Growth in UK manufacturing between 1970–92

By Gavin Cameron of Nuffield College, Oxford,[1] James Proudman of the Bank's Monetary Instruments and Markets Division, and Stephen Redding of New College, Oxford and CEPR.

This article[2] examines productivity growth and levels in UK manufacturing between 1970–92. During this period, UK manufacturing output fell, but by less than the number of hours worked in manufacturing, and so labour productivity increased. Within manufacturing, economic performance varied considerably, both across sectors and time, including a notable difference between the two peak-to-peak business cycles 1973–79 and 1979–89. To understand manufacturing economic performance more fully, the article considers disaggregated data for 19 manufacturing industries, using two measures of productivity: labour productivity and Total Factor Productivity.

Introduction

Between 1970–92, real output (as measured by constant price value added at factor cost) in UK manufacturing fell at an average annual rate of 0.2%.[3] Manufacturing hours worked fell even more, at an average annual rate of 3.4%, and so labour productivity in the manufacturing sector as a whole increased during the period. Within manufacturing, there were interesting variations in economic performance across sectors; but these were not always taken into account by the hypotheses put forward to explain the changes in the performance of the UK manufacturing sector during this period (such as changes in the exchange rate, macroeconomic policy and industrial relations law). Before formulating and testing these hypotheses, we need a detailed understanding of the nature of economic growth at a disaggregated level within manufacturing. This article examines the nature of the decline in manufacturing value added and the associated changes in productivity, using disaggregated data on 19 manufacturing industries for the period 1970–92.[4]

It is not just productivity growth that is of interest, but also levels of productivity across industries. The information on productivity growth rates is therefore combined with a measure of the level of productivity in a base year to analyse changes in productivity levels across industries over time, drawing on analytical techniques already employed in the cross-country growth literature. This analysis reveals that productivity in an increasing number of sectors is concentrating around or just below mean values, while that in a few high-productivity sectors is diverging from mean values.

The structure of the article is as follows. The second section examines the variation in rates of growth of value added and hours worked across industries and over time. Two alternative measures of productivity growth are then considered: labour productivity growth and Total Factor Productivity (TFP) growth. Growth accounting techniques are used first to decompose the rate of growth of value added into the contributions of physical capital accumulation, labour input, and a residual—TFP growth; and second, to evaluate the contributions of capital accumulation and TFP growth to labour productivity growth. The two measures of productivity growth may then be explicitly related to one another.

The third section considers how much labour productivity and TFP growth in total manufacturing may be attributed to shifts in resources between sectors, rather than productivity growth within sectors, and assesses the contribution of individual sectors to changes in aggregate productivity. The fourth section analyses the distribution of levels of labour productivity and TFP across manufacturing sectors at the beginning and end of the sample period. The fifth section models how productivity levels change across sectors and time. The final section summarises our conclusions.

Productivity growth

Value added and hours worked

As noted above, constant price value added and hours worked in UK manufacturing both fell between 1970–92. But Table A, which gives disaggregated data for 19 manufacturing industries, shows that rates of growth of

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(2) Based on a paper 'Deconstructing growth in UK manufacturing', produced for the Bank's Openness and Growth Project, by Gavin Cameron, James Proudman and Stephen Redding (December 1997, Bank of England *Working Paper* No 73). The project was reviewed at an academic conference held at the Bank in mid September. The conference proceedings, including the research papers and the comments of participants, will shortly be published by the Bank. Space prevents us from thanking all those from whose comments and suggestions we have benefited, but we are particularly indebted to Nigel Jenkinson, John Muellbauer, Danny Quah, Jon Temple and Peter Westaway.
(3) The source for all figures used (except where otherwise specified) is a database derived from the Census of Production and described in further detail in the Annex to this article (see also Cameron (1996)).
(4) For further details on the data set, see the Annex.

Table A
Value added and labour productivity growth, 1970–92

All figures expressed as percentage rates of growth

Industry	SIC 1980	Value added	Hours worked	Labour productivity Y/L
Total manufacturing	2 to 4	-0.2	-3.4	3.2
Food and drink	41/42	-0.2	-2.4	2.1
Textiles and clothing	43/4/5	-1.5	-4.5	3.0
Timber and furniture	46	-0.7	-2.5	1.8
Paper and printing	47	0.9	-2.2	3.0
Minerals	23/24	-2.3	-3.7	1.4
Chemicals	25/6+48	1.4	-2.2	3.6
Chemicals nes (a)	25+26-257	0.3	-3.0	3.3
Pharmaceuticals	257	4.7	-1.6	6.3
Rubber and plastics	48	1.2	-1.6	2.8
Basic metal	22	-3.6	-6.7	3.1
Iron and steel	221/2/3	-4.2	-7.4	3.2
Non-ferrous metals	224	-1.9	-4.8	2.9
Fabricated metal	3	0.0	-3.7	3.6
Metal goods nes (a)	31	-1.0	-3.8	2.8
Machinery	32	-1.5	-4.0	2.5
Computing	33	7.6	-1.8	9.4
Electrical machinery	34	0.8	-3.5	4.3
Other electrical	34-344-345	-0.3	-3.7	3.4
Electronics	344/5	1.9	-3.3	5.2
Motor vehicles	35	-1.2	-3.7	2.5
Aerospace	364	2.6	-2.0	4.6
Instruments	37	2.2	-2.4	4.5
Other manufacturing	49	-1.4	-3.9	2.5

Source: see the Annex. Estimates corrected for double-counting of R&D.

(a) nes: not elsewhere specified.

value added and hours worked varied considerably across these industries. This suggests that the decline in the size of the UK manufacturing sector during the sample period was associated with considerable changes in the relative size of individual sectors (whether defined in terms of shares of value added or hours worked). Nine industries experienced positive rates of growth of value added. Computing and Pharmaceuticals had the highest annual rates of growth (7.6% and 4.7% respectively), and Iron and steel and Minerals had the lowest (-4.2% and -2.3% respectively). Hours worked fell in all sectors, but again there were substantial variations across sectors: the average annual rate of decrease for the bottom five sectors was more than twice that of the top five sectors.

In general, average rates of growth of value added were much lower in the first peak-to-peak business cycle (1973–79) than in the second (1979–89). For manufacturing as a whole, value added fell at an average annual rate of 1.1% between 1973–79, but rose at an average annual rate of 1.0% between 1979–89. Only four industries had higher rates of growth of value added in the first peak-to-peak business cycle (Machinery, Motor vehicles, Instruments and Metal goods not elsewhere specified). In contrast, hours worked typically fell more slowly in the first peak-to-peak business cycle period than in the second: for total manufacturing, the average annual rates of decline were -1.6% and -3.7% respectively.

(i) Labour productivity growth

From rates of growth of value added and rates of growth of hours worked, we obtain the first and simplest of our measures of productivity growth, the rate of growth of value added per hour worked—known as labour productivity growth (also shown in Table A). During the period 1970–92, hours worked grew less than the rate of growth of value added for all 19 manufacturing industries, and so labour productivity increased in all sectors. In manufacturing as a whole, annual labour productivity growth averaged 3.2%, though with substantial variations across both sectors and time. Average annual rates of labour productivity growth during 1970–92 were highest in Computing and Pharmaceuticals (9.4% and 6.3% respectively), and lowest in Minerals and Timber and furniture (1.4% and 1.8% respectively).

Average annual rates of growth of labour productivity for total manufacturing were substantially higher in the second peak-to-peak business cycle (4.7%) than in the first (0.5%). Average rates of growth of labour productivity were higher in the second peak-to-peak business cycle in all industries except one (Instruments).

(ii) Total Factor Productivity growth

Using the rate of growth of value added per hour worked as a measure of productivity growth has the advantage of imposing very few (if any) theoretical restrictions on the data. But it measures the productivity of only one factor of production. So one cannot, for example, determine whether labour productivity is high because of a high degree of technical efficiency, or because of a large stock of physical capital. A measure that includes the productivity of other factors of production is therefore needed. Under the assumptions of perfect competition and constant returns to scale, the rate of growth of value added in each sector can be decomposed into the contributions of increased hours worked, physical capital accumulation, and a residual. This residual provides a second, wider measure of productivity, TFP, which encompasses the effects of influences on how efficiently existing quantities of capital and labour are used. It includes, for example, the influence of technology, the extent of competition, capacity utilisation, training and unionisation. However, a wide range of empirical evidence suggests that the long-run rate of growth of the residual is largely determined by technological progress.

The disadvantage of using TFP as a measure of productivity is that it imposes greater theoretical restrictions on the data than labour productivity. In terms of the present analysis, the key assumptions are perfect competition and constant returns to scale; in principle, each of these assumptions may be relaxed.[1] Moreover, this decomposition, though informative, yields no conclusions about causality. For example, even if capital accumulation accounts for a substantial amount of output growth, this capital accumulation may be ultimately induced by increases in TFP.

In the rest of the article, we use two measures of rates of productivity growth and levels of productivity. We estimate

(1) Hall (1988) introduces imperfect competition into the analysis, while Caballero and Lyons (1989) and Oulton (1996) extend the analysis to admit variable returns to scale.

rates of growth of TFP under the assumptions of perfect competition and constant returns to scale—a common benchmark throughout the empirical literature. We also present information on the relatively atheoretic but somewhat less informative rates of growth of labour productivity. If our estimates of TFP growth yielded radically different information to the figures for labour productivity growth, we might be more concerned about the validity of these assumptions than otherwise. In fact, all the main conclusions of this article are robust to the use of either labour or total factor measures of productivity.

Decomposing the rate of growth of value added

Table B decomposes the rate of growth of value added in UK manufacturing into the contributions of increased hours worked, capital accumulation and TFP growth.(1) These estimates of productivity growth rates may be compared with the figures for labour productivity growth presented in Table A. The fall in average annual hours worked in manufacturing sectors noted earlier is reflected in the negative contribution from hours worked in all 19 industries throughout the sample period (and in each of the two peak-to-peak business cycle periods, with the exceptions of Motor vehicles in the period 1973–79 and Computing in 1979–89). The average contribution of physical capital accumulation to output growth is positive in 17 industries during the entire sample period (the exceptions are Textiles and clothing and Aerospace), and the ratio of output to capital rose in all industries during the period.

Table B
Value added and labour productivity growth, 1970–92

All figures expressed as percentage rates of growth

Industry	Value added	Labour	Capital	TFP
Total manufacturing	-0.2	-2.2	0.6	1.4
Food and drink	-0.2	-1.2	1.2	-0.3
Textiles and clothing	-1.5	-3.1	-0.1	1.8
Timber and furniture	-0.7	-1.8	0.9	0.3
Paper and printing	0.9	-1.4	1.0	1.3
Minerals	-2.3	-2.1	0.8	-1.1
Chemicals	1.4	-1.1	1.0	1.5
Chemicals nes (a)	0.3	-1.6	0.8	1.1
Pharmaceuticals	4.7	-0.6	1.5	3.9
Rubber and plastics	1.2	-1.2	0.9	1.6
Basic metal	-3.6	-5.4	0.1	1.7
Iron and steel	-4.2	-6.5	0.0	2.2
Non-ferrous metals	-1.9	-3.4	0.3	1.2
Fabricated metal	0.0	-2.6	0.5	2.1
Metal goods nes (a)	-1.0	-2.7	0.3	1.4
Machinery	-1.5	-2.7	0.5	0.7
Computing	7.6	-1.2	3.1	5.7
Electrical machinery	0.8	-2.4	0.8	2.4
Other electrical	-0.3	-2.6	0.6	1.7
Electronics	1.9	-2.3	1.2	3.0
Motor vehicles	-1.2	-2.7	0.6	0.9
Aerospace	2.6	-1.5	-0.1	4.2
Instruments	2.2	-1.7	0.9	3.0
Other manufacturing	-1.4	-2.7	0.0	1.3

Source: see the Annex. Estimates corrected for double-counting of R&D.

(a) nes: not elsewhere specified.

Although value added in total manufacturing fell at an average annual rate of 0.2% between 1970–92, TFP rose at 1.4%. Again, rates of productivity growth vary considerably across manufacturing sectors during the sample period. Average annual rates of TFP growth range from 5.7% and 4.2% in Computing and Aerospace respectively to -1.1% and -0.3% in Minerals and Food and drink respectively.

Rates of TFP growth between the two peak-to-peak business cycle periods also varied markedly. Between 1973–79, TFP in total manufacturing actually fell at an average annual rate of 1.0% (with falls in 13 of the 19 industries); between 1979–89, it rose at an average annual rate of 3.1% (with no falls in any of the 19 industries). The performance of the Iron and steel industry changed particularly notably, with negative measured TFP growth in the first peak-to-peak business cycle and the most rapid rate of TFP growth in the second.

As noted earlier, TFP growth is essentially a residual, and includes the influence of a wide range of factors besides technological progress that affect the efficiency with which factors of production are employed. So negative measured TFP growth for certain time periods and industries is actually quite plausible. For example, it seems reasonable that many manufacturing industries experienced decreases in technical efficiency in the 1970s—a period characterised by temporary factor hoarding, the costly adjustment of production processes to oil price rises, and increased exercise of trade union power.(2) There are also several problems in measuring the capital stock (see, for example, Muellbauer (1991)), and these negative estimates for TFP growth may reflect measurement error. But even if there are particular problems associated with the measurement of TFP, it is important to note that the main qualitative features of the data and the variation in productivity growth rates across sectors were confirmed in the analysis of labour productivity growth in Table A.(3)

The decomposition may be also used to evaluate the relative size of the different contributions (ie those of capital accumulation and TFP growth) to output growth. The conclusions here should be viewed as somewhat more tentative, as they are likely to be more sensitive to the assumptions invoked in the calculation of TFP growth and to measurement error. In the sample period, TFP growth contributed more to value-added growth (or rather, reduced the fall in value added more) than physical capital accumulation for 16 of the 19 industries, as well as for manufacturing as a whole. Particularly noteworthy is the increase in the contribution to value-added growth originating from rises in TFP, relative to that from capital accumulation, between the first and second peak-to-peak business cycles. The size of this increase suggests that to overturn this result there would need to be substantial

(1) Again, details concerning data sources and definitions are contained in the Annex.
(2) In principle, it is straightforward to make allowances both for cyclical factors distorting TFP in the short run and for factors of long-run significance, such as the degree of trade union power (see, for example, Cameron, Proudman and Redding (1997)). In this article, however, we aim to examine the underlying data while imposing as few theoretical assumptions as possible.
(3) The Spearman rank correlation coefficient across sectors between time-averaged labour productivity growth and time-averaged total factor productivity growth (time-averaged for the entire sample period) is 0.93.

changes in the assumptions made, or significant measurement error.

Linking labour productivity and Total Factor Productivity growth

The rate of growth of labour productivity can be decomposed into the contributions of TFP growth and increases in the capital/labour ratio (K/L), so that the two measures of productivity growth may be explicitly related to one another, as shown in Table C. Here too, the conclusions are tentative. In total manufacturing in the sample period, capital accumulation and TFP growth contributed about 60% and 40% respectively to the observed increase in labour productivity. Again, there are important variations across industries and time. For example, TFP growth accounted for just less than one sixth of the 1.8% average annual rate of growth of labour productivity in Timber and furniture. In general, the contribution of capital accumulation relative to that of TFP growth is much higher in the first peak-to-peak business cycle than in the second. Between 1979–89, TFP growth accounted for about two thirds of the 4.7% average annual rate of growth of labour productivity in total manufacturing, whereas between 1973–79, TFP growth made a negative contribution to labour productivity growth.

Table C
Sources of labour productivity growth, 1970–92

All figures expressed as percentage rates of growth

Industry	Labour productivity Y/L	Capital/labour ratio K/L	TFP
Total manufacturing	3.2	1.8	1.4
Food and drink	2.1	2.4	-0.3
Textiles and clothing	3.0	1.2	1.8
Timber and furniture	1.8	1.5	0.3
Paper and printing	3.0	1.7	1.3
Minerals	1.4	2.5	-1.1
Chemicals	3.6	2.1	1.5
Chemicals nes (a)	3.3	2.2	1.1
Pharmaceuticals	6.3	2.5	3.9
Rubber and plastics	2.8	1.3	1.6
Basic metal	3.1	1.4	1.7
Iron and steel	3.2	1.0	2.2
Non-ferrous metals	2.9	1.7	1.2
Fabricated metal	3.6	1.6	2.1
Metal goods nes (a)	2.8	1.4	1.4
Machinery	2.5	1.8	0.7
Computing	9.4	3.7	5.7
Electrical machinery	4.3	1.2	2.4
Other electrical	3.4	1.7	1.7
Electronics	5.2	2.2	3.0
Motor vehicles	2.5	1.6	0.9
Aerospace	4.6	0.4	4.2
Instruments	4.5	1.6	3.0
Other manufacturing	2.5	1.3	1.3

Source: see the Annex. Estimates corrected for double-counting of R&D.

(a) nes: not elsewhere specified.

Changes in sectoral composition

This section seeks to relate the experience of individual industries to the behaviour of total manufacturing. Taking the UK manufacturing sector on its own,[1] there are two possible sources of aggregate productivity growth: reallocations of resources from low to high-productivity sectors ('between-sector reallocations') and productivity growth within individual industries ('within-sector growth'). The analysis earlier showed that the relative size of different manufacturing sectors (measured by either shares of value added or hours worked) has changed considerably. This section considers the implications of these changes for productivity in total manufacturing.

Labour productivity in aggregate manufacturing at any point in time may be expressed as a weighted sum of labour productivity in individual manufacturing industries, with weights equal to each sector's share in total hours worked (see Bernard and Jones (1996c)). Under the assumption of a common, time-invariant Cobb-Douglas production technology in each sector, a similar decomposition may be undertaken for TFP growth in aggregate manufacturing (see Bernard and Jones (1996a)).[2] The results of undertaking these decompositions for both labour productivity and TFP growth in UK manufacturing are presented in Table D. As the table shows, as much as 97% of the growth in labour productivity in total manufacturing in the sample period was found to be explained by within-sector productivity growth. The corresponding figure for TFP was somewhat smaller (91%), but again, within-sector productivity growth accounted for the vast majority of productivity growth in aggregate manufacturing.

Table D
'Within' and 'between' decompositions for labour productivity and Total Factor Productivity[a]

	Between	Within	Total
Aggregate Y/L growth	3.0	97.0	100
Aggregate TFP growth	9.2	90.8	100
Contributions of sectors to aggregate TFP growth			
Food and drink	12.1	2.1	14.2
Textiles and clothing	-8.5	9.8	1.4
Timber and furniture	2.6	-0.7	1.8
Paper and printing	11.2	9.0	20.2
Minerals	-0.6	-5.0	-5.7
Chemicals nes (b)	1.5	9.3	10.8
Pharmaceuticals	2.1	10.0	12.2
Rubber and plastics	4.7	4.5	9.2
Iron and steel	-9.7	-0.4	-10.1
Non-ferrous metals	-1.4	0.8	-0.6
Metal goods nes (b)	-2.7	4.7	2.0
Machinery	-5.5	2.7	-2.8
Computing	2.1	8.6	10.8
Other electrical	0.1	3.9	4.0
Electronics	2.3	9.6	11.9
Aerospace	-1.0	17.6	16.5
Motor vehicles	0.1	0.3	0.4
Instruments	1.1	2.6	3.8
Other manufacturing	-1.2	1.3	0.1

(a) Figures may not sum exactly across columns owing to rounding. The results in Table D are not strictly comparable with those in Tables B and C. In Table D, TFP is calculated using fixed (rather than Divisia) input weights.
(b) nes: not elsewhere specified.

So though the relative size of individual manufacturing sectors has changed significantly, the reallocation of resources between sectors has not been an important source of aggregate productivity growth in the sample period. This

(1) For a whole-economy analysis at a more aggregate level for the OECD, see Bernard and Jones (1996a).
(2) Note that this imposes a more restrictive form for the production function than the earlier analysis (where we only needed to assume constant returns to scale).

finding suggests that hypotheses about aggregate manufacturing performance should concentrate on explaining productivity growth within individual sectors, rather than switches in factor resources between sectors with differing levels of productivity.

Interestingly, 7 of the 19 industries account for more than 95% of the TFP growth in total manufacturing (the sum of the 'within' and 'between' effects): Food and drink, Paper and printing, Chemicals not elsewhere specified, Pharmaceuticals, Computing, Electronics and Aerospace. Averaged for the sample period, these account for less than 44% of total value added.(1)

Productivity levels

Table E presents information on how average values of labour productivity, Y/L′, for each of the 19 manufacturing industries relate to the mean level for the 19 industries and for total manufacturing, during both the entire sample period and the two peak-to-peak business cycles.

Table E
Labour productivity relative to manufacturing mean Y/L′

Value added per hour worked

Industry	1970–92	1973–79	1979–89
Food and drink	1.0	1.1	0.9
Textiles and clothing	0.5	0.5	0.5
Timber and furniture	0.7	0.8	0.6
Paper and printing	1.0	1.1	0.9
Minerals	1.1	1.2	1.0
Chemicals nes (a)	1.5	1.6	1.5
Pharmaceuticals	2.1	1.9	2.1
Rubber and plastics	0.8	0.9	0.7
Iron and steel	0.9	0.8	0.9
Non-ferrous metals	1.0	1.0	0.9
Metal goods nes (a)	0.7	0.8	0.7
Machinery	0.8	0.9	0.8
Computing	2.1	1.5	2.5
Other electrical	0.7	0.8	0.7
Electronics	0.9	0.8	1.0
Motor vehicles	0.8	0.9	0.8
Aerospace	1.2	1.2	1.1
Instruments	0.7	0.8	0.7
Other manufacturing	0.7	0.8	0.6
Mean (b)	**8.3**	**6.2**	**9.2**
Total manufacturing (b)	**7.0**	**5.6**	**7.6**

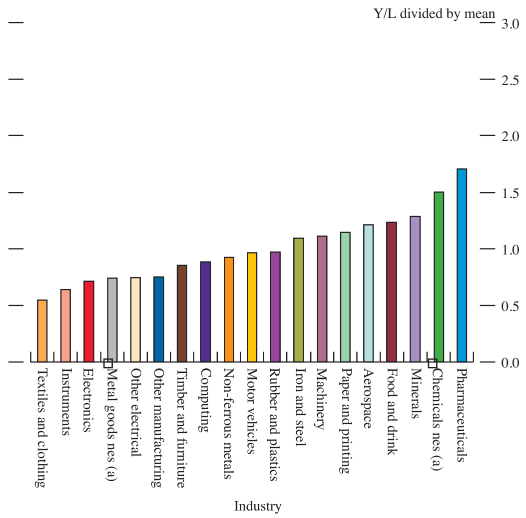
(a) nes: not elsewhere specified.
(b) £ per hour worked.

As the table shows, average productivity levels vary considerably across industries during the period, ranging from a low of 0.5 times the manufacturing mean (£8.3 per hour worked) in Textiles and clothing to a high of 2.1 times in Pharmaceuticals.(2) In addition, as a result of the extent of variation in rates of labour productivity growth documented in Tables A and C, the relative ranking of industries in terms of labour productivity levels changes during the sample period. For example, Computing overtook Pharmaceuticals to become the sector with the highest level of labour productivity between the two peak-to-peak business cycles.

We next consider the evolution of productivity levels across industries over time. The analysis will be concerned both with intra-distribution dynamics (how the productivity levels in industries move relative to one another, an issue touched on above) and changes in the external shape of the productivity distribution (whether, for example, it exhibits more or less dispersion around the mean, or is characterised by increasing or decreasing skewness).

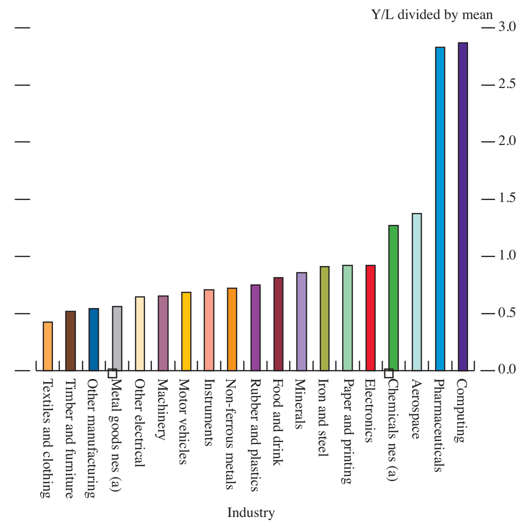
We begin by simply graphing the distribution of labour productivity levels across industries at the beginning and end of the sample period in Charts 1 and 2. The industries in the two charts are sorted in terms of increasing labour productivity in 1970 and 1992 respectively, so that the order

Chart 1
Labour productivity relative to mean, 1970



(a) nes: not elsewhere specified.

Chart 2
Labour productivity relative to mean, 1992



(a) nes: not elsewhere specified.

(1) The sources of aggregate labour productivity growth are less concentrated. The seven industries that contributed most to aggregate labour productivity growth were Food and drink, Textiles and clothing, Paper and printing, Chemicals not elsewhere specified, Machinery, Electronics and Aerospace. Together, these account for 61% of the growth in labour productivity and (on average for the entire sample period) constitute 60% of total value added.
(2) The values for mean value added per hour worked in the 19 industries (£8.3) and the figure for total manufacturing (£7.0) compare with whole-economy GDP per hour worked of approximately £8.3 (based upon constant price (1985) GDP at factor cost of £307,902 million, workforce in employment of 24,712 million and an average of 1,498 worker hours per year). Note that the labour input for manufacturing has been adjusted for employment in R&D, but the whole-economy figure has not.

of industries is not necessarily the same in both charts. In 1970, labour productivity was relatively uniformly distributed across industries, but by the end of the sample period, it had become increasingly positively skewed across industries. This is shown even more clearly in Charts 3 and 4, where the range of values of labour productivity is divided into ten discrete cells, and a histogram is drawn of the frequency distribution of industries across cells.

Chart 3
Frequency distribution of labour productivity relative to mean, 1970

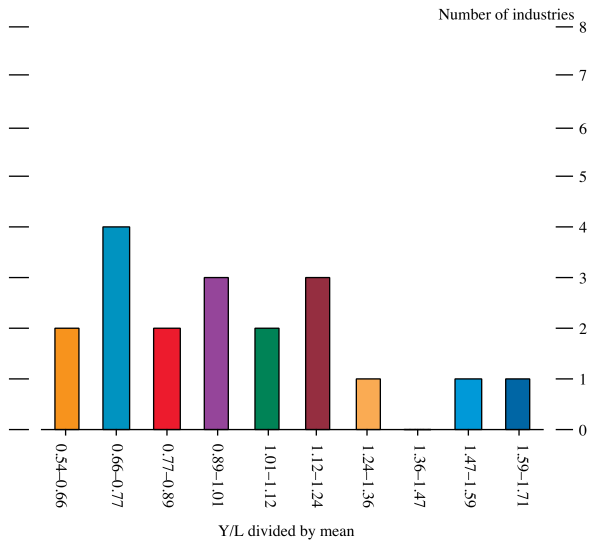
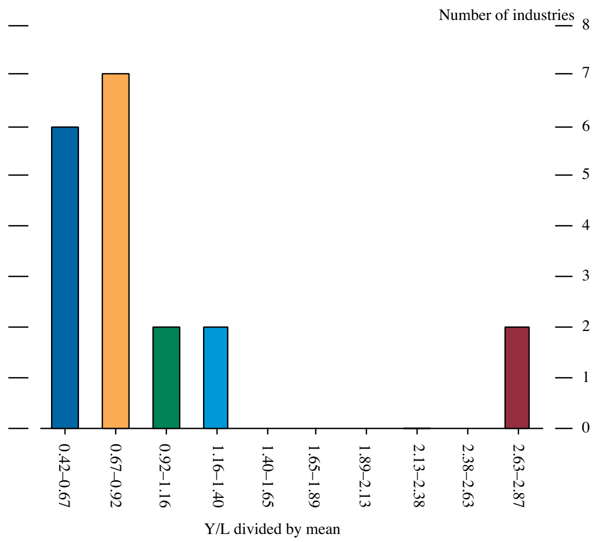


Chart 4
Frequency distribution of labour productivity relative to mean, 1992



In order to arrive at a measure of the level of TFP in each year of the sample period, the minimal further step that needs to be taken is to combine the measured rates of growth, discussed above, with an estimate of the level of TFP in a base year. Here we take 1985 as the base year, and estimate the level of productivity by assuming, following Bernard and Jones (1996b), that the production process is characterised by a Cobb-Douglas technology. Averaging the resultant levels of TFP over the sample period shows substantial variations across industries. Average TFP ranges from a low of 0.4 times the mean for total manufacturing in Textiles and clothing to a high of 4.2 times in Pharmaceuticals. In fact, the extent of dispersion in levels of productivity relative to the mean for total manufacturing, as measured by the sample standard deviation, is greater for TFP than for labour productivity (averaged for the whole sample period, the sample standard deviation takes the values of 0.9 and 0.5 respectively). As is to be expected, levels of TFP and labour productivity are highly (though not perfectly) positively correlated across industries (correlating time-averaged values of the two measures of productivity across industries, the Spearman rank correlation coefficient is 0.88).(1) So industries with high levels of TFP tend to be those with high levels of labour productivity. (There are obvious exceptions related to capital intensity, such as Iron and steel and Motor vehicles.)

As a result of the variation in rates of TFP growth shown in Tables B and C, the relative ranking of industries in terms of TFP changes during the sample period (though less often than labour productivity). Computing and Pharmaceuticals remained the industries with the highest and second-highest levels of TFP respectively in every year of the sample period. As with labour productivity, the distribution of TFP productivity across sectors became increasingly positively skewed during the sample period, with productivity levels in a few sectors (in particular Computing and Pharmaceuticals) rising increasingly away from mean values. We outline below in more depth why one might expect to observe TFP levels either converging or diverging over time within a cross-section distribution of sectors. The informal evidence here nevertheless suggests that, for at least a small sub-sector of industries, the development of technology may be quite specific to individual sectors and does not spill over rapidly into many other manufacturing sectors. This trend in the observed distribution is also consistent with the evidence shown in Table D that aggregate TFP growth is highly concentrated in a small number of sectors.

Productivity dynamics

The analysis in the previous section suggests that there have been significant changes in the distribution of both labour productivity and TFP across industries during the sample period. This section turns to the task of modelling these changes. A general model of productivity dynamics requires an explicit analysis of the evolution of the entire distribution of productivity across industries, an analysis that is undertaken in the final section below (using techniques employed by Quah (1993b), (1996a,b,c)). We begin with two somewhat simpler, less general, but nonetheless informative methods of analysing productivity dynamics.

(1) The high degree of correlation is unsurprising, since if the shares of labour and capital in value added are constant over time (as they will be, for example, in the special case of a Cobb-Douglas production technology), log *TFP* is simply a weighted average of log (*Y/L*) and log (*K/L*), log $TFP = \alpha \log(Y/L) + (1 - \alpha)\log(Y/K)$.

(i) Mean reversion

When analysing changes within the distribution, one question of interest is whether productivity levels across industries exhibit mean reversion (that is, whether they tend to converge towards the mean). This question is closely related to the issue of whether productivity levels converge or diverge across sectors in what has been described in the cross-country growth literature as 'absolute β-convergence'. Levels of income per capita are said to exhibit absolute β-convergence when the rate of growth of income per capita across countries is negatively correlated with the initial level of income per capita (see for example Barro and Sala-í-Martin (1991)).

Across countries, there are clear reasons for expecting levels of income per capita to converge. Absolute β-convergence between similar economies or regions within an economy is an implication of the neoclassical, Solow-Swan model of growth and of some models of technology transfer. (See, for example, Aghion and Howitt (1997), Chapter 2.) Across industries, it is less clear whether one should expect productivity levels to exhibit absolute β-convergence or absolute β-divergence, or indeed whether one should expect any relation at all between rates of productivity growth and initial levels. In an equilibrium with factor mobility, one would expect the marginal products of capital and labour to be equalised—which may or may not induce productivity convergence, depending on the nature of industries' production technologies. Undoubtedly, the production processes in some of these industries are very different, and this in itself might lead one to expect relatively constant productivity differentials over time.

'Learning by doing' that is specific to a sector may be a reason to expect productivity levels to diverge over time. Other things being equal, industries with high initial levels of productivity will attract more factors of production. If the rate of learning by doing increases with levels of employment or cumulative investment, then these sectors will experience faster rates of productivity growth from learning by doing. But if technological knowledge can be transferred across sectors, this may provide a force for a reduction in the degree of productivity dispersion. For instance, there are numerous anecdotal pieces of evidence of innovations made in one sector that turn out to have important applications in others. There is also econometric evidence of significant R&D spillovers across sectors.(1)

Table F shows the results of testing for whether productivity levels across industries are reverting to or diverging from a common mean. The estimated values of β are negative for labour productivity and positive for TFP. But in each case, the estimated value of β is not statistically significantly different from zero at the 10% level. So there is no evidence that productivity levels are converging to or diverging from a common mean. One interpretation of this finding would be that intra-distribution dynamics are not important in the sample period—for example, one might conclude that productivity differentials across industries simply persist over time (perhaps as a result of fundamental differences in the nature of the production process). But as will be shown below in the context of a more general analysis of productivity dynamics, this interpretation is not supported by the data.

Table F
Testing for reversion to versus divergence from a common mean across industries

Variable	α	β
Y/L	-0.0051	-0.0027
	(0.005)	(0.016)
TFP	-0.0073	0.0060
	(0.004)	(0.007)

Note: Standard errors in parentheses.

(ii) Changes in the extent of dispersion

A second aspect to productivity dynamics concerns changes in the external shape of the distribution of productivity across industries. One issue of interest here is changes in the extent of dispersion in productivity levels across industries. This issue is related to the question of whether productivity levels converge or diverge across industries in what has been described in the cross-country growth literature as the 'σ-convergence' sense. In the cross-country growth literature (see, for example, Barro and Sala-í-Martin (1991)), levels of income per capita are said to exhibit σ-convergence across countries when the extent of dispersion in income per capita is declining over time, as measured, for example, by the sample standard deviation.

This second concept of convergence is entirely distinct from that of β-convergence: in particular, β-convergence does not necessarily imply σ-convergence.(2) In the cross-country context, there are clear reasons for expecting levels of income per capita between similar economies, and regions within economies, to exhibit σ-convergence.(3) Across industries, it is less clear whether productivity levels should converge or diverge in this second sense (for many of the same reasons listed above).

Table G presents information on the evolution of the sample standard deviation of productivity relative to the manufacturing mean, for both labour productivity and TFP measures. For both labour productivity and TFP, there is evidence of an increase in the extent of dispersion of productivity levels across manufacturing industries over time.(4) However, analysing changes in the extent of dispersion does not, in general, reveal all information about changes in the external shape of the distribution of

(1) See, for example, Griliches, Z (1992).
(2) Inferring from a negative correlation between rates of growth and initial levels of income per capita that the dispersion of income per capita is falling over time is an example of Galton's Fallacy (see for example Friedman (1992) and Quah (1993a)).
(3) In particular, this is also an implication of the deterministic Solow-Swan neoclassical model of growth. Suppose, for example, that all economies have the same steady-state level of income in the deterministic Solow-Swan model. Then from any initial distribution of income across economies (except the steady-state distribution, from which the extent of dispersion is unchanging), σ-convergence will be observed.
(4) This result is confirmed if one evaluates the extent of dispersion in shorter intervals of time than the two peak-to-peak business cycles (eg in successive five-year periods).

Table G
Changes in the extent of dispersion of productivity levels relative to the manufacturing mean in the sample period

	1970–92	1973–79	1979–89
TFP′			
Standard deviation	0.9	0.8	1.0
Y/L′			
Standard deviation	0.5	0.4	0.5

productivity levels. In particular, it is completely uninformative about the marked tendency seen earlier for the distribution of both labour productivity and TFP to become increasingly positively skewed during the sample period. We therefore turn to a more general analysis of productivity dynamics.

(iii) Modelling productivity dynamics

Following Quah (1993b), (1996a,b,c), the evolution of the distribution of relative productivity over time can be modelled in terms of a stochastic difference equation (ie the probability of observing a value for labour productivity in one period is a function of the same probability in previous periods). In the empirical analysis that follows, we assume for simplicity that this equation is annual, first-order and time-stationary. If the range of possible values of productivity relative to the manufacturing mean is divided into a number of discrete cells, the evolution of productivity levels over time may be modelled using a matrix of transition probabilities, each of which may be estimated by counting the number of transitions into and out of each cell.(1) By iterating this stochastic transition probability matrix forward an infinite number of times, one may obtain the implied steady-state distribution of relative productivity.(2)

By explicitly modelling the evolution of the entire distribution of relative productivity, one can assess the probability of an industry moving from one segment of the distribution to another, and thereby obtain a more complete picture of changes within the distribution. Information about changes in the external shape of the distribution of relative productivity may be obtained both by directly analysing the distribution of productivity across industries (as was done earlier in this article) and from the steady-state distribution implied by the transition probabilities.

Tables H and I present estimates of the probabilities of movement between the discrete cells of the distributions of relative labour productivity and TFP respectively. Each table can be interpreted as follows.(3) The numbers in parentheses in the first column are the total number of industry/year pairs beginning in a particular cell; the first row of numbers denotes the upper endpoint of the corresponding grid cell. Thereafter, each row denotes the probability of passing from one state into another. For

Table H
First-order, time-stationary transition probabilities for relative labour productivity

Y/L′	Upper endpoint			
Number	0.506	0.704	1.088	∞
(96)	0.88	0.13	0.00	0.00
(102)	0.18	0.71	0.12	0.00
(102)	0.01	0.15	0.75	0.10
(99)	0.00	0.00	0.13	0.87
Ergodic	0.389	0.265	0.198	0.148
		Single-period transitions iterated 21 times		
	0.44	0.28	0.17	0.10
	0.41	0.27	0.19	0.13
	0.34	0.25	0.22	0.19
	0.28	0.23	0.25	0.24

Table I
First-order, time-stationary transition probabilities for relative TFP

TFP′	Upper endpoint			
Number	0.506	0.704	1.088	∞
(99)	0.93	0.07	0.00	0.00
(98)	0.08	0.85	0.07	0.00
(102)	0.00	0.14	0.82	0.04
(100)	0.00	0.00	0.07	0.93
Ergodic	0.389	0.337	0.175	0.098
		Single-period transitions iterated 21 times		
	0.48	0.34	0.14	0.04
	0.39	0.35	0.18	0.08
	0.31	0.34	0.21	0.14
	0.16	0.26	0.25	0.32

example, the second row of numbers presents the probability of passing from the lowest productivity state to the lowest, lower/intermediate, higher/intermediate and highest-productivity states successively. The final row of the upper section of each table gives the implied steady-state distribution; in the lower section of each table, the single-transition matrix is iterated 21 times.

Estimated values of transition probabilities close to one along the diagonal indicate persistence, while large off-diagonal terms imply greater mobility. Tables H and I suggest a degree of mobility in productivity levels across industries: there are important changes in relative levels of productivity across industries, particularly in the middle of the distributions. So the earlier finding of no statistically significant evidence of either reversion to or divergence from a common mean conceals considerable changes within the distribution. These changes are greater for relative labour productivity than for relative TFP.

These changes are of further interest for their implications for the evolution of the external shape of the two distributions of relative productivity. For both labour productivity and TFP, there appears to be more downward than upward mobility. (The sum of the off-diagonal terms is greater below the diagonal than above it.) Indeed, the steady-state distributions for both measures of productivity are significantly positively skewed, with a relatively large number of industries with productivity levels just below

(1) More generally, if one continues to treat productivity as being continuous, one may estimate the stochastic kernel associated with P^* (see, for example, Quah (1996c)). But in the present application, there are too few cross-sectional units (industries) for such estimation, and hence we proceed by dividing the space of possible values of productivity into discrete cells.
(2) That is, the ergodic or limit distribution towards which relative productivity is evolving.
(3) All estimation was carried out using Danny Quah's TSRF econometrics package. We would like to thank (without implicating) Danny Quah for making the latter available to us. Any results, opinions and errors are the responsibility of the authors alone.

the mean, and a few industries with above-average productivity. (A tendency for the United Kingdom's distribution of productivity across industries to become increasingly positively skewed during the sample period is also evident if one directly analyses the distribution of both relative labour productivity and TFP in each year of the sample period.)

In addition, the industries with above-average productivity tend to remain the same over time, particularly for TFP. For example, in all 23 years of the sample period, Computing and Pharmaceuticals are ranked first and second respectively in terms of TFP. There is more mobility in the case of labour productivity, but even here, Computing is ranked first in eleven years and second in eleven years, while Pharmaceuticals is first in twelve years and second in four years. There is no evidence that productivity levels in industries with below-average productivity are 'catching up' with these two lead sectors.

So there is evidence that an increasing number of UK industries are concentrating at productivity levels just below the manufacturing mean, with a few industries continuing to exhibit above-average productivity. Moreover, productivity levels in these industries not only persistently remain above average, but actually increasingly move away from mean values during the sample period. This is evident from a comparison of Charts 1 and 2 or Charts 3 and 4, and is revealed by an analysis of the cross-section distribution of average productivity growth rates in the sample period, which is significantly positively skewed. From Charts 2 and 4, the industries where productivity levels increasingly depart from mean values are Computing, Pharmaceuticals and Aerospace. All three of these industries are among the seven industries found earlier to account for 95% of aggregate manufacturing TFP growth. In fact, these three industries alone account for just under 40% of the TFP growth in aggregate manufacturing.

It is important to note that in stating these conclusions, we make no claims about what is driving these changes in relative levels of labour and TFP and draw no policy inferences. Only further research will tell us whether persistence of high levels of productivity in a few industries is simply the result of fundamental differences in the nature of the technologies in these industries (in which case it is still an interesting fact), or is instead the result of economic forces at work in these industries (such as unionisation, R&D spending, human capital, or openness to international trade).

Summary

This article has reported a detailed analysis of the nature of growth in 19 UK manufacturing industries between 1970–92. The main results were:

- The decline in both constant price value added and hours worked in aggregate manufacturing was found to conceal considerable differences across sectors, with substantial changes in the relative size of individual manufacturing sectors.

- In all 19 industries, the average rate of growth of value added exceeded that of hours worked, and so labour productivity growth increased in each sector. Rates of labour productivity and TFP growth varied considerably across sectors, with close correlation between the two measures.

- Rates of growth of value added, hours worked, labour productivity and TFP also displayed sizable variations over time. Growth rates of labour productivity and TFP were (with only one exception) higher in the second peak-to-peak business cycle (1979–89) than in the first (1973–79). In addition, increases in TFP, relative to those in capital accumulation, were estimated to account for a larger share of value added and labour productivity growth in the second peak-to-peak cycle than in the first.

- Despite substantial changes in the relative size of individual manufacturing sectors, the vast majority of productivity growth in aggregate manufacturing during the sample period (whether measured by labour productivity or TFP growth) was found to be due to within-sector productivity growth, rather than reallocations of resources between sectors. The sources of aggregate TFP growth were more concentrated than those of labour productivity growth: more than 95% of TFP growth in aggregate manufacturing between 1970–92 was accounted for by seven sectors, which together constituted (on average in the period) less than 44% of value added.

- Productivity levels (whether measured by labour productivity or TFP) also varied markedly across sectors. In the sample period, levels of both labour productivity and TFP displayed no statistically significant tendency to revert to or diverge from a common mean. So there was no evidence that productivity levels were converging or diverging across sectors in the sense of β-convergence or β-divergence.

- This summary technique for characterising movements within a distribution concealed considerable interesting intra-distribution dynamics. An analysis of the evolution of the entire distribution of productivity across industries revealed substantial mobility in levels of relative labour productivity and TFP, with more mobility in the middle of each distribution. The extent of mobility was greatest for labour productivity; and for both measures of productivity, there was more mobility downwards than upwards.

- The dispersion of levels of labour productivity and TFP around the mean both increased during the sample period, so that there was no evidence of productivity convergence across sectors in the σ-convergence sense. But an analysis of the sample standard deviation alone was found to conceal interesting changes in the external shape of the productivity distribution. Direct inspection of the distribution of relative productivity across industries revealed that the latter became increasingly positively skewed during the sample period. Productivity in an increasing number of UK industries appears to be concentrating at levels just below the manufacturing mean. Productivity growth in a few sectors remained consistently above average during the sample period, and productivity levels in these sectors rose further away from mean levels.

This detailed, disaggregated analysis of growth within UK manufacturing has revealed a number of stylised facts about productivity growth (whether measured in terms of either labour productivity or TFP). These stylised facts are not only of interest in themselves, but are important in informing subsequent research into the explanations for the UK manufacturing sector's performance in the 1970s and 1980s (see, for example, Cameron, Proudman and Redding (1997)).

Annex

A Data definitions and sources

Value added: Value added is gross value added at factor cost from the Census of Production. This is equal to gross output minus purchases; minus increases in stocks of materials, stores and fuel; minus the cost of industrial and non-industrial services. Spending on R&D intermediate goods was added back in to remove the 'expensing bias' discussed by Schankerman (1981). Gross value added was deflated by the producer prices (output) index (market prices), to give a single-deflated value-added index.

Since value added is essentially gross output minus intermediates and the time series profiles for the price indices associated with these components may be different, it follows that theoretically one should deflate gross output and intermediates separately in each industry and then subtract the resulting constant price series from one another (double deflation). But we are concerned about the quality of intermediate input deflators at the disaggregated level within UK manufacturing, and therefore follow a number of other authors (see, for example, van Ark (1996)) in using single-deflated value added. Cameron (1996) calculates double-deflated value added for total manufacturing (at which level intermediate input deflators may be more accurately measured). Although there are clearly differences, the time series profile of the double-deflated measure is broadly similar to its single-deflated counterpart.

Producer prices: Producer price (input and output) indices supplied by the Office for National Statistics.

Labour input: Total employment is from the Census of Production. From this, the number of R&D workers was subtracted. Normal and overtime hours worked per week (full-time males) are taken from the *New Earnings Survey* and from information supplied by the Employment Department. Weeks worked are taken from *Employment Gazette* (data for total manufacturing are assumed to apply to all industries). Hours worked per year in manufacturing are the result of multiplying numbers of employees by hours per week by weeks worked.

Capital input: Data for manufacturing were supplied directly by the Office of National Statistics. Spending on capital equipment for R&D purposes was subtracted.

B Industry concordance

The concordance is based upon Kong (1988), O'Mahony and Oulton (1994) and Cameron (1996). The manufacturing data set is composed of 19 industries. It was not possible to obtain a perfect concordance between SIC 1968 and SIC 1980. Where discrepancies arise, these are detailed in Table 1 below, which gives information on the percentage error in the value-added data between the two classifications. Of the 23 industries in Table A, four (Chemicals, Basic metals, Fabricated metals and Electrical machinery) are aggregates of other industries presented in the table. In view of the large role played by public procurement policies and government intervention, shipbuilding is excluded from our sample of manufacturing industries.

Table 1
Industry concordance

Industry	SIC 1980	SIC 1968	Error (%)
Chemicals nes (a)	25+26-257	V+411-272-2796-(05*276)	1.2
Pharmaceuticals Products	257	272+2796	2.0
Office machinery and computing	33	338+366	-4.7
Other electrical engineering	34-344-345	IX-363/4/6/7	3.6
Electronics	344/5	363/4/7+0.5*(354)	-2.9
Motor vehicles	35	381	2.0
Aerospace	364	383	1.2
Instrument engineering	37	VIII-0.5*(354)	-4.6

(a) nes: not elsewhere specified.

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