.4	4.5	3.9	4.7
Capital-labour ratio	5.2	7.0	3.3	4.1	3.1	9.3	4.0	4.7	0.1	3.6	3.6
Factor substitution[b]	1.6	1.4	0.7	1.6	1.3	2.8	1.4	1.5	0.0	1.3	1.5
1979-86[c]											
Labour	0.7	1.0	–1.4	-0.7	1.1	–1.8	-0.4	0.4	1.1	1.8	1.0
Capital	3.0	4.5	4.1	2.5	2.3	3.8	2.7	3.0	2.0	3.5	3.4
Capital-labour ratio	2.4	3.4	5.5	3.2	1.3	5.6	3.1	2.6	0.9	1.7	2.4
Factor substitution[b]	0.7	0.7	1.1	1.3	0.6	1.7	1.1	0.8	0.5	0.6	1.0

a) See notes to Table **1.**
bl 'Factor substitution' is equal to the growth in the capital-labour ratio times the **1985** capital share.
c) **1979-85** for Turkey.

Table 3. labour productivity and TFP growth in a historical context

Total economy, average percentage changes at annual rates

	Labour productivity			TFP	
	1870-1973	1913-73	1973-84	1913-73	1973-84
United States	2.3	2.5	1.0	1.9	0.5
Japan	3.1	4.0	3.2	2.9	1.2
Germany	2.5	2.9	3.0	2.2	1.6
France	2.6	3.2	3.4	2.4	1.8
United Kingdom	1.8	2.2	2.4	1.5	1.2
Netherlands	2.1	2.7	1.9	2.1	0.8

- The growth of TFP and capital productivity since **1973** remains below longer-run historical trends, as well as below the unusually high rates of growth in the **1950s** and **1960s,** while gains in labour productivity have roughly returned to historical trends. Capital productivity growth has been particularly low, indeed negative, in the **1970s** and early **1980s** (Tables 2 and 3, Maddison, **1987).**
- There are nearly parallel movements of output, TFP and labour productivity growth (Chart A).

In Table **1,** basic data on output, input and productivity growth are presented as annual average growth rates over three sub-periods: the period from the early or mid-**1960s** to **1973,** i.e. the end of the postwar "golden era"; the period between the two oil shocks from **1973-79;** and the period after the second oil-price shock from **1979-86.** These time periods have been chosen, with a view to comparing productivity gains through complete cycles and to focusing on average rates of growth.

As can be seen from Table **1** and Chart **A,** there was a near universal tendency for gains in TFP and labour productivity to fall from the **1960s** to the mid-**1980s.** In many cases, this declining trend continued after **1979,** albeit at a slower rate. In terms of average growth rates from **1979-86,** there is little or no evidence that there has been a significant general improvement in trend TFP growth compared with the earlier periods, even though the slowdown seems to have been arrested. While TFP growth in a number of countries has accelerated with the recovery from the recession of the early **1980s, it** is unclear to what extent this change is primarily cyclical. In individual countries, for example, the United Kingdom and Italy, there are indications that at least part of the TFP improvement since the recovery is structural, rather than purely cyclical.

Turning to TFP developments at the sectoral or industry level, the main features are:

- For virtually all countries during the past two decades, productivity growth in manufacturing, a sector relatively open to international trade, has been higher than in business activities as a whole, which include non-tradables like construction and most services (Table 4);

Table 4. Productivity growth in the business and manufacturing sectors

Average percentage changes at annual rates

		Total factor productivity[a]			Labour productivity (output per employed person)		
		Pre1973[b]	1973-79	1979-85	Pre-1973[b]	1973-79	1979-85
United States	Business – per employed person	1.5	–0.1	0.0	2.2	0.3	0.6
	Manufacturing – per employed person	2.8	0.3	2.5	3.4	1.0	3.6
	Manufacturing – hourly	2.6	0.4	2.4	3.2	1.3	3.4
Japan	Business – per employed person	6.3	1.8	2.0	8.8	3.2	3.1
	Manufacturing – per employed person	6.5	2.2	4.5	10.3	5.2	6.3
	Manufacturing – hourly	6.9	2.4	4.4	10.9	5.6	6.2
Germany	Business – per employed person	2.8	1.8	0.8	4.9	3.4	2.0
	Manufacturing – per employed person	2.9	2.2	1.5	4.8	3.3	2.4
	Manufacturing – hourly	3.6	2.8	2.0	5.9	4.3	3.1
France	Business – per employed person	4.4	2.1	1.3	5.9	3.5	2.4
	Manufacturing – per employed person	4.9	2.4	1.2	6.4	4.0	2.5
	Manufacturing – hourly	5.4	3.0	1.9	7.1	4.9	3.5
United Kingdom	Business – per employed person	2.1	0.3	1.0	3.3	1.2	1.9
	Manufacturing – per employed person	2.9	–0.4	1.9	4.1	0.6	3.4
	Manufacturing – hourly	3.3	0.0	2.3	4.6	1.2	3.9
Italy	Business – per employed person	4.8	1.6	0.6	6.6	2.4	1.2
	Manufacturing – per employed person	4.4	1.7	1.3	6.2	2.7	2.9
	Manufacturing – hourly	5.6	2.1	1.6	8.0	3.3	3.3
Canada	Business – per employed person	2.2	1.1	-0.3	2.9	2.0	1.3
	Manufacturing – per employed person	3.0	0.4	0.1	4.1	1.2	1.4
	Manufacturing – hourly	3.2	0.7	0.2	4.5	1.6	1.5
Belgium	Business – per employed person	3.7	1.6	1.3	5.0	3.0	2.4
	Manufacturing – per employed person	5.8	4.1	3.5	7.2	5.0	4.1
	Manufacturing – hourly	6.6	5.0	3.7	8.3	6.1	4.5
Norway	Business – per employed person	1.6	2.6	1.1	3.0	4.3	2.4
	Manufacturing – per employed person	2.6	-0.4	1.5	3.9	0.6	2.1
	Manufacturing – hourly	3.3	0.8	1.5	4.9	2.3	2.1
Sweden	Business – per employed person	1.4	0.6	0.4	3.1	1.9	1.4
	Manufacturing – per employed person	3.5	-0.2	2.4	5.0	1.1	3.0
	Manufacturing – hourly	4.5	0.9	2.5	6.5	2.7	3.2

a) Output is value added at constant prices.
b) The starting years are as follows: United States 1960, Japan 1966, Germany 1961, France 1964, United Kingdom 1960, Italy 1960, Canada 1962, Belgium 1962, Norway 1964, Sweden 1964.

- There was a fairly widespread weakening of TFP growth in most industries, manufacturing as well as services, in the **1973-79** period, although its intensity differed across sectors and countries (Table 5);
- In the **1979-83** period, TFP trends became more diverse, with a few manufacturing industries in some countries showing a recovery and service industries exhibiting a further fall in most countries;
- There is little or no sign of stronger TFP trends overall in the service sector or in what are generally thought to be information-intensive service industries, such as trade or financial services.

Table 4 compares productivity trends in the business sector and in manufacturing for a number of countries for which data are available. For virtually all countries and sub-periods both TFP and labour productivity growth in manufacturing exceeds overall productivity growth in the business sector. In some countries, productivity gains in manufacturing accelerated after **1979** but failed to return to pre-**1973** rates of growth. In several instances, the differential between manufacturing and total business sector productivity growth widened after **1979.** This gap, of course, reflects weak productivity trends in the service sector, a sector of growing importance in many countries. Placing undue emphasis on TFP trends in the service or manufacturing sector alone can therefore give misleading impressions about productivity behaviour.

In a reversal of earlier trends, the United States has enjoyed a better productivity performance in manufacturing in recent years than most other countries, Japan being the major exception. However, the downturn in manufacturing output has been longer-lasting and more severe in Europe than in the United States. In addition, adjustments for hours worked improve the European performance significantly relative to that of the United States.

Disaggregated data, based on Meyer-zu-Schlochtern (1988), show a synchronised weakening of TFP trends in almost all industries after **1973,** although its degree differed substantially across sectors and countries (Table 5). In contrast, TFP trends became more diverse after **1979,** with some industries, primarily goods-producing and energy-intensive industries, showing a recovery and others a further weakening. Most of the industries with improved TFP performance after **1979** witnessed little or no output gains, while employment fell. Although generalisations are difficult, recent TFP growth appears to have been strongest in the machinery and equipment, textile and leather, and chemical industries.

A surprising feature of recent productivity trends has been the near-generalised failure of TFP growth to recover in what has been labelled the information-intensive service industries – wholesale and retail trade (Trade); transportation, storage and communication (Tran); and finance, insurance, real estate and business services (Fin). Although technological innovation is commonly thought to have been strong in these industries, sustained increases in labour and capital inputs generally resulted in

Table 5. TFP growth **by industry**

Average percentage change at annual rate

		Manufacturing								Services								
		Total	Food	Tex	Paper	Chem	BMI	MEQ	Other	Total	Trade	Tran	Fin	Soc	Min	CST	Agr	Producers of govern-ment services
United States	1970-73	5.6	5.8	4.3	6.1	6.2	6.8	5.4	3.2	1.9	2.6	4.1	0.9	0.9	–1.7	–3.8	-0.3	-0.1
	1973-79	0.4	-0.1	3.2	-0.5	0.2	–3.2	0.7	–0.7	0.2	–0.8	1.6	0.4	0.1	–5.3	–2.5	–0.2	0.1
	1979-83	1.7	3.5	3.7	0.7	1.5	-4.5	2.4	–2.0	–0.1	–0.4	-0.1	–0.4	0.7	-4.7	–1.0	–0.7	0.8
Japan	1970-73	4.3	3.9	2.0	6.5	4.8	6.7	5.4	–10.6	2.2	6.2	1.4	3.2	–1.2	3.8	–1.3	4.0	0.1
	1973-79	2.7	–0.4	4.4	-0.5	3.2	-0.2	5.5	2.2	-0.1	2.7	0.2	-0.6	–1.9	-0.9	–2.1	–2.8	2.0
	1979-83	3.8	–2.1	8.8	3.4	2.9	–5.0	8.2	2.3	0.2	3.2	2.4	–1.8	-0.7	3.7	–6.1	–1.2	1.6
Germany	1970-73	2.9	0.5	1.4	2.8	4.8	1.2	2.6	0.3	1.9	1.1	–3.1	1.6	2.6	–1.8	2.7	3.8	0.4
	1973-79	2.4	1.9	3.5	2.0	1.8	2.1	2.4	0.4	2.5	1.4	2.4	3.1	1.5	–1.9	1.3	2.7	0.4
	1979-83	0.7	1.1	1.4	1.4	-0.2	-0.6	0.7	–3.4	1.1	0.2	0.4	1.1	0.0	–3.7	-0.4	3.1	0.3
France	1970-73	3.7	3.9	3.9	–0.9	3.2	2.8	3.8	4.2	3.2	2.0	4.2	1.9	2.7	..	0.9	4.0	0.9
	1973-79	3.0	2.2	1.6	2.0	2.8	0.9	3.6	3.3	1.2	0.6	0.4	1.7	0.3	..	-0.2	1.4	1.0
	1979-83	1.4	0.9	1.8	2.1	3.0	1.1	0.9	–1.9	0.2	-0.3	–1.0	-0.4	0.9	..	0.2	1.3	-0.4
United Kingdom	1970-73	4.9	2.3	5.0	4.0	6.0	1.7	4.1	3.9	1.2	-0.5	3.1	–2.5	2.0	32.7	–2.3	3.4	2.1
	1973-79	–0.4	0.4	0.8	-0.5	0.6	–1.8	-0.3	-0.6	0.4	–1.5	0.6	1.2	1.9	-0.8	-0.7	0.7	0.2
	1979-83	1.5	1.1	1.4	–2.9	1.2	1.3	1.9	–3.1	1.2	–1.5	2.3	1.6	0.3	3.4	-0.4	4.7	0.7
Italy	1970-73	3.7	4.7	3.8	4.6	5.3	2.7	0.3		2.0	3.1	1.4	..	0.6	..	3.6	0.9	-0.7
	1973-79	2.1	2.0	3.7	1.8	3.0	0.2	0.9		0.2	0.9	1.1	..	–1.4	..	-0.4	1.8	-0.6
	1979-83	0.9	2.1	–1.7	1.5	2.7	-0.1	1.7		–1.5	–1.2	-0.2	..	–2.7	..	-0.2	3.5	-0.5
Canada	1970-73	4.2	..							2.8	3.7	3.2	2.7	0.6	4.2	0.2	2.0	–1.2
	1973-79	0.7	..							0.6	-0.1	1.7	0.0	1.7	–7.8	–1.2	–1.7	–1.2
	1979-83	–1.3	..							-0.8	–1.6	0.8	-0.3	–1.9	–6.6	-0.8	1.6	–1.2
Belgium	1970-73	5.9	2.6	4.3	3.5	9.2	4.7	7.0	9.4	1.5	0.8	0.2	1.4	3.5	..	3.8	5.9	2.4
	1973-79	3.7	1.7	3.3	3.2	6.1	2.9	3.5	3.2	0.1	0.2	-0.8	0.3	0.5	..	0.7	0.0	-0.2
	1979-83	2.6	1.4	6.7	–2.5	4.5	0.8	2.5	0.7	0.7	0.2	–1.8	0.9	2.8	..	0.7	3.7	0.3
Denmark	1970-73	4.4	3.2	7.0	3.9	8.9	-6.6	3.4	7.1	2.6	2.9	-0.4	2.6	0.5	8.6	0.7	3.2	–2.3
	1973-79	2.3	2.9	6.0	0.5	1.5	4.0	2.1	–2.4	1.0	1.5	-0.4	-0.6	0.9	13.2	–3.5	2.6	–0.1
	1979-83	3.0	2.9	2.8	-0.6	7.7	7.9	2.3	4.3	0.3	2.7	–2.3	–2.0	0.1	12.6	-0.1	4.3	0.7
Finland	1970-73	2.6	..							3.5	5.4	3.6	–0.2	0.8	–3.6	2.5	0.9	0.9
	1973-79	1.9	..							1.8	1.1	1.0	1.1	-0.2	1.4	2.1	2.6	0.5
	1979-83	2.9	..							1.9	0.8	2.4	2.2	1.1	2.6	1.9	0.1	0.3

Norway	1970-73	3.5	0.4	1.9	1.9	7.0	5.9	1.8	4.5	1.6	3.0	3.4	–2.0	1.2	15.2	3.6	4.2	1.5
	1973-79	-0.3	-0.3	-0.6	–1.3	–1.7	1.1	-0.5	–2.2	1.9	2.0	3.3	0.1	0.5	20.1	2.4	1.3	1.9
	1979-83	0.6	-4.0	2.9	0.6	3.0	0.8	0.0	–2.5	-0.6	–2.4	0.5	–1.4	–1.0	0.0	0.7	3.6	2.0
Sweden	1970-73	2.9	–1.1	8.2	3.6	5.9	3.9	1.9	1.5	2.1	2.7	3.1	0.0	4.4	5.9	2.2	3.3	–1.6
	1973-79	0.4	-0.3	1.1	0.2	–1.0	1.6	0.7	3.9	0.6	0.4	2.4	-0.5	2.4	–5.7	2.4	–2.0	-0.9
	1979-83	2.0	0.4	-0.7	0.3	3.3	6.4	3.2	–21.8	0.1	0.2	-0.2	-0.1	0.1	–4.4	0.5	4.5	-0.1
Australia	1970-73	2.1							..	1.2	0.9	2.9	..	0.9	..	–1.5	0.8	0.5
	1973-79	1.7	..						..	0.3	-0.7	3.0	..	0.4	..	0.2	4.0	0.1
	1979-83	0.4	..						..	0.6	0.5	1.5	..	0.0	..	1.4	3.0	-0.3
Average of	1970-73	4.5	4.0	3.7	5.1	5.5	4.6	4.5	-6.3	2.0	2.9	2.6	1.2	0.8	4.9	–1.0	1.8	0.1
above	1973-79	1.5	0.7	3.2	0.1	1.4	-0.5	2.2	1.7	0.5	0.2	1.3	0.5	-0.2	–3.8	–1.3	0.2	0.3
countries	1979-83	1.8	1.5	2.7	0.9	1.7	–2.1	3.4	1.0	0.0	0.1	0.5	-0.3	–0.1	–3.1	–1.7	0.9	0.5

Note: Food = food. kindred products and tobacco; Tex = textiles, leather; Paper = paper and printed products, printing and publications; Chem = chemicals; BMI = primary metals industry; MEQ = machinery and equipment; Other = other manufacturing; Trade = wholesale, retail trade, restaurants and hotels; Tran = transport, storage and communications; Fin = financial institutions. insurance, real estate and business services; Soc = community, social and personal services; Min = mining and quarrying; CST = construction; Agr = agriculture. Total refers to the indicated industries and is not comparable to data for manufacturing reported in Table 4.

Source: See Meyer-zu-Schlochtern (1987).

lower TFP growth after 1979. The important exceptions to this generalisation are Japan (Trade and Tran), the United Kingdom (Tran), Denmark (Trade) and Finland (Tran and Fin). Labour productivity growth in the community, social and personal services industries has been frail in most OECD countries. A sector of strong employment growth, this industry may be particularly resistant-.to **productivity-** enhancing technological innovations.

Several explanations have been offered to resolve the apparent paradox of widespread process innovation in some service industries and no sign of stronger TFP growth. Measuring productivity is most difficult for new or changing products or where the output is an intangible service of unknown quality (**Baily,** 1986; U.S. Department of Commerce, 1986). Moreover, low productivity gains may reflect an over-investment in hardware and an under-investment in software and end-user training. There may also be long training and learning periods before employees can use the new technology efficiently (Freeman, 1986; Kimbel, 1987). Finally, and perhaps most importantly, the view that these industries have been major beneficiaries of new technology may be misleading: some evidence to this effect will be presented in Englander ***er*** al. (1988), in which an attempt is made to gauge the flow of technology into the service sector.

Although manufacturing productivity growth has persistently exceeded that of service industries, patterns in TFP growth across industrial subsectors within a given country changed markedly in most countries after 1973 (Tables 5 and 6). The energy-intensive industries (paper, chemicals, mining and construction) of most countries saw either a sharp fall in TFP growth in the 1973-79 period compared to 1970-73, or TFP levels actually fell in response to severe output losses. In contrast,

Table 6. Rank correlation **coefficients of** industries ranked by **TFP** growth within an **individual** country

	1970-73 ranking *vs.* 1973-79 ranking	1973-79 ranking *vs.* 1979-83 ranking
United States	0.05	**0.75****
Japan	0.30	0.59'.
Germany	0.03	**0.64****
France	0.20	**0.54***
United Kingdom	0.13	0.28
Italy	**0.68****	0.14
Canada	-0.14	0.71**
Belgium	**0.93****	**0.71****
Denmark	0.41	**0.78****
Finland	-0.26	0.09
Norway	0.34	-0.34
Sweden	-0.03	0.15

* Significantly different from zero at the 10 per cent confidence level.
** Significantly different from zero at the 5 per cent confidence level.

Table 7. Are TFP movements industry- or country-specific?
Pooled cross-country, cross-industry

Time period	Adjusted R^2 from regressions with TFP growth as the dependent variable and the following independent variables: Country dummies (1)	Industry dummies (2)	Country and industry dummies (3)	As (1) plus output growth	As (2) plus output growth	As (3) plus output growth
1970-73	-0.00	0.11	0.11	0.51	0.53	0.63
1974-79	0.05	-0.03	0.02	0.66	0.74	0.84
1980-83	0.04	0.11	0.18	0.48	0.68	0.71
1970-83	0.03	0.10	0.15	0.51	0.70	0.79

the relative rankings of sectors within a country did not change greatly after 1979 compared to the 1973-79 ranking. Stronger efficiency gains emerged in as many as six to eight, mostly manufacturing, industries in the United States, Japan, the United Kingdom and Sweden. The revival of TFP growth in these industries often coincided with a fall in output, implying an even larger fall in factor inputs, primarily labour[3].

The picture of broadly similar movements in TFP growth in specific industries across countries is supported by regression analysis. ***Industry-specific*** factors provide a better "explanation" or description of TFP growth across countries and industries than do ***country-specific*** factors (Table 7, columns 1-3). This pattern is maintained when industry output changes are added as an explanatory variable, although very strong correlations exist between industry output and TFP growth. Thus, while macroeconomic factors are important, the data point to common industry factors across countries, as well as industry growth, as being more closely associated with TFP growth.

II. IMPLICATIONS OF FASTER TFP GROWTH: INTERLINK SIMULATIONS

Before discussing the sources of TFP growth and its slowdown, it is useful to review the interaction of TFP and other macroeconomic variables. First, the impact of TFP growth is far more pervasive than simply raising trend output growth and real wages. It lowers inflation and eases constraints on economic policy, enabling lower unemployment rates. Second, if labour markets are rigid in the face of falling productivity growth, there are likely to be feedback effects from policy back to TFP through slower growth, which may exacerbate the initial impacts of the TFP slowdown. Finally, it is useful to distinguish between the impacts of supply-driven increases of TFP growth and purely demand-driven increases in terms of medium-term effects on output, employment and inflation.

The simulation results are taken from Torres (1988). Two sets of simulations are presented. The first presents the effects of a common increase in productivity growth across OECD countries, while the second highlights the productivity impact of a pure demand-side-induced increase in productivity growth.

In the INTERLINK supply block, technological progress for the seven major countries is assumed to be Harrod-neutral – i.e. labour productivity-augmenting, and thus is measured by an index of labour efficiency (Jarrett and Torres, 1987)[4]. In addition, the United States is the country with the highest level of TFP (measured at purchasing power parities), and a "catch-up" hypothesis is incorporated into the model. Thus, rates of growth of labour efficiency in the other countries are assumed to converge eventually to the U.S. rate.

In the framework of the model, a given rise in technical progress relative to baseline raises labour productivity and, for a given level of output, labour input declines. This employment-reducing effect, though, is offset by two effects. To the extent that real wages do not fully absorb the gains in labour efficiency, profitability rises relative to baseline. This raises the level of desired or optimal output, with positive effects upon investment and, hence, on aggregate demand.

Higher productivity also serves to lower prices relative to baseline through two main channels; a reduction in unit labour costs and an increase in the gap between actual and potential output, an effect which produces downward pressures on inflation relative to baseline. For a given level of inflation, output growth and employment can both proceed faster as a result. The strength of these positive effects is primarily conditioned by the extent to which real wages catch up with increased productivity.

The first simulation of Table 8 shows the effects of a simultaneous sustained rise in the labour efficiency index by 1 percentage point in each country as derived from the INTERLINK model. No fiscal stimulus is assumed and monetary policy is non-accommodating. The simulation has been carried out in linked mode, with fixed exchange rates. As expected, the rise in labour efficiency in all countries leads to gains in employment and output. This reflects a stronger rise in profitability and associated effects on output supply and investment[5].

In contrast to the results reported above, in which TFP may be regarded as increasing from exogenous or supply side factors, the second simulation shows the results of attempting to exploit the correlation between TFP growth and output growth. A demand shock is simultaneously applied to all countries. As can be seen, the increase in demand and output growth leads only to a temporary increase in TFP, but is accompanied by faster wage and price growth. This rise in inflation emerges

	1 percentage point increase in labour efficiency growth[b]			1 percentage point increase in government expenditure (relative to GDP)		
	Years					
	(1)	(3)	(5)	(1)	(3)	(5)
Labour productivity	0.4	1.3	1.a	1.0	0.9	0.4
Real output	0.6	1.9	2.7	1.5	1.1	0.7
Prices	-0.2	–1.0	–1.7	0.1	2.2	4.1
Employment	0.2	0.6	0.9	0.5	0.8	0.3
Real wages	0.3	1.4	2.5	0.4	0.8	1.1
Profitability[c]	0.3	0.6	0.8	-0.2	-0.5	-0.9
Real private consumption	0.2	1.1	1.a	0.4	0.5	0.1
Real private investment	1.1	4.5	6.4	1.7	1.5	–2.1

a) The simulations, which have been carried out in linked mode with fixed exchange rates, assume constant interest rates and, in the first simulation, unchanged real public expenditure. The figures in the table refer to average changes for the major seven countries.
b) As an approximation, total factor productivity growth is labour efficiency growth times labour's share of output.
c) Proxied by the ratio of output prices to input costs.

because the demand growth is accompanied by significantly tighter capacity utilization, an effect which swamps the induced productivity gain.

To the extent that these simulations reflect the actual structure of OECD economies, their policy message is that TFP growth pays its greatest dividends when it is a result of supply side or structural improvements. Purely demand side gains run the risk of provoking additional rounds of inflation.

III. SOURCES OF THE TFP GROWTH SLOWDOWN

This section examines past TFP trends from a number of different perspectives and, to the extent possible, tries to determine the role of microeconomic or structural factors as well as demand growth in explaining the TFP slowdown and productivity differences between countries. The structural factors considered include changes in energy prices, changes in the composition of output and employment, capital-deepening, the process of international catch-up and convergence, and trends in research and development expenditure.

The methodology used does not permit an exact parcelling out of the factors behind the TFP slowdown: it is impossible to place all the contributing factors within a common framework that is amenable to empirical analysis. In general, the results point strongly towards the slowing in capital deepening and of catch-up opportunities as being important factors for many countries. Countries with higher R&D outlays, which contribute to a rapidly expanding technological base, also appear to have faster TFP growth, although the slowing of R&D growth itself (as opposed to its potency as discussed in Englander *et* al., 1988), does not seem generally to account for much of the slowdown. In contrast to other studies (Lindbeck, 1983; Bruno and Sachs, 1985), the demand side and energy prices seem somewhat less important in a direct way. However, the indirect effects especially of energy prices may have been more important than our estimates or methodology permit.

A. Embodiment effects: capital accumulation and TFP growth

Most of the slowing in output and labour productivity growth can be attributed to slower TFP growth as opposed to capital accumulation. Yet concerns about the rate of capital accumulation and capital deepening are widespread. It is often thought that the impact of capital formation on productivity developments may be greater than that suggested by the growth-accounting framework. In such a framework, all firms are generally assumed to use the same technology, operating at the same degree of efficiency. Alternatively, the distribution of efficiency across firms is viewed as being fixed. In either case, there is no allowance for the average-practice firm to approach, or further drift away from, the best-practice firm. Hence, in the growth-accounting framework, TFP growth is an inward shift of the capital-labour isoquant, whereas capital accumulation is a movement along a fixed isoquant. TFP is implicitly assumed to incorporate all of capital's effect on output.

One of the main channels, however, through which firms might increase efficiency is via the installation of more recent capital vintages embodying new technology. A movement along an isoquant toward more capital might therefore result in an inward shift of the isoquant. If capital input growth is the vehicle by which new technologies are incorporated into the production process, a slowing of capital accumulation may be tantamount to a less rapid diffusion of new techniques (Metcalf, 1981)[6].

While embodiment effects from capital accumulation are widely believed to exist, they have been difficult to quantify (OECD, 1979; Helliwell *et al.*, 1986; Jarrett and Torres, 1987). There is considerable evidence, though, that the average age of the capital stock has increased in an era of reduced output growth (Maddison, 1987; United Nations, 1986). Thus, by the early 1980s the share of the capital stock aged five years or less was 15 percentage points lower than in the mid-1960s in many countries.

Another possibility is suggested by recent work of Scott (1987) and Baily (1981). If capital is not perfectly malleable, changes in factor prices or demand patterns may render obsolete portions of the capital stock. In this case, a faster growing capital stock may be equivalent to a capital stock which is more efficient and, perhaps more importantly, more appropriate to current economic conditions. Hence, a correlation between capital stock and productivity growth may reflect the greater suitability of newer capital, as well as the other possible technological advantages discussed above.

Regression analysis over a cross-section of seventeen countries indicates that the relationship between output and capital is much stronger than implied by TFP calculations (Table 9, lines 1-2). Given an average capital share of about 30 per cent and relating output growth to the growth of capital and labour the impact on output of capital should be less than half that of labour. Instead, the estimated coefficients reveal a roughly equal impact. When constant returns to scale are imposed, the standard assumption in TFP calculations, capital is still shown to have an equal weight to that of labour. These results, which persist even in disaggregated data,

Table 9. Capital stock, catch-up, and R&D effects on output growth: cross-country regressions for seventeen countries

	Capital growth	Labour growth	Relative labour productivity (US = 100)	R&D stock growth	SEE	Adjusted R^2	Number of observations
1)	0.48 (5.61	0.51 (4.2)	–	–	0.93	0.76	51[b]
2)	0.57[a] (7.7)	0.43[a] (7.7)	–	–	0.79	0.79	17[c]
3)	0.37 (4.0)	0.70 (5.1)	–0.03 (–2.61	–	0.88	0.78	51[b]
4)	0.42[a] (4.2)	0.58[a] (4.2)	–0.03 (–2.2)	–	0.62	0.83	17[c]
5)	0.44 (4.8)	0.57 (4.5)	–	0.05 (1.5)	0.92	0.76	51[b]
6)	0.50[a] (6.3)	0.50[a] (6.3)	–	0.06 (2.0)	0.64	0.82	17[c]
7)	0.36 (3.9)	0.71 (5.1)	–0.03 (–2.1)	0.02 (0.6)	0.89	0.78	51[b]
8)	0.40[a] (4.2)	0.60[a] (4.2)	–0.02 (–1.5)	0.04 (1.2)	0.61	0.84	17[c]

a) Constant returns to scale imposed.

b) Growth rates averaged over 1970-73, 1973-79, 1979-85 except for catch-up variable which is defined as a 3-year moving average of relative labour productivity centered in 1970, 1973 and 1979 respectively. Unreported shift dummies for 1973-79 and 1979-85 and a constant term also were included.

c) Growth rates averaged over 1970-85. Catch-up variable defined as 3-year moving average centered in 1970. An unreported constant term was also included.

Note: The seventeen countries are the United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, Austria, Belgium. Denmark, Finland, Ireland, the Netherlands, Norway, Spain and Switzerland. t-statistics are in parentheses.

point to a strong association between TFP growth and capital accumulation. These findings, however, are not conclusive because, as discussed below, other omitted factors which are positively associated with TFP may be correlated with capital accumulation. Still, at the very least, the results suggest that the factors which have stimulated capital formation have also had a positive impact on TFP growth.

The strong relationship between TFP and capital growth can be interpreted in a number of ways. Capital and labour growth are both components of the definition of TFP growth, and hence a negative short-term correlation between inputs and TFP is probably in the data by construction. If this is the case, there are no policy implications of a positive relationship between TFP and capital growth. But the results discussed above cover complete business cycles. Hence, the adjustment lags and measurement errors that cause the short-run negative correlation of TFP and input growth are likely to average out. Moreover, it is unlikely that cyclical accelerator effects on capital growth are large when averaged over business cycles. Finally, TFP growth may itself affect input use if, for example, new technology always requires a higher capital-labour ratio. In this case, capital growth is an indicator, but not a source, of TFP growth.

To limit the simultaneity between TFP growth and capital accumulation, average rates of TFP growth in three periods (1969-73, 1973-79 and 1979-85) were pooled for seventeen countries and regressed on average rates of growth in the capital-labour ratio and average changes in capacity use (Table 10), similar to the procedure used by MacMahon (1984). Two-stage least squares were used with profitability, relative factor costs and lagged capital-labour growth as instruments, on the assumption that their movements are largely independent of current TFP growth. The estimated equations indicate a significant effect from capital deepening to TFP[7].

Taken together, these results suggest that the process of capital deepening has a positive impact on TFP growth. Hence, a slowing in the relative price of labour

Table 10. Pooled cross-country estimates of the relationship between TFP growth, changes in the capital-labour ratio and capacity utilization[a]

	Growth of the capital-labour ratio	Change in capacity utilization[c]	SEE	Adjusted R^2	Number of observations
Dependent variable: average TFP growth in three sub-periods (1969-73, 1973-79 and 1979-85) for 13 countries[b]	0.41 (2.4)	0.91 (3.5)	0.52	0.50	39

a) The equation is estimated by two-stage least squares with fagged values of the growth of the capital-labour ratio, profitabilityend the growth rate of labour costs relativeto the cost of capital used as instrumentsfor the growth of the capital-labour ratio. Country-specific interceptterms are included in the regression. t-statistics are reported in parentheses.

b) The thirteen countries are the seven largest OECD economies plus Belgium, Denmark, Finland, Sweden, Australia and New Zealand.

c) The change in capacity utilization is based on a phased average trend.

may not be an unmitigated advantage if it reduces the pace of capital-for-labour substitution, without raising profitability. Moreover, to the extent that such real wage moderation is caused by economic slack, which also lowers profits, the negative effects on productivity of a recession would be reinforced. A similar inference is drawn by Gordon (1986). Although these results need to be examined cautiously, they seem robust across a variety of specifications. They suggest the desirability of policies to maintain the pace of capital accumulation, particularly when capacity utilization changes and factor substitution are pushing in the opposite direction. Obviously, such policies should be neutral to the extent possible with respect to different types of capital.

B. Catch-up and convergence

The earlier analysis indicated that the TFP slowdown appeared in many countries to be a continuous process beginning in the mid- to late 1960s. The catch-up hypothesis would be consistent with this description. During the 1960s, the United States was the technological leader in many fields. Also, given the exceptionally large scale of the U.S. market and the unrestricted flow of resources within this market, the degree of specialization typically has been high. All these factors have been accounting for the high level of U.S. productivity.

One way in which other countries could rapidly improve their own technology was by tapping into that of the United States, especially in an environment of rapidly expanding international trade and reduced trade barriers. The capacity to **do** so undoubtedly was contingent on an already high level of human capital. In the early stages, technology could be improved easily and advances would be large and rapid. However, as technologies in all countries converged towards the U.S. level, there would be less and less room for improvement. Similarly, potential benefits from trade liberalization have declined after rapid progress in dismantling trade barriers in the 1960s. Given low economic growth and large swings in real exchange rates, protectionism has even risen over the recent years, impeding the efficient allocation of resources worldwide. In these conditions, part of the long-run TFP slowdown may be explicable in terms of a fading away of favourable influences (Lindbeck 1983; Helliwell *er* al., 1985; Fagerberg, 1987).

The distance behind the overall technology leader can be measured by the level of labour productivity in each country relative to that in the United States. These relative labour productivity levels for the total economy and for manufacturing are reported in the right-most columns of Table 11; 1985 purchasing power parities from Blades and Roberts (1987) have been used to define productivity levels in U.S. dollars. Labour productivity is used because it is much more easily quantifiable in a common currency. For each of the six large countries, the data show a steady process of catch-up and convergence towards the level of labour productivity in the

Table 11. Catch-up and TFP growth

	Estimated coefficients on the catch-up variables[a]				Labour productivity relative to U.S.[b]				Labour productivity in manufacturing relative to U.S.[b]			
	(1)	(2)	(3)	(4)	1968	1973	1979	1986	1968	1973	1979	1984
Japan	-0.09 (-8.02)	-0.10 (-7.30)	-0.20 (-4.17)	-0.17 (-3.57)	32.2	46.1	54.7	64.0	34.2	46.9	60.2	68.6
Germany	-0.04 (-2.11)	-0.06 (-4.41)	-0.08 (-3.05)	-0.08 (-2.62)	47.6	57.7	69.4	76.3	62.2	65.2	74.8	69.7
France	-0.03 (1.78)	-0.07 (-7.69)	0.06 (1.71)	0.01 (0.69)	46.4	59.5	72.2	82.6	65.1	72.4	86.5	81.9
United Kingdom	0.01 (0.67)	0.00 (-0.07)	0.07 (2.60)	0.05 (2.45)	49.0	57.6	60.9	66.9	58.1	59.1	57.6	57.8
Italy	-0.03 (-2.02)	-0.06 (-6.31)	-0.07 (-3.23)	-0.08 (-3.34)	49.8	63.5	72.2	75.9	59.1	63.0	69.7	67.2
Canada	-0.02 (-0.79)	-0.04 (-0.82)	-0.03 (-0.24)	0.00 (-0.04)	69.3	71.9	86.3	89.1	85.4	86.7	87.6	76.9

a) The dependent variable in each regression is TFP growth. The independent variables in each regression are the level of labour productivity as per cent of U.S. level (the estimated coefficient of which is repotted in the table) and the change in capacity utilisation (current and three lags) and shift dummy variables beginning in 1974 and 1980. In addition the equation in column (1) includes the growth in the capital-labour ratio (current and lagged value); the equation in column (3) is as in (1) but includes a continuous time-trend variable; and the equation in column (4) includes time trend and squared time trend. Equations in columns (1) and (3) are estimated with two-stage least squares with lagged growth in the capital-labour ratio, current and lagged growth in the ratio of real wages to cost of capital used as instruments for the growth in the capital-labour ratio. *t*-statistics are reported in parentheses.

b) Productivity levels are based on revised purchasing power parity data based on 1985 price and expenditure data, 1984 for manufacturing. For a further discussion, see Blades and Roberts (1987). The productivity data are calculated as business sector output divided by total employment, which can differ markedly from GDP per *capita*.

United States from the late **1960s** to the mid- **1980s** (see also Maddison, **1987).** The apparent decline after **1978** in relative productivity levels in manufacturing for a number of countries is a result of defining productivity as output per employee rather than manhours (Table 4).

In order to assess the importance of catch-up effects for TFP growth, the level of labour productivity in each country relative to the United States, was introduced as an explanatory variable in a number of aggregate TFP growth equations each of which included other explanatory variables such as the change in capacity utilization, the growth in the capital-labour ratio, etc. (Table **11).** A negative estimated coefficient on the catch-up term indicates that as the gap relative to the United States narrowed, TFP growth slowed.

According to the estimation results, catch-up could have been a major source of productivity growth for the major OECD countries except for Canada (and the United States, of course). Roughly speaking, **if** the average coefficient is about 0.05 and the average advance relative to the United States about **25** to 30 percentage points, then about **1.2** to **1.5** percentage points of the slowdown could be attributable to diminishing catch-up possibilities. One pattern common to several countries is that the estimated catch-up effect is smallest when the capital to labour growth term also appears in the regression. Some of the catch-up may therefore be embodied in new vintages of capital goods which contain the most advanced technology. In other words, the growth in the capital-labour ratio has been strong in countries where the relative productivity level initially was low, and vice versa.

Similar results are found in an explicitly medium-term context (Table **9,** lines **3** and 4). Countries with more room to catch-up tend to have faster growth rates. Moreover, the catch-up variable clearly is related to capital stock growth. When the two are included in the same regression the coefficient of capital falls to levels somewhat closer to the capital share in output.

While the United States has remained the overall technological leader, other countries have surpassed it in particular industries. For example, in the textile industry Belgium appears to have a higher productivity level, while Japan appears to be the OECD leader in the basic metals industry. Hence, an industry-level analysis of catch-up and convergence would treat the United States and other countries symmetrically*.

It is also noteworthy that catch-up has not been more pronounced in the manufacturing sector than the overall business sector. As was seen in Table 4, however, **U.S.** manufacturing productivity growth performance was stronger relative to other OECD countries than its aggregate business sector performance. Moreover, the transfer of technology is not necessarily confined to manufacturing, as the growing use of larger retail spaces with higher volume per employee, or the introduction of jet aircraft in transportation industries suggests. Nor is the phenomenon of converging productivity levels by any means restricted to the OECD

Table 12. Labour productivity growth in the newly-industrializing countries[a]

Average percentage changes at annual rates

	All industries	Manufacturing
Hong Kong		
1975-79	5.5	9.6
1979-84	6.0	5.8
South Korea		
1975-79	6.3	7.9
1979-84	4.2	5.5
Singapore		
1975-79	3.0	3.1
1979-84	5.6	3.6
Taiwan		
1973-79		7.1
1979-86		6.1
Brazil		
1975-79	3.6	3.9
1979-82	–1.7	–2.1
Argentina		
1975-80	0.8	..
Mexico		
1975-80	2.9	
Memorandum item:		
Japan		
1973-79	**3.3**[b]	5.1
1979-85	**2.9**[b]	4.4

a) Output at constant prices per employed person.
b) Business sector.
Source: **U.N.** *Statistical Yearbook for Asia and the Pacific,* 1985; U.N. *Statistical Yearbook for Latin America and the Caribbean,* 1985; ILO *Yearbook of Labour statistics,* 1986.

area. Assisted by low labour costs and foreign direct investment, newly industrializing countries (NICs) experienced large output gains for labour-intensive products. The accompanying increases in labour productivity in industry among Asian NICs even exceeded those in Japan, where such gains are among the highest in the OECD area (Table 12).

C. R&D spending

Research and development (R&D) is often thought to be a principal contributor to new technology and TFP growth as documented, for example, in Kendrick and Vaccara (1980). Positive effects have been found in numerous studies at the disaggregated level and to a lesser extent at the aggregate level. In this section, the possible role of a slowing in aggregate R&D spending on TFP growth is examined, while in Englander ***et al.* (1988)**, a more detailed look at the sectoral impact of R&D and the possible shifting of its relationship with productivity growth is examined. In general, the aggregate data used in this section suggest that countries with rapidly growing R&D stocks have faster TFP growth, but that the relationship between R&Q growth and TFP growth is quite possibly linked with other factors, such as the room for catch-up and the pace of capital accumulation.

Although the patterns across countries are variable, real growth in R&D expenditure weakened in most countries at some point in the **1970s.** but has picked up substantially in the **1980s** (Table **13).** The important exceptions are Germany and the United Kingdom where recent R&D spending has been lower than in the previous periods. In most countries these rates of growth have been significantly higher on average than GDP growth. Consequently, R&D investment has come to represent a higher share of GDP over time despite a temporary decline in the share of R&D in GQP in the **1970s** (Table **14).**

Most of the countries with rapid growth in R&D spending were starting from fairly low levels relative to GDP. From Table 14, it appears that 2.5 per cent of GDP represents a ceiling which the larger countries are just beginning to consistently exceed. Looking at a larger sample of countries, there is a wide discrepancy in the shares of GDP devoted to R&D: the largest five countries, Switzerland and perhaps

Table 13. **Growth** in total real **R&D** expenditure in OECD countries

National currency; average percentage change at annual rates

	Long period	1965-1970	1970-1975	1975-1980	1980-1985
United States	3.01[a]	2.03	-0.39	3.87	6.54
Japan	9.19[a]	14.94	6.03	6.77	9.25
Germany	5.348	9.49	3.77	4.90	3.30
France	**4.09**[a]	4.09	2.81	3.70	5.80
United Kingdom	1.72[a]	1.39	0.75	3.64	1.10
Italy	**7.06**[a]	12.18	3.54	2.08	10.80
Canada	**3.48**[b]		–1.18'	4.43	6.38
Australia	2.61[c]		0.80	0.90	6.22
Austria	**8.13**[c]		12.91	7.20	4.45
Belgium	**5.69**[d]	9.57	3.38	3.86[j]	
Denmark	3.50[e]		2.98	3.20	**5.56**[k]
Finland	7.65'		7.43	6.53	9.90'
Ireland	4.148		7.10	1.56	3.87[m]
Netherlands	2.038		3.25	1.22	1.52"
Norway	6.658		8.13	4.28	7.81'"
Portugal	4.58[g]		1.38	6.93	5.75[m]
Spain	9.08'		16.37	4.60	5.03'
Switzerland	**2.59**[h]	5.22	2.12	0.89	5.60"

a) 1965-1985. *e)* 1970-1982. *i)* 1971-1975. *m)* 1980-1984.
b) 1971-1985. *f)* 1970-1983. *j)* 1975-1979. *n)* 1980-1981.
c) 1970-1985. *g)* 1970-1984. *k)* 1980-1982.
d) 1965-1979. *h)* 1965-1981. *l)* 1980-1983.
Source: OECD, DSTI database.

Table 14. R&D expenditure as a percentage of GDP and per employed person

	Percentage of GDP					Per employed person (1980 constant U.S. dollars)				
	1965	1970	1975	1980	1985	1965	1970	1975	1980	1985
United States	2.76	2.65	2.32	2.39	2.83	670	670	606	636	810
Japan	1.55	1.85	2.01	2.18	2.61	111	206	270	353	544
Germany	1.60	2.06	2.24	2.41	2.66	200	318	395	492	612
France	2.03	1.91	1.80	1.84	2.31	247	291	326	382	536
United Kingdom	2.30	2.18	2.03	2.24	2.32	290	314	322	381	464
Italy	0.67	0.88	0.93	0.86	1.33	72	130	153	162	264
Canada	..	1.36[a]	1.09	1.15	1.38	..	304[a]	253	273	370
Australia	..	1.23	1.07	0.98	1.14	..	213	204	201	260
Austria	..	0.61	0.92	1.10	1.27	..	79	140	192	252
Belgium	1.05	1.31	1.30	1.36[b]	..	133	204	236	274[b]	..
Denmark	..	0.96	1.01	1.04	1.25	..	140	162	181	208[e]
Finland	..	0.78	0.91	1.07	1.53	..	96	131	172	223[d]
Ireland	..	0.74	0.83	0.72	0.80	..	79	109	109	133[c]
Netherlands	..	2.01	2.02	1.89	1.99	..	385	456	453	487[c]
Norway	..	1.10	1.34	1.27	1.53	..	175	234	257	337[c]
Portugal	..	0.35	0.30	0.33	0.40[c]	..	24	24	32	39[c]
Spain	..	0.22	0.35	0.40	0.48[c]	..	25	53	72	86[d]
Switzerland	2.14	2.25	2.40	2.31	2.27[d]	347	431	483	496	493[f]
Average of above countries[g]	..	2.12	1.99	2.07	2.45	..	439	430	474	622

a) 1971.
b) 1979.
c) 1984.
d) 1983.
e) 1982.
f) 1981.
g) Weighted average of above countries based on 1985 current price GDP at 1985 exchange rates.
Source: OECD, DSTI database.

the Netherlands are the only countries devoting as much as 2 per cent of GDP to R&D, with all other countries spending considerably less.

With the exception of Japan and Germany, defence expenditure makes up significant portions of R&D spending among the larger countries (Table 15). Often such research is regarded as having less of an effect on measured TFP than civilian research, because there is no adequate way of measuring how much military output is enhanced. For civilian purposes, the United States, France and the United Kingdom spend about 1.6 to 1.8 per cent of GDP on R&D, a somewhat higher percentage than in the early 1970s. For the United States, the overall decline in R&D spending between 1978 and 1975 came from a fall in the military component. More generally, the rise in R&D growth seems to mirror greater activity by business enterprises, whose share of R&D funding has risen significantly in the United States, France, Canada and a number of smaller countries.

Table 15. Estimated non-defence R&D expenditure

	As a percentage of GDP				As a percentage of total R&D			
	1971	1975	1980	1984	1971	1975	1980	1984
United States	1.68	1.72	1.86	1.82	65.9	74.1	77.8	71.1
Japan	1.84	2.00	2.17	2.64	96.8	99.5	99.5	99.6
Germany	2.03	2.10	2.30	2.47[a]	92.3	93.8	95.4	97.2[a]
France	1.46	1.46	1.43	1.79	76.4	81.1	77.7	79.6
United Kingdom	1.50[b]	1.32	1.72[c]	1.61[a]	68.8[b]	65.0	76.8[c]	73.5[a]

An effort was made to measure the independent effects of R&D on aggregate TFP growth. For many reasons, the direct econometric relationship between R&D and TFP is likely to be weak. First, R&D only measures the inputs into research rather than the production of new technology, and, as mentioned earlier, the productivity of R&D may have slipped in the 1970s. Secondly, the lags between R&D and its effects on productivity are likely to be highly variable, with diffusion of new technology depending to some extent on the business cycle and pace of capital investment. Thirdly, there are problems in measuring the stock of R&D and its rate of obsolescence. Fourthly, even measuring the levels of real R&D spending is difficult, as specialized deflators are largely non-existant or highly experimental. For these reasons, much of the R&D literature is based on highly disaggregated cross-section data sets or on case studies, where many of these problems do not exist. Because R&D spending tends to be fairly stable, intertemporal relationships are hard to find in time-series.

Over the longer term on a purely cross-sectional basis, one finds some relationship between R&D and TFP, but this disappears when the time period is divided into separate business cycles and the catch-up variable is included (Table 9, lines 5-8). These results suggest that TFP growth is linked to all three factors but that they tend to move similarly, hiding individual contributions, and pointing towards the possibility that these factors have been complements in the process of increasing TFP.

D. Employment and composition effects

Shifts in the composition of output and employment are normally induced by changing consumer habits (largely linked to increases in the level of real income), variations in exchange rates and shifts in relative factor prices (Blades, 1987).

Autonomous factors such as the large rise in female participation rates may also be important in specific countries or time periods. Since sectoral rates of productivity growth differ, changes in the distribution of factor inputs across sectors may affect aggregate productivity growth and be part of the explanation of the TFP slowdown. The results do not suggest much effect, although they can be justifiably criticised because the level of aggregation is so high. More detailed studies for specific countries occasionally find stronger composition effects.

One way of measuring the compositional effect is to weight increases in sectoral productivity growth by employment shares in different periods. This captures the effect on productivity growth of the shift in employment towards sectors with relatively slow productivity growth. Calculations of this kind are naturally highly sensitive to the base year in which productivity levels are measured. In the discussion below, the data refer to the total economy minus agriculture and producers of government services.

For about half of the countries (the United States, Japan, the United Kingdom, Belgium, Denmark and Sweden), the shift of labour resources into sectors with below-average productivity growth results in an average growth in labour productivity using 1979 employment shares which is about 0.2 percentage points lower than that based upon 1970 shares (Table 16). A similar result is reported in

	Average growth 1970-83			Average growth 1979-83	
	Actual growth	Effect of shifting employment weights 1979 vs. 1970	Effect of using 1970 U.S. employment weights vs. 1970 national shares	Actual growth	Effect of shifting employment weights 1979 vs. 1970
United States	0.8	-0.2	0.0	0.8	-0.2
Japan	3.5	-0.4	0.3	2.8	-0.5
Germany	2.8	0.0	-0.2	1.7	0.0
France	2.5	0.0	-0.1	1.4	-0.1
United Kingdom	1.7	-0.2	-0.3	1.9	-0.1
Italy	1.6	0.0	-0.4	0.0	0.0
Canada	0.9	0.0	0.0	-0.3	-0.1
Belgium	2.9	-0.3	-0.4	2.0	-0.2
Denmark	2.3	-0.2	0.2	1.8	-0.3
Finland	3.0	0.0	-0.2	2.8	0.0
Norway	3.9	0.0	-0.2	2.3	-0.1
Sweden	2.1	-0.1	-0.1	1.5	0.0

Lindbeck (1983). For Japan, the stronger impact reflects an exceptionally strong inflow of labour into community, social and personal services and out of manufacturing.

Given the weak productivity performance of the United States, it is of interest to calculate labour productivity growth in non-U.S. countries using U.S. employment shares. This shows the degree to which the different employment structures outside the United States account for some of the differential between labour productivity growth in the United States and other countries. The third column of Table 16 reveals that eight countries would have seen moderately lower gains in labour productivity growth had they had the same structure of employment as the United States in 1970. However, the data clearly show that differences in employment

Table 17. Employment growth by demographic group

Average annual percentage increase

		Adult males	Adults females	Males under 25	Females under 25
United States	1960-73	0.70	2.45	3.71	5.62
	1973-79	1.45	4.10	1.47	3.54
	1979-86	1.47	3.41	–1.87	–0.87
Japan	1967-73	2.30	1.39	–2.00	–2.18
	1973-79	1.67	2.09	-6.15	-4.76
	1979-86	0.68	1.49	0.69	0.66
Germany	1968-73	0.11	0.75	2.19	1.80
	1973-79	–0.71	–0.24	0.11	–0.79
	1979-86	–0.43	0.28	–0.11	0.39
France	1968-73	0.80	2.07	–0.54	–0.41
	1973-79	0.07	2.12	–2.72	–2.94
	1979-86	–0.13	1.72	–2.61	–2.85
United Kingdom	1970-73	–0.46	3.14	–3.33	–1.60
	1973-79	–0.65	0.54	0.78	1.91
	1979-86	–1.62	0.33	–0.88	–0.12
Italy	1967-73	0.05	0.66	–3.17	–2.06
	1973-79	0.08	4.65	4.41	1.02
	1979-85	0.00	1.86	–5.11	–1.75
Canada	1966-73	1.48	4.58	3.57	4.28
	1973-79	1.71	5.84	2.96	4.14
	1979-86	1.33	4.42	–1.79	–0.54
Australia	1966-73	1.92	5.34	1.84	2.12
	1973-79	0.36	2.27	0.32	0.68
	1979-86	1.20	4.07	–0.16	1.42
Finland	1963-73	0.64	1.23	0.75	–0.05
	1973-79	0.23	1.25	–3.52	–2.70
	1979-86	1.06	1.77	–1.12	–0.32
Sweden	1970-73	–0.18	2.42	–2.82	–2.87
	1973-79	0.12	2.96	0.32	1.84
	1979-86	–0.16	1.57	–0.57	0.09

Source: OECD, *Labour Force Statistics.*

Table 18. **Total factor productivity adjusted for hours worked and demographic changes**

Average percentage changes at annual rates

		Business sector (from Table 1)	Adjusted for hours worked[a]	Adjusted for demographics[b]
United States	Pre-1973	1.5	1.7	1.8
	1973-79	-0.1	0.2	0.1
	1979-86	0.0	0.0	-0.1
Japan	Pre-1973	6.3	6.8	6.0
	1973-79	1.8	2.3	1.5
	1979-86	1.8	1.9	1.9
Germany	Pre-1973	2.8	3.4	2.9
	1973-79	1.8	2.5	1.8
	1979-86	0.8	1.2	0.9
France	Pre-1973	4.4	5.0	4.4
	1973-79	2.1	2.8	2.1
	1979-86	1.4	1.9	1.4
United Kingdom	Pre-1973	2.1	2.6	2.1
	1973-79	0.3	1.0	0.5
	1979-86	1.1	1.7	1.3
Italy	Pre-1973	4.8	5.5	4.7
	1973-79	1.6	2.3	1.9
	1979-86	0.7	1.1	0.6
Canada	Pre-1973	2.2	2.7	2.5
	1973-79	1.1	1.5	1.4
	1979-86	-0.3	0.0	-0.3
Austria	Pre-1973	3.4	4.0	–
	1973-79	2.0	2.8	–
	1979-85	0.9	1.3	–
Finland	Pre-1973	3.4	3.8	3.4
	1973-79	1.7	2.1	1.6
	1979-85	1.3	1.7	1.3
Sweden	Pre-1973	1.4	2.3	1.4
	1973-79	0.6	1.4	0.8
	1979-85	0.4	0.4	0.5
Australia	Pre-1973	2.0	2.2	2.1
	1973-79	0.7	1.6	0.8
	1979-85	0.4	0.8	0.5

		Business sector (from Table 1)	Adjusted for hours worked[a]
Belgium	Pre-1973	3.7	4.7
	1973-79	1.6	3.0
	1979-85	1.3	2.0
Denmark	Pre-1973	2.3	3.4
	1973-79	0.2	1.0
	1979-85	1.1	1.1
Netherlands	Pre-1973	3.3	4.1
	1973-79	1.3	2.4
	1979-85	0.5	0.8
Norway	Pre-1973	1.6	2.9
	1973-79	2.6	3.5
	1979-85	1.1	1.4
Switzerland	Pre-1973	2.2	2.4
	1973-79	0.6	-0.3
	1979-85	0.9	1.3
New Zealand	Pre-1973	0.4	0.6
	1973-79	-2.6	-1.8
	1979-85	1.4	1.7

a) Based on average yearly man-hours in the business sector.
b) In the demographic adjustment, a weight of 0.6 is given to adult women, one of 0.4 to female teenagers, one of 0.5 to male teenagers and one of 1.0 to adult males. These weights are close to those used by Darby (1984) for the United States.
Note: *See* Table 1 for the starting dates of the pre-1973 period.

shares can only explain a minor part of the difference between labour productivity growth across countries. The two exceptions are Japan and Denmark, where labour productivity growth based upon U.S. employment shares exceeds the observed rate. In both cases, this surprising outcome largely reflects the high U.S. employment share in the retail and wholesale trade sector and the relatively large recent labour productivity gains in this sector in Japan and Denmark.

Changes in the composition of the labour force can also affect aggregate productivity growth given different relative productivity levels for different demographic groups. For the major countries, the rate of growth of employment for adult women has been faster than for adult men, except in Japan in the 1968-73 period (Table 17). In several countries, however, there has also been a tendency for the employment of young people (under 25) to fall relative to adults. The relatively faster growth of female employment implies that employment growth as measured conventionally (with equal weights applied to all labour force participants) is likely to be biased upward, assuming that women have lower average labour productivity compared with men. Conversely, the relatively slower growth recently of young people should bias the conventional measure of employment growth downward, as compared to a skill-corrected measure, assuming that young people on average display lower productivity than adults, a reflection of a smaller stock of human capital. Hence, measures of productivity would be biased upward.

Standardizing the employment series to take account of demographic changes produces effects which vary, both in direction and magnitude, across countries (Table 18). Standardization has the most significant effects in the United States and Japan, contributing or subtracting around half a percentage point in most periods. However, in no country did the standardization procedure substantially change the pattern of a marked slow-down in productivity growth for the 1973-79 period. The same applies to an adjustment for hours worked.

E. Energy and the TFP slowdown

Another factor often viewed as having played a direct causal role in the TFP slowdown are the large increases in energy prices in the 1970s. This is one of the most debated issues in the literature[g]. In the following, two questions are addressed: first, how important is energy in accounting for the productivity slowdown? Second, how did the structure of production change after the surge in energy prices in 1973? The framework is provided by estimated three-factor – capital, labour and energy – trans-log production functions for the major seven economies (Blöndal, 1988). The implied restrictions on the associated input share equations are used in order to identify the parameters of the production function. While the estimated equations are likely to be poor reflections of short-run cyclical movements in the economy, they may give some indication of longer run relationships.

Because energy represents such a small share of production costs in the business sector as whole (about 7 per cent on average for the major seven economies in the OECD INTERLINK model), it would take a huge substitution of capital and labour for energy to account for even a modest slowdown in TFP growth measured in value added terms. In very rough terms, it would take about a 15 per cent reduction per year in energy use per unit of output to obtain a 1 per cent per year slowdown in TFP growth measured in value added terms. In fact, energy use in the business sector rose in most countries between 1973 and 1985; relative to gross output, energy use fell by a little more than 1 per cent per year, about 15 per cent in total over the entire period. Although this is perhaps larger than what could have been expected *ex ante,* such a reduction in energy intensity is clearly not enough to explain a large portion of the productivity slowdown.

Since substitution away from energy cannot by itself account for much of the productivity slowdown, some analysts have argued that there is a complementarity in production between energy and capital[10]. On this view, energy and capital are so closely linked in production that the two can be considered as a single bundled input. A sharp rise in energy prices would lead to a much smaller increase in the overall price of the bundle, since the price of capital would not necessarily change, but would induce a fall in both energy and capital inputs. This would be consistent with the relatively small observed annual decline in energy intensity and, to the extent that the measured capital stock does not reflect the lower intensity of use, lower output and measured TFP as well. However, this complementarity hypothesis is rejected in many engineering studies (cf. those cited in Miller, 1986) and some econometric studies (Pindyck, 1979; Rao and Preston, 1983). It is important, therefore, to test whether the data appear to be supporting such a production structure.

Energy price increases could also directly affect TFP growth if the process of technological change itself has an important energy-using bias. The argument is that because of the increasing energy intensity of new technology, the pace of technology would slow markedly during a period when energy use was even marginally reversed, since the economy would not be able to exploit one of the main factors in technological improvement. While such a high energy-using bias of technological change does not seem intuitive, Jorgenson and Fraumeni (1981) have found energy-using biases for most U.S. industries. Hence, at constant relative factor prices, output and TFP gains are accompanied by increases in energy use. This hypothesis is tested below.

There are a number of indirect paths by which energy could affect productivity growth, although these are not likely to be directly testable. If capital is not very flexible after it has been put in place (i.e. "putty-clay"), then a sudden change in relative prices or demand patterns could make a portion of the capital stock obsoiete, or sharply raise the amount of replacement capital needed to maintain the productivity of the capital stock. Because the capital, scrapped or under-used following such shifts, would still be on the books of firms, productivity would be seen as falling (Baily, 1981; Scott, 1987). Capital and energy could then be long run substitutes, but in the short run could appear to be complements. Allowing for this in the estimated production function framework is difficult.

Another indirect path, suggested by Bruno and Sachs (1985), relates to the real income loss among energy and materials-importing countries in the early 1970s. These involved inflationary pressures which could only be curbed by restrictive demand policies. The cyclical output effects would be mirrored by a cyclical decline in productivity growth. This hypothesis, which does not have any implications for the direct relationship between energy prices and trend productivity, is consistent with the discussion of the macro effects below and can be tested in a full-model context.

In general, the production-function estimation results assign no major direct role for energy in the productivity slowdown. It was only possible to obtain substitution elasticities for five of the seven major economies (Table 19)[11]. In four of the five cases, the estimates suggest high elasticities of substitution between energy and all other factors through the sample period. (In the translog framework, substitution elasticities along the isoquant and over time are variable and not necessarily fixed.) Only for Japan do the estimates suggest that capital and energy are complements, and the degree of complementarity is minimal and had almost disappeared by 1985.

Table 19. Energy-capital substitution elasticities

	1966 I	1973 II	1979 II	1985 II
Japan	-0.23	-0.34	-0.20	-0.09
Germany	1.50	1.55	1.42	1.36
France	2.71	2.47	2.19	2.03
United Kingdom	1.45	1.53	1.41	1.43
Canada	0.30	0.33	0.49	0.52

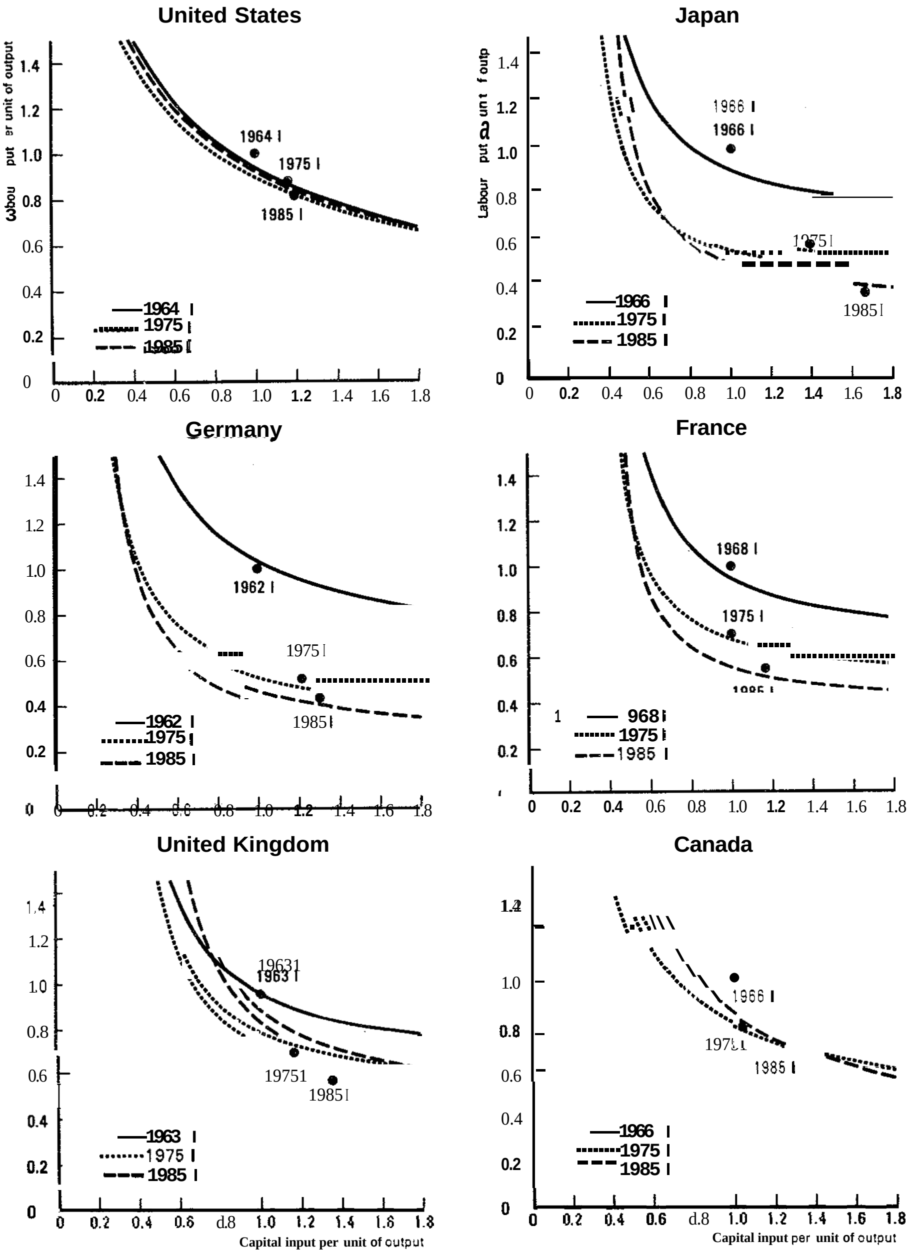
Note: Positive value indicates substitute.

All three factors of production were found to be substitutes. This is consistent with both engineering studies and the intuition that in the medium or long run two major factors of production can hardly be so linked in production as to make them complements. Even for the United States and Italy, the countries for which the Substitution elasticities could not be calculated, there are indications that capital and energy are substitutes.

CHART 8

INPUT OF CAPITAL AND LABOUR REQUIRED PER UNIT OF OUTPUT

Capital-Labour isoquants



Note: Unit energy requirements are at actual levels for each period. ● refers to actual labour and capital input per unit of output.

Based on the estimated production functions, the biases of technological change do not seem large enough to have had a major effect on the overall rate of TFP growth. Technological progress appears to be energy using for all countries except Japan, labour saving in all countries except Italy, and capital using in all countries except the United States and Italy. While the reduction in energy intensity has diminished the pace of TFP growth, the continued increasing intensity of capital use and diminishing intensity of labour use has generally offset much of this effect. In no case can the reversal of the bias component of technological progress account for more than about 0.2 per cent of the slowdown, and in most countries it is much less[12].

The capital-using bias of technological progress found here corresponds to the results discussed earlier concerning the link between capital accumulation and TFP growth. Such links are also evident in Chart B which plots out the estimated combinations of capital and labour required to produce one unit of output (i.e. isoquants) at various points in time, holding unit energy levels at actual historical intensities. The isoquants are obtained by solving the quadratic equation implied by the translog function for capital in terms of labour, energy and output, and calculating the capital-labour isoquants relative to actual output and energy use. The countries with a more rapid pace of capital deepening (as measured by the change in the slope of the line connecting the origin and the actual capital and labour combinations) are also the countries in which technological progress is the fastest.

F. Output and TFP growth

Productivity gains and output growth are normally positively correlated. In the very short run, output fluctuations clearly affect TFP; evidence that demand shocks are more important than supply shocks in determining TFP growth over the short term is presented in Annex I. Short-run correlations between output and TFP are not very interesting, though, because they reflect only the sluggish response of inputs to output movements. Thus, the shorter the time period examined, for example quarters as opposed to years, the more likely it will appear that output leads TFP. And, indeed, it is generally the case that models which use quarterly or even annual data find a strong effect from output or capacity use to TFP (Helliwell *et al.*, 1985).

The more interesting question concerns the medium-run relationship between productivity and output. Obviously, an "autonomous" rise in TFP growth, ***ceteris paribus***, will raise potential output growth and, presumably with a lag, the actual growth rate. But if an economy grows persistently below trend, will trend productivity growth similarly weaken, or does it return to trend after an initial adjustment period? The answer to this question carries a number of policy implications. First, if medium-term output slowdowns translate into concommitant productivity declines, this implies larger welfare losses from slow growth. Secondly, part of inflation-reducing benefits of a downturn emerge because firms tend to discount cyclical productivity swings in their pricing decisions while wages respond rapidly. If the downturn and productivity losses persist over the medium term, it is unlikely that firms will be able to ignore them.

There are a number of mechanisms whereby output growth might affect medium and long-term TFP trends. At the plant and enterprise level, it has been argued that there is substantial scope for TFP gains as output increases and economies of scale are exploited (Todd, 1984). Similarly, at the aggregate level higher output growth may be positively related to productivity trends given dynamic economies of scale linked to learning-by-doing, the expansion of markets and the associated increased division of labour, etc. The importance of these effects, although difficult to establish empirically, has been stressed by successive generations of economists such as Smith (1776), Young (1928), Verdoorn (1949) and Kaldor (1967)[13].

The relationships between TFP and output are difficult to test empirically given both the strong short-term cyclical links and the simultaneous movements of trend TFP and output. It is clear from Chart A that any simple time-series analysis, especially on high-frequency data, will show a strong positive relationship between the growth of TFP and output. Such an analysis may reveal nothing about causality and instead be primarily a reflection of the nature of the productivity and output data. For these reasons, the regression analyses reported below have been done on average TFP and output growth for complete business cycles. Since this reduces the amount of tirne-series data available for any single country to three observations, the analysis has been done primarily on cross-country data averaged over selected time periods.

This procedure seems preferable to Granger-Sims-type causality tests which analyse ieads and lags between variables. Causality analysis is typically geared to identifying short-term relationships. As noted above, and discussed in Annex I these are likely to run primarily from output to TFP and cast little light on medium-term links which are more relevant for policy. Moreover, the medium-term causal relationship is likely to be contemporaneous in nature and not suited to the Granger-Sims-type analysis.

To examine the medium-term relationship, cross-country regressions were run with the change in TFP growth between two sub-periods as the dependent variable and the corresponding change in trend output growth and the change in capacity utilization as the independent variables. Trend output was alternatively defined as either a phase-average-trend or a quadratic trend. The data have been specified as changes in growth rates in order to eliminate country-specific effects.

Implicitly this approach is trying to partition output growth into components due to supply and demand. The change in trend output can be considered to be primarily supply driven (i.e. affected by trend productivity and employment growth) while the changes in capacity utilization can be regarded as the component of output growth responding to demand factors. The problem with such a procedure is that there are few independent measures of aggregate capacity utilization. However, the technique used here to construct trend and cyclical components of output growth is a conservative one, which tends, if anything, to understate the fluctuations in capacity use.

If the only relationship were between trend output and TFP, with cyclical variables having an estimated coefficient insignificantly different from zero, this would be suggestive of prolonged cyclical movements having no effect on TFP. As the period of analysis is lengthened, average output growth should then largely reflect supply factors such as demographic trends and trend productivity growth. However, if actual, as opposed to trend, output, or equivalently, if changes in capacity use (the deviation of actual from trend output growth) have significant effects on TFP over the medium term, this would point to prolonged slumps or booms being reflected in medium-term productivity slowdowns and pick-ups.

The estimation results indicate that changes in capacity use or actual output, have significant effects on TFP growth over the medium term (Table 20). The significance of the capacity utilization term (equivalent to the difference between the change in actual and the change in trend output growth) is quite robust and emerges in other estimated equations. The estimated coefficients seem high on *a priori* grounds and suggest that, even over periods of six years, a substantial portion of a cyclical slowdown shows up as productivity declines rather than as input reductions.

Table 20. Cross-country estimates of the relationship between changes in TFP growth and capacity utilization[a]

Cross-country estimates for thirteen countries

Dependent variable: change in TFP growth between subperiods	Constant	Change in trend output growth	Change in capacity utilization[b]	SEE	Adjusted R^2	Number of observations
1973-79 growth minus pre-1973 growth						
Trend determined by phased average trend	-0.25 (–0.68)	0.72 (5.01)	0.53 (1.79)	0.85	0.68	20
Trend determined by quadratic trend	0.06 (0.15)	0.93 (4.15)	0.55 (3.90)	0.82	0.70	20
1979-86 growth minus 1973-79 growth						
Trend determined by phased average trend	0.15 (0.87)	0.70 (7.32)	0.89 (8.66)	0.68	0.86	20
Trend determined by quadratic trend	0.23 (0.65)	0.81 (3.45)	0.79 (10.40)	0.72	0.85	20

a) The regressions are done by OLS on cross-country data for 20 countries (the seven largest OECD economies plus Austria, Belgium, Denmark, Finland, Greece, Ireland, the Netherlands, Norway, Spain, Sweden, Switzerland, Australia and New Zealand). *t*-statistics are reported in parentheses.
b) The change in capacity utilization over the two subperiods is defined as the difference between actual and trend output growth.

However, both methods of determining trend output involve fairly small average changes in capacity use over these time periods. As a result, the net effect on TFP growth of changes in capacity use is small, about 0.5 percentage points at most, relative to the overall change in TFP growth.

These results are broadly consistent with those reported in OECD (1979), Lindbeck (1983) and Bruno and Sachs (1985). They imply that capacity use changes do have effects on TFP growth over the medium term and that the slowing of demand growth after 1973 probably had an impact on subsequent productivity growth. The results do not imply, however, that demand policy should be used to increase output growth in order to improve TFP performance. As discussed in Part III, such a policy may have infiation and budgetary consequences which are unacceptable and which may lead to productivity-decreasing distortions.

CONCLUSION

The analytical results are consistent with the following broad-brush description of the productivity slowdown and the respective roles of microeconomic or structural factors on the one hand and aggregate output growth and macroeconomic policy on the other. By the early 1970s, the combined influence of a number of structural factors – the end of postwar reconstruction, the reduced scope for catch-up, less rapid expansion of international trade, slowdown of technological advances, changes in the composition of the labour force, and perhaps increased government regulations – had resulted in reduced TFP growth. With this reduced productivity growth not, however, reflected in real wage developments and with economies operating near full capacity inflationary pressures resulted, which were further greatly strengthened by large increases in commodity prices in the early 1970s. The increased inflation and the ensuing policy responses led to major recessions in the mid-1970s and the early 1980s; the accompanying reduction in capacity use and slowing of capital accumulation exacerbated the productivity slowdown. Structural rigidities which had built up over time, and perhaps been masked by the high growth of the 1960s, may have further contributed to the slowdown, if not directly, through their interaction with the supply shocks and low growth of the 1970s and early 1980s.

Thus, structural factors were probably the initial cause of the productivity slowdown of the late 1960s and early 1970s. Reduced levels of capacity use and capital formation subsequently steepened the productivity slowdown. Some slowdown was probably inevitable under any set of policies, but the magnitude might have been smaller had there been more rapid adjustment to supply shocks and less overheating of economies in the late 1960s and early 1970s mitigating the need for subsequent restrictive policies.

NOTES

1. In theory, it would be preferable to calculate TFP using moving weights at a disaggregated level. For many countries such data are not available. More importantly, there have been strong trends in self-employment over the period of analysis which make it difficult to accurately allocate output between capital and labour in some countries in earlier periods.
2. See for example, Jorgenson (1987), and U.S. Bureau of Labor Statistics (1983).
3. There were only a few isolated cases of an absolute fall in the capital stock and these occurred in the textile, chemical, primary metals and construction industries. After declining in the 1973-79 period, capital productivity growth rose in chemicals (seven countries), textiles and financial institutions (three countries) and mining, food, paper and transportation (two countries). Japan, Denmark, and Finland were the only countries where the level of capital productivity in manufacturing increased in the 1979-85 period.
4. Because technical progress only augments labour productivity in the INTERLINK model, TFP growth is approximately equal to labour efficiency growth times the labour share.
5. For more detail see Torres (1988).
6. An embodiment effect in principle, and in practice to some degree, can be captured by national statistical agencies by recognizing the extent to which new vintages of capital are more productive than old. In some countries, however, adjustments for quality are made only insofar as they cost more. An improvement which is free would show up as a TFP gain rather than additional quality. To the extent that this is the case or that there are externalities to more rapid capital accumulation, one may justifiably search for such an effect. One should also distinguish between ***a)*** capital deepening where a higher capital to labour ratio can represent an improved technology and ***b)*** a joint increase in capital and labour which replicates a constant technology. Also. if factor and product markets are not perfectly competitive the assumption that factor shares equal output elasticities with respect to particular factors may not be justified.
7. Regressions were also run for the major seven OECD countries in which determinants of capital accumulation, relative factor prices and profitability, were used in place of the actual capital-labour ratio. The estimated coefficient on the profitability variable is correctly signed, and significantly different from zero in the regressions for the United States, Japan, the United Kingdom and Italy; a significant positive effect from the relative price term is found for Japan, the United Kingdom and Canada. Cross-country regressions show that the profitability effect is stronger than the relative price effect. Replacing the capacity-use term with the unemployment rate produced similar results.
8. As there are no industry level PPPs available, the quality of the data on relative productivity levels at the industry level are suspect.

9. Miller (1986), Berndt and Wood (1979), Grubb (1986) and the references they cite provide a good summary of both sides of the discussion. Given the small weight of energy, studies such as Rasche and Tatom (1977), which relate productivity directly to energy prices rather than energy use, are misleading and possibly spurious because the implied degree of substitutability between energy and other factors of production in their estimations is much higher than actually observed. Solow (1987) and Chichilnisky and Heal (1983) argue that general equilibrium considerations make either result possible in the aggregate even in the absence of technical substitution possibilities for individual products.

10. Hudson and Jorgenson (1974) and Berndt and Wood (1979) make the strongest arguments. To some extent, the OECD INTERLINK model's supply block also assumes complementarity, see Table 6 of Jarrett and Torres (1987).

11. The elasticities reported in Table 19 are Allen cross-elasticities of substitution which are defined as the percentage change in relative input use divided by the percentage change in relative prices, holding other factor prices, but not quantities, fixed. Sometimes these are also called net price elasticities. The elasticities are not defined for the United States and Italy because the marginal rate of substitution is not convex at all points (i.e. there may be a range of increasing marginal returns to some inputs). Inspection of the quadratic terms causing this problem shows that they are not very large. In terms of substitution elasticity calculations the quadratic terms only affect a common denominator for the cross-elasticities. If the numerator in the calculation of the capital-energy elasticity is of the same sign as that of the capital-labour elasticity, it means that capital is either a complement or substitute for both energy and labour. This is the case for both Italy and the United States, although one can not give this too much weight, given the problems in the rest of the estimation.

12. Jorgenson and Fraumeni (1981) argue that the disaggregated four-factor production framework which they use is to be preferred. They find that in most industries technological progress is capital, labour and energy ***using*** and intermediate materials saving, a possibility that a three-factor framework can not capture. However, their estimation procedure imposes many econometric restrictions, and it is not clear why using more direct primary inputs (capital and labour) and less indirect primary inputs (as embodied in intermediate products) should enhance technological progress.

13. A negative relationship between output growth and productivity may occur in a situation where sub-normal profits induce productivity gains via input shedding, i.e. the removal of inefficient labour and unprofitable capital vintages (Lindbeck, 1983; Klau and Mittelstadt, 1986). The recovery in TFP growth in many countries prior to the trough of the early 1980s recession, which is apparent in Chart B, may be a reflection of this type of input shedding. These productivity gains (typical of some industrial subsectors after 1979) may Simply reflect a shift of mean productivity as a result of the elimination of the least efficient producers and need not reflect any rise in productivity gains by the remainder. Hence, they need not represent an improvement in trend TFP growth.

Annex I

SOURCES AND DEFINITIONS

This Annex provides information about capital stock data for the business sector underlying the calculations of changes in total factor productivity. Business sector output includes the output of the private sector and public enterprises. On the input side the capital stock excludes residential housing, except for Turkey, and general government capital.

The data used in calculating TFP growth are taken from the supply block of the OECD INTERLINK model. Where possible, these data are based on national source data, in particular for the seven major countries Australia, Finland, New Zealand and Sweden. For the other countries, the OECD Secretariat has used the perpetual inventory method to calculate the capital stock. Aggregate investment was broken down into non-dwelling construction, machinery and equipment and, where possible, transport equipment. The investment series were extended backwards over time based on country-specific data on historical growth rates of output and ratios of investment to output, similar to the methods used in Meyer-zu-Schlochtern (1988). The stock of capital was then obtained by cumulating each category of investment over time, using rates of scrapping based upon average service lives as presented in Blades (1983). A more complete description of the data sources and methodology is available from the Growth Studies Division of the OECD Economics and Statistics Department.

The wage share was determined by calculating the share of compensation in output in each country. The wages of self-employed were imputed on the average compensation levels. This may lead to an underestimate of the capital share in countries where significant portions of capital income are unreported. For Greece and Ireland the capital share was set at 20 per cent.

The hours of work data come from OECD (1986). For the post-1979 period the following assumptions were made for the annual rate of reduction in average hours worked: France –0.8; Austria –0.4; Belgium, 1979-83 rate was used; Finland, 1979-84 rate was used; Sweden, 1979-84 rate was used; Switzerland –0.6; Australia –0.6. The hours trend for Denmark and New Zealand were assumed to be those of Sweden and Australia, respectively.

Annex II

DO SHORT-TERM PRODUCTIVITY FLUCTUATIONS RESULT FROM SUPPLY OR DEMAND SHOCKS?

Recently Shapiro (1987) has argued that the econometric evidence points to cyclical fluctuations in productivity being due more to supply shocks than demand shocks. This implies that the causal relationship between output and productivity runs from the latter to the former even in the very short run. More generally, this so-called real business cycle approach argues that business cycles themselves are caused by productivity shocks rather than by shifts in aggregate demand. If correct, most of the analysis presented in the main text of this paper would be invalid, as the text generally assumes that short-term business cycle fluctuations are exogenous to productivity. Hence, they should be purged from the data in order to observe trend productivity growth.

There appears, however, to be an econometric problem with Shapiro's estimations. He tries to determine whether output growth contributes to explaining productivity growth, as measured on the production side, when productivity growth, as measured on the dual cost side, is also included as an explanatory variable. Productivity growth on the dual side is the difference between growth in unit factor payments and prices. Under this hypothesis, if supply shocks are causing the changes in productivity, then productivity as measured on the dual cost side should be strongly positively correlated with productivity as measured directly through outputs and inputs. Hence, if output shocks reflected productivity (supply) shocks, one should observe factor returns moving in the same direction. If productivity shocks reflected demand shocks, while factor returns reflected the true productivity of factors, then output growth should explain the deviations of productivity growth and the return to factors. Thus, the significance of demand fluctuation would be an indicator of whether the production side measure of productivity differed from the true measure in a cyclical way.

Shapiro's results suggest that demand is not significant. However, in order to account for the short-run fixity in capital, the dual side formulation of productivity growth includes a term which, in fact, is capital productivity growth as measured by the production side. Thus both the left-hand and right-hand side of his equations include the same measure of capital productivity (as well as other different terms). As capital productivity is highly cyclically-sensitive, the inclusion on both sides biases the equation both towards finding a close relationship between dual and direct productivity measures and away from finding a cyclical effect, since the capital productivity term already imparts one to both the productivity terms.

Table III reports the results of re-estimating Shapiro's equation for the seven largest OECD countries after eliminating the common capital productivity term. In each case GDP growth has a positive, significant and large effect, suggesting that demand fluctuations do in fact explain a good portion of the cyclical fluctuation in productivity.

Table II. 1. Are productivity shocks supply- or demand-induced?

Country		Coefficient on real wage	Coefficient on output growth
United States	1)	0.92 (5.9)	–
	2)	0.48 (2.7)	0.34 (3.5)
Japan	1)	0.86 (4.3)	–
	2)	0.19 (3.3)	0.80 (18.1)
Germany	1)	0.71 (5.3)	–
	2)	0.21 (1.3)	0.51 (4.1)
France	1)	0.65 (3.6)	–
	2)	0.19 (0.0)	0.71 (13.2)
United Kingdom	1)	0.53 (2.6)	–
	2)	0.20 (1.3)	0.58 (4.8)
Italy	1)	0.74 (4.7)	–
	2)	0.19 (2.4)	0.89 (11.4)
Canada	1)	0.39 (2.4)	–
	2)	0.36 (2.8)	0.39 (3.6)

Notes:
1) $lp = a + b*w$
2) $lp = a + b*w + c*q$
t-statistics in parentheses.

lp = growth in labour productivity
w = real wage growth
q = real output growth

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