

Technological progress, structural change and productivity growth: a comparative study

by

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Abstract: The relationship between the economic structure of a country and its productivity growth has received a lot of attention in recent decades. For instance, several theoretical models in this area now suggest that countries that specialize in technologically progressive industries will enjoy high rates of growth compared to other countries. This paper focuses on the impact of specialization and structural changes on productivity growth in manufacturing, using a sample of 39 countries and 24 industries between 1973 and 1990. The results show that while structural change on average has not been conducive to productivity growth, countries that have managed to increase their presence in the technologically most progressive industry of this period (electronics) have experienced higher productivity growth than other countries.

Keywords: Technological progress; Structural change; Productivity growth

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1. Introduction

The relationship between the economic structure of a country and its productivity growth has received a lot of attention in recent decades. For instance, several theoretical models in this area now suggest that countries specializing in technologically progressive ('high tech') activities will enjoy high rates of productivity growth compared to other countries (see, e.g. Lucas, 1988, 1993; Grossman and Helpman, 1991). Countries specializing in 'low-tech' activities, on the other hand, should be expected to have relatively slow productivity growth. In a globalized world, this may not imply slower growth in welfare in the latter as long as differences in productivity growth are fully reflected in prices. However, if producers of high-tech products are able to keep most of the rewards from faster technological progress to themselves by controlling prices (Reinert, 1993), the prospects for countries specialized in low-tech may be rather bleak. In such a case, it may pay off for a country to change its pattern of specialization towards more promising areas through policy intervention, as suggested by Lucas (1988).

Despite the growing interest, and the novelty of some recent modeling efforts, this is not a new line of research. Arguably, the idea that the economic structure — and changes in this pattern — matters for growth is as old as economics itself (Reinert, 1993, 1995). Salter (1960), in his now classic work on productivity and technical change, emphasized that the scope for technological progress/productivity advance differs markedly across industries. Hence, 'a flexible structure of production is an important element in the high rate of productivity increase, for it allows an economy to rapidly redistribute its resources so as to take maximum advantage of changing patterns of technological progress' (ibid. p. 9). In his empirical analysis of UK productivity growth in the first half of the 20th century he showed that this flexibility, i.e. the ability to undertake structural change, was of great empirical importance: 'This suggests that structural changes play a role equally important as increases in productivity within individual industries' (ibid. p. 151). The growth-accounting literature (Denison, 1967; Chung and Denison, 1976) also emphasized structural change as a major impetus to growth.¹ However, in contrast to the detailed analysis of Salter, these later studies focused mainly on the shift from agriculture to manufacturing. Consequently, the growth accounting literature has little to say about the possible impact of specialization and structural change within manufacturing on productivity growth. This holds also for the more recent exercises in this tradition (e.g. Young, 1995).

This paper focuses on the relationship between specialization, structural change and productivity growth in manufacturing in recent decades. The perspective is similar to that of Salter in the sense that we analyze the manufacturing sector as composed of a number of different industries. However, we share with Denison the comparative approach to studies of economic growth: the present sample includes 39 market economies (on different levels of development), basically all countries within this category for which data are available. The next section presents the data and shows how productivity growth differs across

¹ For an overview see Fagerberg (1994)

industries and countries. We also analyze the extent to which rapid productivity growth goes hand in hand with low price growth. Then we turn to the relationship between structural change and productivity growth, using both an accounting approach (shift-share methodology) and econometric testing. The final section outlines the main findings and discusses the implications for policy.

2. An overview of the data

The data used in this paper are drawn from the UNIDO Industrial Statistics Database 1996, supplied by the Industrial Statistics Branch of the United Nations Industrial Development Organization (diskette version). While the database exists both at the 3-digit and 4-digit level of the International Standard Industrial Classification (ISIC), only the former was used, since the coverage of the latter is much more limited in terms of variables, time span and countries. Another problem is that many countries report data for combinations of one or more ISIC groups. In many cases this could not be resolved and we had to exclude either the countries or industries in question from the analysis. Because of such differences in reporting we decided to merge the three subgroups in ISIC 36 into one industry (Glass, pottery, etc.).² In addition, petroleum and coal products (ISIC 353 and 354) were excluded from the analysis, since data for these products were lacking for many countries. There were also some problems for other industries, especially metals, but these problems were in most cases resolved by checking the records of the database against published statistics. This left us with 24 industries (Table 1).

To ensure comparability across countries, the analysis was limited to what can be broadly described as market economies (as opposed to the so-called socialist or communist countries such as the former USSR). Regarding the time period, we wanted to focus on the decades following the end of the post-war growth boom (Abramovitz, 1994), i.e. the most recent decades. After some experimentation the years 1973 and 1990 were chosen, since this combination allowed us to include the largest number of countries. This left us with 39 countries, characterized by large differences in productivity levels and performance (Table 2). Although many of these countries are European, Asia and America are also relatively well represented. However, due to data limitations, we were only able to include three countries from Africa.

The main focus of our study is on labor productivity defined as value added per worker.³ In the database value added is reported in dollars in current prices, employment in numbers of workers. To facilitate comparison between the two years we wished to deflate the value added data for 1990 to constant 1973 prices. Since no suitable deflator was available in the database, we decided to construct a price index based on data for industrial

² A similar problem arises for Indonesia and Netherlands for sectors 371 and 372. This was solved by treating the two sectors as one (i.e., 371) for these two countries. Note that sector 372 is small relative to sector 371 in both countries, so this is not likely to cause much problem.

³ Hence, differences in hours worked across countries and years could not be taken into account.

production (which were included in the UNIDO database both in current prices and as an volume index) and apply this to value added as well. Hence, the price index applied here is both industry and country specific.⁴

Table 1. Growth of world labour productivity by industry, 1973-1990

ISIC Industry	Productivity Growth ¹	Price growth
383 ELECTRICAL MACHINERY	4.7	4.3
313 BEVERAGES	2.9	5.6
352 OTHER CHEMICALS	2.8	6.1
341 PAPER AND PRODUCTS	2.7	6.1
390 OTHER MANUFACTURED PRODUCTS	2.6	5.0
382 NON-ELECTRICAL MACHINERY	2.6	5.9
371 IRON AND STEEL	2.4	5.6
311 FOOD PRODUCTS	2.3	5.2
351 INDUSTRIAL CHEMICALS	2.3	6.5
385 INSTRUMENTS	2.3	6.2
321 TEXTILES	1.7	5.5
372 NON-FERROUS METALS	1.6	5.8
384 TRANSPORT EQUIPMENT	1.6	6.8
342 PRINTING AND PUBLISHING	1.4	7.0
355 RUBBER PRODUCTS	1.4	5.5
356 PLASTIC PRODUCTS	1.4	6.7
381 METAL PRODUCTS	1.4	6.7
314 TOBACCO	1.2	6.6
360 GLASS, POTTERY ETC.	1.0	6.8
323 LEATHER PRODUCTS	0.8	6.5
331 WOOD PRODUCTS	0.7	5.4
332 FURNITURE	0.5	6.6
322 CLOTHING	0.3	6.2
324 FOOTWEAR	-2.5	8.5
TOTAL	2.3	5.9
STANDARD DEVIATION	1.26	0.82
MEAN	1.70	6.13
COEFFICIENT OF VARIATION	0.74	0.13

(1) Constant prices, average annual rate of growth.

⁴ In some cases there were missing values that had to be estimated through interpolation/extrapolation (based on information from earlier or later years). Five countries (Brazil, Iran, The Netherlands, Turkey and Sri Lanka) lacked price deflators for sector 385 or sector 390 or both. These were estimated on the basis of aggregate country and sector deflators.

Table 2. Labor productivity in manufacturing, by country, 1973–1990

Country	Annual Growth ¹	Total Change	Level 1973, US Dollars
KOREA	8.4	315.7	2869
TAIWAN	8.0	289.7	2603
PHILIPPINES	7.8	274.5	2956
IRELAND	6.7	211.3	8253
HONG KONG	4.5	113.7	3224
TURKEY	4.1	99.5	5208
FINLAND	3.8	89.9	9015
JAPAN	3.7	87.7	13503
BELGIUM	3.7	86.2	11797
SINGAPORE	3.5	82.8	4560
AUSTRIA	3.3	74.0	8963
NETHERLANDS	3.1	68.0	13707
IRAN	3.0	67.5	4992
SPAIN	3.0	66.7	6131
UNITED STATES OF AMERICA	2.8	61.8	21248
ALGERIA	2.7	59.5	7467
PORTUGAL	2.6	56.4	3903
FRANCE	2.6	56.1	11566
COLOMBIA	2.6	56.0	4604
UNITED KINGDOM	2.6	55.9	8536
AUSTRALIA	2.6	54.5	11849
GERMANY (WEST)	2.5	53.4	14684
NEW ZEALAND	2.4	51.3	9121
URUGUAY	2.3	48.0	3608
EGYPT	2.3	47.4	1613
INDIA	2.2	44.9	1127
SWEDEN	2.0	39.4	16310
INDONESIA	1.8	35.8	1186
CANADA	1.5	29.2	17388
ITALY	1.5	28.1	10705
DENMARK	1.2	22.3	12272
CYPRUS	1.1	21.4	4429
NORWAY	0.8	14.6	11613
SOUTH AFRICA	0.7	12.6	5180
SRI LANKA	0.6	10.7	1584
GREECE	0.5	9.4	7327
BRAZIL	0.0	0.8	6716
ECUADOR	-0.6	-9.5	4167
CHILE	-2.3	-32.1	11497
WORLD	2.3	48.0	12298

(1) Constant prices, average annual rate of growth.

Table 1 reports growth of labor productivity in constant prices at the industry level for the world as a whole (i.e. the 39 countries included in our sample). Overall productivity growth, as calculated in this study, was 2.3% per year. The differences across industries were quite substantial. However, the true differences may be even larger, since statistical agencies often fail to distinguish properly between quality improvements, commonly assumed to be frequent in technologically progressive industries, and price increases (Griliches, 1979). At the very top, electrical machinery (which includes much of electronics⁵), productivity increased by 4.7% per year over the period, nearly two percentage points more than the second most fast growing industry in our sample. Nine industries displayed annual growth rates between 2 and 3%. This group includes the industries other than electrical machinery that are normally classified as science-based (Pavitt, 1984), such as ‘other chemicals’ (including pharmaceuticals) and instruments (often regarded as a part of electronics). There were, however, also a number of traditional industries in this category, such as beverages, food products, paper, iron and steel, etc. The remaining fourteen industries all grew less than 1.8% per year, and consist to a large extent of typically ‘mature’, low-tech industries producing for the mass market, such as, for instance, rubber products, plastic products, metal product, textiles, clothing and footwear. Hence, there appears to be a relationship between the degree of technological sophistication of the industry and productivity growth, although there are probably also other factors at play.

The table also reports growth in prices at the industry level in US dollars. On average it appears as if industries with high productivity growth have relatively low price growth and vice versa. In fact, of the eight most fast-growing industries, five had below average price growth. Conversely, seven of the eight slowest growing industries had above average price growth. However, as shown by the coefficient of variation (bottom line), there is much more variation in productivity growth than in price growth, indicating that changes in productivity do not always carry over to prices (or at least not fully so). To explore this further we present in Table 3 estimates of the relationship between price growth and productivity growth for each industry. Following traditional (neoclassical) theory, in a (perfectly) competitive market a reduction in unit costs caused by technological progress should result in a similar decrease in prices. Hence, the estimated coefficient should under these conditions be expected to be equal to -1 . But to the extent that firms are able to influence prices (have market power), it may be that some of the fruits of technological progress are appropriated within the industry itself and is reflected in increased factor rewards there rather than in lower prices. In the extreme case in which an industry has sufficient market power to keep the rewards from technological progress entirely to itself, there would be no relationship whatsoever between price growth and productivity growth (in this case the estimated coefficient should be expected to be zero). However, since the calculation of productivity growth in constant prices depends on the very same price indices that are used to calculate price growth, ordinary least squares would normally lead to biased estimates. To avoid such bias we applied 2SLS (two stage least squares)

⁵ Most categories of what is commonly regarded as electronics (semiconductors, telecommunication equipment, etc.) are included in electrical machinery (ISIC 383). However, the data-machines as such are categorized as non-electrical machinery (ISIC 382). Ideally, one would have wished to merge all electronics groups into one category, but with the present data set, this was not possible.

and instrumented productivity growth with a set of variables that are assumed to be correlated with it (but not with price growth).⁶

Table 3. Productivity growth and price growth

INDUSTRY (ISIC)	PRODUCTIVITY GROWTH	R ² ADJUSTED FOR DEGREES OF FREEDOM
311 FOOD PRODUCTS	- 0.23 (2.00) *	0.08
313 BEVERAGES	- 0.14 (0.86) ***	0.04
314 TOBACCO	0.00 (0.03) ***	0.00
321 TEXTILES	- 0.37 (1.96) ***	0.14
322 CLOTHING	- 0.73 (8.55) *	0.75
323 LEATHER PRODUCTS	- 0.64 (4.95) *	0.42
324 FOOTWEAR	- 0.76 (5.54) **	0.60
331 WOOD PRODUCTS	- 0.67 (4.45) *	0.49
332 FURNITURE	- 0.66 (3.55) **	0.29
341 PAPER AND PRODUCTS	- 0.53 (3.43) *	0.31
342 PRINTING AND PUBLISHING	- 0.46 (2.74) *	0.25
351 INDUSTRIAL CHEMICALS	- 0.49 (4.93) *	0.40
352 OTHER CHEMICALS	- 0.40 (3.89) *	0.30
355 RUBBER PRODUCTS	- 0.75 (5.59) **	0.45
356 PLASTIC PRODUCTS	- 0.48 (3.57) *	0.36
360 GLASS, POTTERY ETC.	- 0.31 (1.81) ***	0.27
371 IRON AND STEEL	- 0.46 (3.43) *	0.33
372 NON-FERROUS METALS	- 0.28 (1.41) ***	0.30
381 METAL PRODUCTS	- 0.88 (6.38) **	0.53
382 NON-ELECTRICAL MACHINERY	- 0.76 (4.72) **	0.48
383 ELECTRICAL MACHINERY	- 0.93 (6.29) **	0.50
384 TRANSPORT EQUIPMENT	- 0.74 (6.82) *	0.64
385 INSTRUMENTS	- 0.81 (7.61) **	0.73
390 OTHER MANUFACTURED PRODUCTS	- 0.65 (4.62) *	0.44

Notes:

* = significantly different from both zero and - 1 at the 5 % level

** = significantly different from zero, but not from - 1, at the 5 % level

*** significantly different from - 1, but not from zero, at the 5 % level

Absolute t-statistics in brackets. Estimated with 2SLS (instrument variables method).

⁶ We used a combination of sector and country specific instruments. The sector specific instruments were: The initial level of productivity relative to the country average, the initial level of productivity relative to the industry average, growth of employment, the initial share of the sector in total manufacturing employment and change in the sector's share of total manufacturing employment. The data used to calculate these instruments were taken from the UNIDO data base. The country specific instruments included enrollment rates in primary and secondary schools, investment as a share of GDP, exports as share of GDP, size of population and growth of gdp per capita (Source: World Bank).

The results⁷ (Table 3) reveal that in about one third of the cases the estimated coefficient is low in absolute value, and not significantly different from zero at the 5% level, consistent with the assumption of high market power. These are in most cases typical ‘low-tech’ industries processing natural resources (beverages, tobacco, textiles and glass/pottery, for instance). There is another third for which the estimated coefficient is high in absolute value and not significantly different from -1 . This group includes some relatively unsophisticated manufactures mostly destined for the mass market (footwear, wood products, furniture and metal products) but also electrical and non-electrical machinery and instruments, the three industries most intimately connected to the electronics revolution. The implication, then, should be that these industries are fairly ‘competitive’ in nature. The remaining industries (of which many belong to the chemical sector) fall in the intermediate range, indicating some — though incomplete — spillover from technological progress to prices. However, it needs to be stressed that the data and methods used here are rough, and that the results therefore should be regarded as just indicative. Still it is worth noting that there is very little support in these data for the idea that market power is especially pronounced in technologically progressive, ‘high tech’ industries.

Table 2 reveals that the differences in productivity growth are much larger across countries than over industries. This may reflect that the alleged failure of productivity statistics to adequately reflect qualitative change is less of a problem at the aggregate level than at the level of the individual industry. For instance, unmeasured quality advances in a supplier industry often end up as measured increases in output in user industries using these supplies, and would hence tend to be included in aggregate productivity growth. But it may also reflect that there is more to cross-country differences in productivity growth than just structural change. At the top of the list we find many of the so-called newly industrializing countries of Asia (Korea, Taiwan and Philippines) joined by some of their counterparts in Europe (Ireland, Turkey and Finland). Japan also does rather well. Among the other industrialized countries that were relatively advanced two decades ago already, the larger ones cluster towards the middle of the list, while there is considerably more diversity among the smaller economies in this category (with the Central European ones doing relatively well and those from Northern Europe lagging). The South American countries also show a weak performance. Hence there are several examples here of groups of countries with common characteristics displaying a similar performance, giving some support to the idea of ‘growth clubs’ (e.g. Baumol, 1986; Durlauf and Johnson, 1995; Quah, 1996).

⁷ Observations for which price growth had been estimated from industry- and country-averages were not included in these regressions.

3. Accounting for structural change

What is the impact of differences across countries in patterns of specialization and structural change on productivity growth? In the following we will use the data just described to analyze this question.

In so doing we will make use of an empirical methodology designed to analyze such issues, often called ‘shift-share analysis’. It has been used frequently by among others economic geographers, economic historians, industrial economists and trade analysts.⁸ Essentially it is a purely descriptive technique that attempts to decompose the change of an aggregate into a structural component, reflecting changes in the composition of the aggregate, and changes within the individual units that make up the aggregate. As such it is closely related to analysis of variance.

There are many versions of this methodology, the main difference being the choice of base year or ‘weights’: initial year, final year, some kind of ‘average’, linked, etc., and each version usually has its critics as well as defenders. The reason for this state of affairs is the well known result in index number theory that if, say, initial or final year weights are applied throughout in a decomposition, a residual will necessarily occur. So what many versions of this methodology do is to try to reduce this residual as much as possible. An alternative solution, that we will pursue here, is to make an economic interpretation of the residual. This is not so difficult, since the very reason for a residual is that the variables taken into account in the analysis interact, i.e. it is an interaction-effect (see Fagerberg and Sollie, 1987).

Formally, the method applied here may be derived as follows: Define P = Labor productivity Q = Value added, N = Labor input (man-years, for instance).

Then

$$(1) P = \frac{Q}{N} = \frac{\sum_i Q_i}{\sum_i N_i} = \sum_i \left[\frac{Q_i}{N_i} \cdot \frac{N_i}{\sum_i N_i} \right]$$

i = industry ($i = 1, \dots, m$)

Define

$$(2) P_i = \frac{Q_i}{N_i} \quad (\text{labour productivity in industry } i)$$

⁸ For early applications of this methodology to the study of the relationship between growth and structural change see Fabricant (1942) and Maddison (1952).

$$(3) S_i = \frac{N_i}{\sum_i N_i} \quad (\text{the share of industry } i \text{ in total employment})$$

Then, by substituting (2) - (3) into (1),

$$(4) P = \sum_i [P_i S_i]$$

Assume

$$\Delta P = P_1 - P_o, \Delta S = S_1 - S_o \text{ etc.}$$

Then, using (4), we have

$$(5) \Delta P = \sum_i [P_{io} \Delta S_i + \Delta P_i \Delta S_i + S_{io} \Delta P_i]$$

or, in “growth-rate” form

$$(6) \frac{\Delta P}{P_o} = \sum_i \left[\underbrace{\frac{P_{io} \Delta S_i}{P_o}}_I + \underbrace{\frac{\Delta P_i \Delta S_i}{P_o}}_{II} + \underbrace{\frac{S_{io} \Delta P_i}{P_o}}_{III} \right]$$

- The first term (I) is the contribution to productivity growth from changes in the allocation of labor between industries. It will be positive if the share of high productivity industries in total employment increases at the expense of industries with low productivity. Thus, it reflects the ability of a country to move resources from low to high productivity activities.

- The second term (II) measures the interaction between changes in productivity in individual industries and changes in the allocation of labor across industries. This effect will be positive if the fast growing sectors in terms of productivity also increase their share of total employment. Hence, it reflects the ability of a country to reallocate its resources towards industries with rapid productivity growth.

- The third (III) is the contribution from productivity growth within individual industries (weighted by the share of these industries in total employment).

Table 4 gives the results from the calculations.

Table 4. Change of labour productivity decomposed, 1973-1990

Country	Total Change	I	II	III
KOREA	315.7	-5.7	-30.0	351.4
TAIWAN	289.7	3.4	-9.8	296.0
PHILIPPINES	274.5	-9.5	-81.1	365.2
IRELAND	211.3	5.6	36.5	169.2
HONG KONG	113.7	-1.0	-11.7	126.3
TURKEY	99.5	-2.0	-12.8	114.3
FINLAND	89.9	3.8	3.1	83.0
JAPAN	87.7	-2.5	4.2	86.0
BELGIUM	86.2	5.7	3.0	77.5
SINGAPORE	82.8	4.4	-41.0	119.5
AUSTRIA	74.0	1.2	-6.1	78.9
NETHERLANDS	68.0	6.9	-6.5	67.6
IRAN	67.5	8.6	-22.5	81.5
SPAIN	66.7	1.8	-12.6	77.4
UNITED STATES OF AMERICA	61.8	1.8	-2.1	62.1
ALGERIA	59.5	2.3	-6.3	63.6
PORTUGAL	56.4	-0.1	-26.9	83.4
FRANCE	56.1	2.1	2.6	51.4
COLOMBIA	56.0	-1.0	-7.0	64.1
UNITED KINGDOM	55.9	1.1	-2.5	57.2
AUSTRALIA	54.5	1.2	-4.2	57.5
GERMANY (WEST)	53.4	0.5	-6.0	59.0
NEW ZEALAND	51.3	2.3	-0.3	49.3
URUGUAY	48.0	1.9	-15.2	61.2
EGYPT	47.4	3.5	-0.9	44.8
INDIA	44.9	2.6	2.3	40.0
SWEDEN	39.4	2.1	0.0	37.3
INDONESIA	35.8	-5.7	-38.0	79.5
CANADA	29.2	0.2	-1.7	30.8
ITALY	28.1	-1.2	-6.0	35.3
DENMARK	22.3	1.0	-5.5	26.8
CYPRUS	21.4	-6.1	-15.9	43.4
NORWAY	14.6	0.6	-6.3	20.3
SOUTH AFRICA	12.6	1.8	-1.8	12.5
SRI LANKA	10.7	-0.5	-52.4	63.6
GREECE	9.4	-1.3	-3.3	14.0
BRAZIL	0.8	2.1	-5.7	4.3
ECUADOR	-9.5	4.4	-3.6	-10.3
CHILE	-32.1	-4.0	-17.6	-10.5

The overwhelming part of total productivity growth is accounted for by productivity growth within individual industries (III). Transfer of resources from low to high productivity activities (I) does not appear to have been an important factor. The interaction

effect (II) had somewhat more impact, but negatively in most cases (the main exception being Ireland). Hence, in contrast to the period studied by Salter, countries in the 70s and 80s did not change their economic structure in a way that was conducive for overall productivity growth. This confirms previous results from other studies based on much smaller samples of countries (Dollar and Wolff, 1988; Timmer and Szirmai, 1999).

It may be pertinent to ask why these results differ so much from those reported by Salter for an earlier period and more limited sample. To answer this question, it is useful to recall that for structural change to have a positive effect on overall productivity growth, there are two conditions that have to be fulfilled. First, there have to be some changes in the sectoral composition of labor over time, that is, some industries have to increase their share of the total labor force at the expense of others. Second, these changes have to be correlated with productivity (effect I) or its rate of growth (effect II). Comparing the evidence studied by Salter with the data used here suggests important differences between the two samples in these respects.

First, it appears to be the case that technical change in the period/sample studied by Salter was much more employment (and — consequently — output) expanding than in the period under study here (Fig. 1).⁹ This is reflected in the steeper curve for the period studied by Salter. In fact, the data suggest that in that sample, 1% higher productivity growth was associated with 1.4% higher growth in employment, while in our sample the relationship between productivity growth and employment is less than one half of that level. This implies that even if productivity growth, including the dispersion around its mean, had been identical in the two samples, there would be much less structural change in our sample than in that of Salter.

Second, although the estimated relationship between employment and output growth was positive and significant in both samples, the explanatory power of the regression was much higher in Salter's case than in our sample. In the period/sample studied by Salter, the rule that industries with rapid productivity growth also increased their shares of total output and employment at a rapid rate was almost without exception. For the more recent

⁹ The results were:

UK sample (28 industries 1924 – 1950):

$$n = -0.82 + 0.58y, R^2 = 0.84$$

(4.66) (11.81)

UNIDO sample (24 industries 1973 – 1990):

$$n = -0.44 + 0.38y, R^2 = 0.38$$

(1.64) (5.89)

where n is employment growth and y is output (or value added) growth. Estimated with ordinary least squares, absolute t -statistics in brackets. The relationship illustrated in Fig. 1 is obtained by substituting productivity growth ($y - n$) into the estimated equations. Salter also provide data for a sample of 27 US industries between 1923 and 1950, the result in that case was:

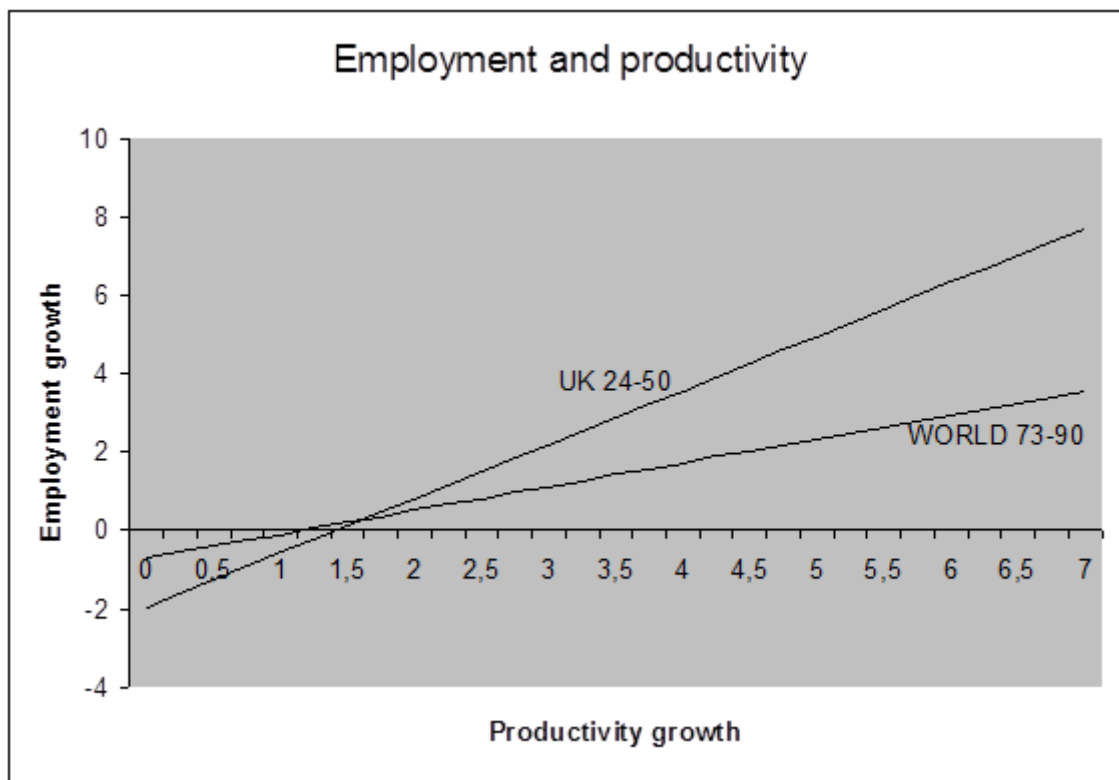
$$n = -1.52 + 0.50y, R^2 = 0.68$$

(5.92) (7.39)

Evidently, trend productivity is higher in the US than in the other samples, otherwise the results are close to the UK sample.

UNIDO sample, this picture is much more blurred. A closer look at the data for the world as a whole reveals that although electrical machinery displayed very high productivity growth, employment in this industry did not expand particularly fast, whether measured through its rate of growth or the change in its share of total employment. In terms of the former it was surpassed by six other industries, five of which had average or below average productivity growth. As for the latter, there were three industries with larger increases in the share of total employment: food products, plastic products and printing and publishing, all with average or low rates of productivity growth.

Figure 1.



Hence, the results point to an important difference between the period/sample studied by Salter and the one under study here.¹⁰ In the former industries characterized by rapid technological change, such as electricity generation, synthetic fibers, etc., also increased their shares of total production and employment at a fast rate. This means that changes in supply, associated with new technological opportunities, went hand in hand with changes in demand. However, the technologically leading industry in the period under

¹⁰ Salter's study was mainly considering UK evidence, and it may be problematic to generalize from this to other capitalist economies at the time. However, Salter also considered data from the US, and although these were not analyzed in the same detail, the main regularities — as far as structural change is concerned — were the same.

study here, i.e. electronics, has not been associated with changes in the structure of demand to the same extent as the technologically leading industries 50 years ago. As a consequence, structural change, as accounted for the methods used in this section, has not been as important for productivity growth as it was in the earlier period/sample studied by Salter.

4. The impact of the electronics revolution

The results reported in the previous section should not be taken to imply that structural changes are unimportant or that the electronics revolution does not matter for productivity growth. What it shows is that structural change *on average* was not conducive to productivity growth. This does not mean that *specific* structural changes that countries underwent were without economic importance. One industry that deserves further scrutiny in this respect is the electrical machinery industry, which by far has the highest rate of productivity growth of all industries in our sample. Moreover, among the industries in our sample, this is the one that has been most affected by the electronics revolution. In fact, one might argue that this industry is at the heart of this revolution, since it both produces electronic components and uses them intensively.

What we are going to explore in this section is to what extent it matters for the productivity growth of a country whether it increases the share of its resources that is devoted to the electrical machinery industry. In a pure accounting sense (as in the previous section) it should, because in most countries electrical machinery is characterized by both a high productivity level and high productivity growth. To take the most fast growing country of our sample, Korea, as example, our calculations show that a 1% increase in the share of total employment working in this industry increased overall productivity growth with around 0.2%.¹¹ Such numbers may differ somewhat from country to country, depending on the level and growth of productivity in the electrical machinery industry relative to other industries. For the world as a whole the effect seems to be a bit lower, about 0.1%. There is also a potential downside to this calculation, not taken into account here, because these workers might alternatively have been engaged in something else. Arguably, the total effect would look very different if these workers were taken from another high-growth, high-productivity industry instead of a declining one. There are, however, reasons to believe that the numbers presented here are closer to a lower than a higher bound. This is so because accounting methods of the type developed in the previous section fail to capture the indirect effects that technological progress in electronics has had for other industries. First, as already noted, there are some doubts as to whether producers of electronics have really been able to appropriate the full economic benefits from the continuous improvements in quality and performance that characterize

¹¹ This is calculated by dividing the contribution to growth of total manufacturing productivity from structural change in the electrical machinery industry (the first and second term in Eq. (6), with i = electrical machinery) with the increase in the share of the total labor force working in that industry.

technological progress in this industry. If not it implies that parts of the recorded productivity improvements in other industries should be classified as originating from the electronics industry. The evidence reached in Section 2 of this paper, indicating more competitive pricing in this industry than in most others, may indicate that this is more than just a theoretical possibility. Furthermore, new and improved products originating in the electronics industry, but used in other industries, are likely to be conducive to innovation in products, processes, organization and management in these industries (so called induced innovations), leading to increased performance. Finally, new knowledge developed through the ‘electronics revolution’, may find new — and unexpected — applications in other industries, leading to new innovations and increased productivity there.

In short, it is likely that technological progress in electronics spills over to other industries and gets recorded as productivity increases there, so that the actual importance of electronics for growth becomes underestimated by accounting-methods of the type applied here. In fact available evidence from several countries indicate that such indirect effects may be quite substantial (Goto and Suzuki, 1989; Bernstein, 1997; ten Raa and Wolff, 1999). Getting a grasp on the geographical boundaries of such spillovers may be trickier, however. If this is a worldwide effect, all countries might be expected to gain equally from it, not only those that have a high (and/or increasing) presence in the electronics industry. But available research on technological spillovers indicates that this is rarely the case. On the contrary distance and country borders are typically shown to have a strong impact (Henderson et al., 1993; Maurseth and Verspagen, 1999). Why this is so is a complex issue, which we cannot pursue here. What we may safely assume, however, is that an important part of such spillovers is local and national in character. This implies that a country’s performance in production of electronics may be expected to have growth effects at the national level exceeding what a pure accounting exercise would lead us to believe.¹²

To explore this issue empirically we regress actual productivity growth in manufacturing on the change in the share of the electrical machinery industry in total manufacturing employment. We also include the change in the share of the work force going to other ‘high growth’ industries (defined as the upper third of the distribution, see Table 1) to allow for the possibility a similar impact there. However, since productivity growth of manufacturing at large may also be influenced by other variables than structural change, we also report regressions with other conditioning variables included. These are all from the country level and may be regarded as representing the pool of resources available for manufacturing in a given country. The conditioning variables (source: World Bank) include the initial productivity level (included as a measure of the scope for catch-up in technology), enrollment in education, the share of investment in GDP, size of population and continent-dummies (to allow for geographical clustering of performance).

¹² Even if one accepts this hypothesis as a fruitful starting point, the performance in electronics remains to be defined. Is it the size of the industry, initially or towards the end of the period, or perhaps the change between the two? We have chosen the latter, partly caused by the focus of our study, but also related to the fact that the electrical machinery industry was much less of an electronics industry around 1970 than it presently is. Hence, the change of this industry is probably a more reliable indicator of a country’s performance in electronics than its initial positioning in the industry.

The results are listed in Table 5. Versions with and without conditioning variables, as well as with and without continent-dummies, are reported. It turns out that increasing the share of electrical machinery (which we see as a proxy for electronics) in total employment is good for productivity growth, while it does not matter much what happens to the other high growth industries. The estimate is highly significant and remarkably stable across different specifications. The explanatory power is also quite respectable. Moreover, the predicted impact is large. If 1% of the workforce switches to electrical machinery from other industries, this will be associated with about 0.5% higher growth (compared to what would otherwise have been the case). Among the other variables, the scope for catch up (measured by the initial productivity level) and enrollment in secondary education received most support, but the inclusion of continent-dummies reduced the significance of these conditioning variables. Investment as a share of GDP did not turn up as an important factor, perhaps because manufacturing investment is only one among several elements that constitute total investment in a country.

Table 5. Structural Change and Productivity Growth

	5.1	5.2	5.3	5.4	5.5	5.6
HIGH GROWTH	-0.07 (0.97)	-0.05 (0.63)	-0.06 (0.86)	-0.03 (0.47)	-0.00 (0.00)	0.05 (0.78)
ELECTRICAL MACHINERY	0.61 (5.58) ***	0.57 (4.66) ***	0.55 (5.11) ***	0.49 (4.32) ***	0.57 (4.01) ***	0.59 (4.18) ***
PRIMARY EDUCATION		0.24 (0.08)				
SECONDARY EDUCATION		2.07 (2.02) *	1.98 (2.19) **	1.76 (1.81) *	1.43 (1.53)	1.21 (1.39)
INVESTMENT		-0.52 (0.38)				
INITIAL PRODUCTIVITY		-0.99 (2.02) *	-0.93 (2.06) **	-0.59 (1.16)	-0.69 (1.46)	-0.18 (0.44)
POPULATION		0.05 (0.20)				
CONTINENT- DUMMIES	NO	NO	NO	YES	NO	YES
R ² (R ²)	0.49 (0.46)	0.57 (0.46)	0.56 (0.51)	0.60 (0.50)	0.42 (0.33)	0.54 (0.41)
N	37	37	37	37	33	33

Note: Estimated with OLS. Absolute t-statistics in brackets. *, **, *** denote significant at the 10, 5 and 1% level, respectively, in a two-tailed test. R² in brackets is adjusted for degrees of freedom.

Since many the fast-growing countries generally increased the share of electrical machinery in total employment quite significantly, the results reached here means that a large part of these countries' exceptionally high productivity growth may be statistically 'explained' by their inroads in electronics and related industries. Four countries moved four per cent or more of their workforce from other industries to the electrical machinery industry; Korea, Singapore, Taiwan and Japan. On average, for these four countries, the estimated growth-bonus from increasing employment in the electrical machinery industry amounts to about one half of actual productivity growth in these countries. The estimate appears large, though, and one might suspect that the reported results to some extent depend on the inclusion of these four countries in the sample. The regressions in the two columns to the far right in Table 5 test for this possibility by excluding these four observations. It turns out that the estimated impact on overall productivity growth of moving resources to electrical machinery is not affected by the inclusion of these countries.

Thus, the results reported in this section point to substantial benefits accruing to countries that change their economic structure towards the technologically most progressive industries, in this case electronics. These benefits are partly related to the fact that electronics is a high-productivity, high-growth industry. However, the lion's share of these benefits appears to be of the indirect type, in the form of positive spillovers from this industry to other industries and sectors in these countries.¹³

5. Conclusion

This paper has focused on the impact of structural changes on productivity growth in manufacturing. It was inspired by previous findings for the UK in the first half of the 20th century, showing that structural change played a very important role for overall productivity growth. The results reported here, based on a sample of 39 countries between 1973 and 1990, indicate that structural change still matters, but in a different way than before. The main difference concerns the role played by new technologies in generating structural change. In the first half of the 20th century, growth of output, productivity and employment were strongly correlated. Employment in industries based on new technologies (such as electricity and synthetic materials) expanded rapidly at the expense of more traditional industries, implying an important role for structural change in explaining overall productivity growth. More recently this relationship between output, productivity and employment has become more blurred. New technology, in this case the electronics revolution, has expanded productivity at a very rapid rate, particularly in the electrical machinery industry, but without a similarly large increase in the share of that industry in total employment. In fact, the industries that increased their role in total

¹³ The strategic role played by electronics in overall growth has also been confirmed by other econometric studies (e.g. Amable, 1996; Fagerberg and Verspagen, 1999).

employment most substantially were generally traditional industries — mostly geared towards private consumption — with average to low productivity growth. Hence, in recent decades, new technology has not been linked with structural changes in demand, output and employment in the same way as before. This explains why structural change — in a pure accounting sense — was more important for productivity growth previously than it appears to have been more recently (at least up to 1990).

However, this does not mean that the electronics revolution — or the structural changes associated with it — have not been important for overall productivity growth in the period under study here. First, the electrical machinery industry (which is the industry most intimately related to the electronics revolution) has experienced much higher productivity growth than any other industry, implying a growth bonus for countries with a superior performance in this industry. Second, there have been important spillovers to productivity growth in other industries, and available research indicates that these have been stronger at the local or national level than globally. Hence, the results presented in this paper suggest that countries that during the period under study here managed to establish themselves firmly in the electronics industry got a sizeable growth bonus from these investments.

This being said, it seems appropriate to issue a warning regarding the possible implications of these findings. First, leading technologies — and the industries most affected — change through time, and so do the conditions for entry and the rewards from it. Thus, the relevant policy conclusion to draw from this is not that every country should move into production of electronics as fast as possible. Rather, the lesson is that there may be important potential gains to overall growth and — possibly — welfare from successful entry in technologically progressive industries that should be taken into account when designing policy. Second, little is said here about what the conditions for such entry were during the period under study or — of even greater importance for policy — are likely to be in the future. Without a clear understanding of these conditions — and how they relate to existing national assets and capabilities — it becomes difficult to discuss policy in a meaningful way. Arguably, these questions deserve a high rank on the future research agenda in this area.

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