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An International Comparison of Manufacturing Productivity in Taiwan
1961-1993

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Abstract

Taiwan has undergone a process of swift industrialization after 1948. Rapid accumulation of physical and human capital enabled Taiwan to exploit new technologies and products, resulting in rapid catch up in labour productivity relative to more advanced economies. Using the industry-of-origin approach, this paper shows that in 1961, Taiwan's labour productivity in aggregate manufacturing was 11% of the level in the United States, increasing to 26% in 1986. This catch up process was found for all 13 manufacturing branches. After 1986, a process of deindustrialization set in and inflow of labour in the manufacturing sector stagnated. Relative labour productivity in aggregate manufacturing still continued to increased to 31% in 1993, but catch up was not shared by all branches. The increase in labour productivity was driven by a large rise in capital intensity from 7% of the US level in 1961 to 47% in 1993. In 1993, capital intensity in Taiwanese manufacturing was about equal to the capital intensity in US manufacturing in 1961. This shows that there are still plenty of opportunities for further capital intensification. TFP growth in Taiwanese manufacturing averaged 2.2% per year for the period 1961-1993, of which only 0.2% was due to a reallocation of resources between manufacturing branches. In contrast to the catch up process in terms of labour productivity and capital intensity, aggregate TFP did not increase relative to the US and stagnated at around 40%. Some branches like wearing apparel and electrical machinery showed strong catch up, but this was offset by the performance in branches like chemicals and paper which were falling behind the performance levels of more advanced economies. Economies of scale do not provide an explanation of the gap in TFP levels between the US and Taiwan. An adjustment for the relatively small size of Taiwanese manufacturing firms adds only 3% to the Taiwanese TFP level. Differences in human capital are more important. Using a growth accounting framework, they explained about 7% of the TFP gap relative to the United States.

1. Introduction: Taiwan and the Paradigm of Late Industrialisation.

In 1950 GDP per capita in Taiwan stood at 10% of the US, which was slightly above Indonesia and Ivory Coast, but well below Ghana. In 1992 it had reached South-European levels and stood at 53% of the US level (Maddison 1995). Industrialization has been an important engine of growth in Taiwan's economic development during this period. This paper measures the comparative productivity performance of Taiwan in an international perspective. It shows that Taiwanese industy went through a number of phases, which resulted in a steady catch up with world productivity leaders. Industrial labour productivity performance went up from 10% of the US level in 1961 to 31% in 1993. It enjoyed the advantages of being backward by adopting technologies practiced at the world technology frontier without the need to devote resources to the development of new technologies. The focus of late industrializing countries like Taiwan can be on learning and incremental productivity and quality improvements related to existing products and processes. Amsden (1989) calls this the paradigm of late industrialization as opposed to the paradigms of the first and second industrial revolutions which were based on invention and innovation respectively. Taiwan, South Korea and Japan, but also Brazil and Turkey are typical examples of such late industrialisers.

Catch up by using unexploited technologies requires investment, not only in physical capital, but also in human capital as upgraded skills are required to operate the new capital goods and to use them efficiently. The pace at which catch up is actually realized depends not only on the accumulation of capital but also on factors which limit the diffusion of knowledge and the rate of structural change in an economy. Abramovitz (1989) also argues that catch up is not guaranteed. The potential for catch up in an economy is not only determined by the degree of backwardness, but also by its social capabilities. Social capabilities of an economy are partly identified with its political, commercial, industrial and financial institutions. Another aspect is the technical competence to exploit new technologies. This depends on workers' skills but also on power, transport and communication infrastructure. Technological congruence, i.e. congruence between the resource endowments and market scale of an economy on the one hand and the characteristics of frontier technologies on the other are another factor which might prohibite automatic catch up.

The idea of conditional convergence has been empirically verified by numerous cross country studies using a host of variables to 'measure' social capacity like educational attainment, life expectancy, public spending on education, government consumption, black-market premiums on foreign exchange, political instability indicators, terms of trade etc. (See Barro and Sala-I-Martin 1995 for an overview).

In the 19th century, Taiwan did not seem to fulfill the conditions for catch up. Ho (1978) describes Taiwan as a sophisticated but inert and traditional agricultural society before it was handed over to the Japanese following the defeat of Imperial China in 1894. Under Japanese rule, Taiwan was mainly an agricultural appendage to the Japanese economy delivering rice and sugar. However, during this period a social and economic infrastructure was created, along with institutions like research institutes, a banking system and peasant associations. The agricultural sector was modernized as new technologies spread rapidly through an island wide extension system. The education of farmers led to an increase in

the literacy rate from 1% in 1905 to 27% in 1940. Industrialization occured only at a slow pace and was dominated by sugar refining factories. The food industry employed more than 50% of the manufacturing labour force during the period 1920-39. The factory enclave was mainly owned and managed by Japanese and generated a growing disciplined industrial labour force. Together with the established infrastructure, conditions for further industrialisation and catch up seem to be fulfilled at the end of the 1930s.

However, the second Sino-Japanese war, which lasted from 1937 to 1945, followed by a disruptive civil war deranged the process. In 1949, the Chinese Nationalist government fled from the mainland and took refuge in Taiwan. The conditions for kickstarting the economy were extremely favourable for the 'new' government. It had no links with vested interests on the island. The extensive land reform programs carried out during 1949-53 diminished the political power of rural land lords. The government gained wide support by these reforms which created an egalitarian society, which would remain an outstanding characteristic of the Taiwanese growth experience (Fei, Ranis and Kuo, 1979). At the same time, about a million mainlanders took refuge in Taiwan upsetting the social structures of the seven million original inhabitants. But they also compensated for the brain drain of withdrawing Japanese entrepreneurs. Government authority was derived by the continuing threat of the mainland which gave the relatively autocratic governments unusual freedom of action in the sphere of economic policy. The huge amount of aid flow from the US, especially during the 1950s, strongly contributed to the stabilizing and growth enhancing role of subsequent governments. Development policies were focused on industrialization alongside further agricultural development. This balanced growth strategy distinguishes Taiwan from South Korea where policies were much more focused on industrialization.

Industrialization in Taiwan proceeded at great speed. Table 1 shows the share of manufacturing in total GDP and the contribution of manufacturing growth to total GDP growth. The periodisation follows the phases of industrialisation as described in the following section. Manufacturing has clearly been an engine of growth in the Taiwanese economy. It increased its share in GDP from 16% in 1954 to 31% in 1993, and contributed 43% to the growth in total GDP from 1961 to 1993. For more than 30 years, the average annual real output growth of more than 11% was exceptional at world standards.

The main aim of this paper is to investigate whether this rapid growth in output was accompanied by growth in productivity and, from an international perspective, by catch up relative to the world productivity leaders. For 13 manufacturing branches, comparisons will be made of labour productivity, capital intensity and total factor productivity levels in Taiwan vis-à-vis the US. Section 2 will give an overview of the phases of the Taiwanese industrialization process and of the accompanying structural changes. In section 3, the industry-of-origin approach to international comparisons will be described and applied to a Taiwan-US manufacturing comparison for 1986. The labour productivity benchmark results are given in section 4. Section 5 discusses alternative data sources to extend the benchmark over time. In section 6, a new estimate of the capital stock in Taiwanese manufacturing is presented. It is used to analyse changes in relative capital intensity and total factor productivity over time. Section 7 provides a first attempt to explain the differences in TFP levels by taking into account the relatively small size of firms in Taiwan, the rapid structural changes and differences in human

capital between Taiwan and the US. A discussion on the interpretation of TFP growth and levels is given in the final section.

Table 1 *Share and Contribution of Manufacturing in Total GDP*

Year	Share of manu-facturing in total GDP at current prices (%)	Period	Average annual real growth of manufacturing GDP (%)	Contribution of manufacturing growth to total GDP growth (%) (a)
1954	16			
1961	19	1961-64	14.6	29
1964	23	1964-73	18.4	49
1973	37	1973-80	10.4	45
1980	36	1980-86	9.0	44
1986	39	1986-93	4.7	21
1993	31	1961-93	11.6	43

Note: (a) begin of period shares of manufacturing in total current GDP multiplied by real growth rates of manufacturing and divided by total GDP growth during the period.
Sources: DGBAS (Directorate-General of Budget, Accounting and Statistics), Executive Yuan, Republic of China, National Income in Taiwan Area of the Republic of China 1994, Jan. 1995.

2. Phases of Industrialisation[1]

Taiwan's post war industrial development can be divided up into four gradually evolving phases, namely from primary import substitution using domestic raw materials (phase 1), to primary export substitution using unskilled labour and imported materials (phase 2), followed by a more knowledge- and capital intensive secondary import substitution (phase 3), and finally secondary export substitution when deindustrialisation sets in (phase 4). The terms import and export substitution are used in the context of manufacturing. Primary import substitution refers to replacement of labour intensive manufacturing imports with home-produced goods. Primary export substitution refers to the replacement of labour-intensive agricultural products by labour-intensive manufacturing products. This term has been introduced by Ranis (1973). Other authors have called this export promotion or an outward-looking strategy. Secondary substitution refers to a shift from labour-intensive to more knowledge- and capital-intensive manufacturing. This process is also called technological upgrading.

1949-64 Primary import substitution phase

Recovering from war damage, manufacturing output grew rapidly with 20% annually during the period 1949-55. In terms of output and employment shares in total manufacturing, food processing was the most important sector during this period. This was partly caused by a relatively productive agricultural sector which was one of the benefits of the balanced growth strategy pursued by the Taiwanese government. Import substitution was encouraged by a mixture of exchange controls, import licensing, protective tariffs, etc. This policy was most successful in cotton textile manufacturing, but also in production of for example bicycles and flour. Because of the small domestic market, import substitution

possibilities were quickly exhausted in industries with relatively simple technologies. Consequently, during the period 1955-63, industrial output growth slowed down to 11% per year. Import substitution contributed no more than 13% to total manufacturing output growth. The major source of growth was domestic demand (44%) which only grew slowly[2]. After some hesitation the government choose to facilitate the shift from domestic to export markets, instead of promoting the production of more technologically sophisticated goods (secondary import substitution). Between 1958 and 1963 numerous reforms and export stimulation programs were slowly but steadily initiated.

1964-73 Primary export substitution phase

The reforms brought about a tremendous export boom which affected almost all industries. Manufacturing exports, which formerly consisted mainly of processed food, included textiles, wood products, plastics, rubber, leather, electronics and other manufacturing products including toys and athletic goods as well. During the period 1961-71 export expansion accounted for 52% of manufacturing output growth and even for 65% of output growth in textiles and electrical machinery manufacturing. As a consequence manufacturing output grew 18% per year. The fastest growing industries were also the ones which absorbed relatively the biggest amounts of labour using labour-intensive technologies. This indicates that Taiwan developed according to its comparative advantage, and did not indulge in capital intensive heavy industries as attempted by South Korea. In 1966, the first Export Processing Zone (EPZ) was established to facilitate exports and other EPZs soon followed. However, the quantitative impact of the EPZs was by no means overwhelming. In 1970, EPZs provided only 7% of total manufacturing employment, which had declined to 4% in 1980. Even as a share of total exports, EPZs were responsible for less than 9% of total exports during the period 1966-80. However, EPZs made a major contribution to the Taiwanese economy. As almost all firms in the EPZs were foreign owned, they played an important role in providing and diffusing new technologies (Ranis and Schive, 1985). Export-induced demand increased even more in importance during the period 1971-76, accounting for 81% of manufacturing output growth. According to Pack (1992, p.83) "… the relative ease of acquiring and mastering the relevant technology, the combination of low wages and a foreign exchange regime neutral between production for the domestic and foreign markets is probably a sufficient explanation of the early rapid growth in labour-intensive exports".

1973-86 Secondary import substitution phase

In 1973, the Taiwanese economy was severely hit by the oil crisis. Industrial output in 1974 declined, but growth quickly recovered, and a phase of secondary import and export substitution started. Output growth remained high at an annual average of 10%. As the labour surplus reservoir shrank and wages rose, Taiwan began to loose its comparative advantage in labour intensive exports. Instead industrial output moved gradually towards metal and machinery manufacturing in order to provide the domestic market with intermediate goods (secondary import substitution) and to the production of electrical machinery for the export market. More importantly, within industries a process of upgrading to higher

[1] This section draws heavily on the excellent review of Taiwan's industrial development by Ho (1978) and Ranis (1995).
[2] Figures in this section on sources of manufacturing output growth are derived from Kuo and Fei, 1985.

quality products took place.[3] Compared to production of lower quality products, these activities were more capital intensive, required more workers' skills, as well as more advanced technologies. These changes are reflected in the dramatic shifts in the revealed comparative advantage of Taiwanese exports away from canned vegetables, clothing, plywood and cotton fabrics during the early 1970s to pottery, travel goods, toys, synthetic fibres, office and textile machinery during the late 1980s (Riedel, 1992). Investment, which could partly increase through high domestic savings rates, was allocated according to comparative advantage. Government intervention gradually changed from direct intervention towards creating a supportive environment for private enterprise. The share of government enterprises in industrial output declined from 56% in 1952 to 21% in 1970 and only 11% in 1988 (Pack, 1992). Instead government activities focussed on creating a science and technology infrastructure by setting up research institutes, providing higher general and vocational education, and stimulating private R&D through fiscal and financial incentives (Hou and Gee, 1993).

1987- 96 Deindustrialization and secondary export substitution phase

The year 1987 represents an important break in the industrialization process of Taiwan. From this year onwards, the share of manufacturing in total GDP has dropped on average 1% per year from 39% in 1986 to only 28% in 1996. This deindustrialisation process has been accompanied by a non-growing manufacturing labour force. Labour shifted massively out of the textile, wearing apparel, wood and leather branches into basic metal and metal products, non-electrical machinery and transport equipment, and paper products and printing. The shift in exports is even more pronounced. During this period the growth of overall export volume has slowed down considerably to 5% annually, but the export share of machinery increased from 29% in total exports in 1986 to 50% in 1996, at the expense of light manufactures.[4] These changes were reflected in a drain of entrepreneurs in labour intensive light manufacturing activities out of Taiwan towards neighbouring Asian countries with lower wages to continue their enterprises.

These development phases characterizing Taiwan's manufacturing sector are clearly visible in the changing distribution of inputs and output across industries. Table 2 shows the share of manufacturing branches in manufacturing gross value added, labour and capital stock for the period 1961-63 and 1991-93. The major shift from food, beverages and tobacco and textile manufacturing towards electronics and subsequently to metal and machinery is clearly visible. Figure 1 illustrates structural change in another way using similarity indices. The basic idea behind the similarity indices is to construct a vector for each year consisting of the shares of 13 manufacturing branches in, for example, total manufacturing value added. For each year the shares of all branches together are represented by one single vector. The angle between any pair of vectors can be interpreted as a measure of the similarity in structures at two points in time. The similarity index, I^{0t}, which is defined as the cosine of the angle, varies between 0 and 1 and is lower in case of greater dissimilarity. In a formula[5]

[3] See Riedel (1992, p.287*vv*) for some circumstantial evidence of this shift.
[4] Ministry of Finance, Monthly Statistics of Exports and Imports, various issues.
[5] These measures are also used in ICP reports although in a different form, see Kravis, Heston and Summers (1982)

$$I^{0t} = \frac{\sum_i S_i^0 S_i^t}{\sqrt{\sum_i \left(S_i^0\right)^2 \sum_i \left(S_i^t\right)^2}}$$

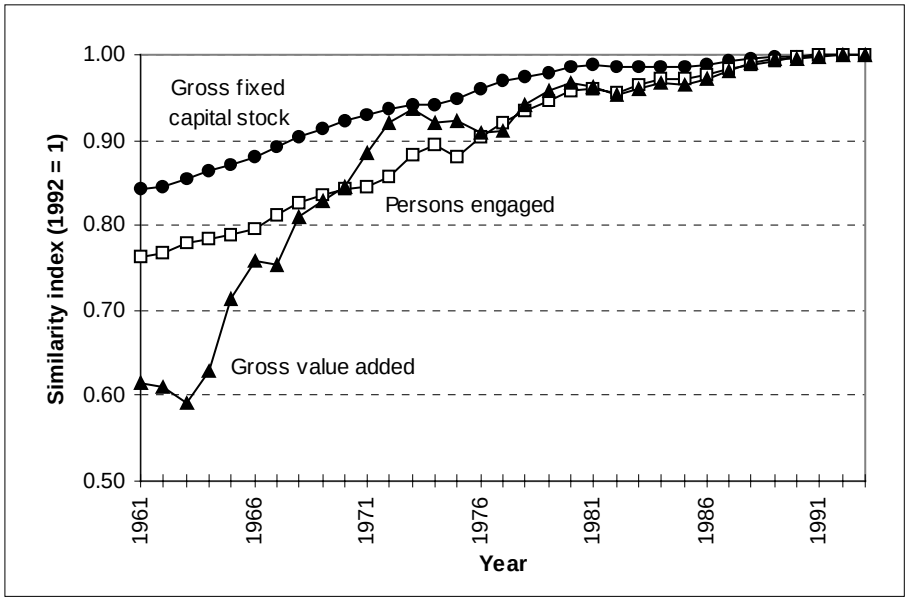
S_i^0 and S_i^t are the branch shares in value added, capital stock or employment in branch i for respectively year 0 and t. The similarity indices are reproduced in Figure 1, taking 1992 as the base year. Shares in gross value added in current prices show the most rapid change, especially during the export substitution phase (1964-1973). The share of food manufacturing declined, while export driven branches expand. The period 1973-77 shows a temporary adverse movement induced by the oil crisis. Since then the shifts towards metals, machinery and transport and electrical machinery has continued. Labour and especially capital stock shares changed less dramatically than before, but in the same direction.

Table 2 *Average Shares of Capital Stock, Employment and Gross Value Added in Manufacturing, Taiwan (%)*

	Gross Fixed Capital Stock (constant 1986 prices)		Persons Engaged		Gross Value Added (current prices)	
	1961-63	1991-93	1961-63	1991-93	1961-63	1991-93
Food, beverages and tobacco	25.1	9.7	16.4	5.6	40.3	9.4
Textile mill products	14.6	11.6	15.7	8.5	10.9	6.9
Wearing apparel	2.1	1.8	5.4	4.0	2.8	3.3
Leather products	1.0	0.8	2.9	2.0	0.2	1.1
Wood products	5.8	2.7	7.6	3.2	4.6	1.6
Paper, printing & publishing	5.9	5.1	6.2	4.9	6.2	3.6
Chemicals products	22.3	29.7	6.2	5.6	13.7	15.6
Rubber and plastic	(a)	(a)	5.9	10.3	1.9	7.5
Non-metallic mineral	7.1	5.7	6.0	4.2	6.9	4.7
Basic & fabricated metal	5.2	16.2	8.6	15.1	4.9	14.0
Machinery & transport equipment	5.0	7.2	10.6	11.8	4.4	12.6
Electrical machinery and equipment	2.5	7.3	4.3	4.3	4.3	4.3
Other manufacturing	3.3	2.1	4.1	6.1	1.2	3.9
Total manufacturing	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Note: (a) included in Chemical products
Sources: *GDP at current market prices* from DGBAS, National Income in Taiwan Area, 1994;
Number of persons engaged from Appendix Table C2. *Gross fixed non-residential capital stock* at 1986 prices excluding land from DGBAS 1994, The Trends in Multifactor Productivity, Taiwan Area, Table 10.

Figure 1 *Similarity Indices for Taiwan Manufacturing*



Source: based on branch shares from appendix tables C1-3. See main text.

3. Unit Value Ratios for Manufacturing

For international comparisons of output, a currency conversion factor is required to express output in a common currency. Exchange rates do not serve this purpose, which has been reaffirmed by the recent currency crises in South and East-Asia. Nevertheless, exchange rates are still used in international comparisons, for instance by Kim and Lau (1994). There are two alternatives to the use of exchange rates: firstly Purchasing Power Parities (PPPs) derived from the expenditure side, and secondly Unit Value Ratios (UVRs) constructed from data on production. PPPs for Taiwan are available from Yotopoulos and Lin (1993), who used the ICP method as described in Kravis, Summers and Heston (1982). In this study UVRs are derived using the industry of origin approach by using production data.

UVRs are conceptually better to convert domestic output as they are calculated as the ex-factory sales value of the products at producer prices divided by the quantity sold (Maddison and van Ark 1988; van Ark 1993). Expenditure PPPs are based on prices of final goods. Hence expenditure PPPs include indirect taxes, transport and trade margins and the prices of imported goods, while excluding the prices of exported goods. In 1986, export sales amounted to 36% of the Taiwanese manufacturing domestic output, while imports accounted for 16% of total demand for manufacturing products.[6] This indicates that the potential bias of the conversion factor is big when using PPPs. Moreover, PPPs only refer to final products so that for deliveries to intermediate demand one needs to utilize the PPPs of close substitutes. In Taiwanese manufacturing, intermediate demand for manufacturing products is 54% of the total demand.[7] These difficulties for currency conversion are totally ignored by Dollar and Wolff (1993) who use GDP PPPs for individual industries. Jorgenson and Kuroda (1990) address only part of

[6] Calculated from DGBAS, 1986 Input-Output Tables, Taiwan Area, ROC, 123 sectors.
[7] *Ibid.*

the problems by 'peeling off' indirect taxes and trade and transport margins for their Japan-US comparison. Hooper and Vrankovich (1995) go somewhat further and make also a rough adjustment for international trade to derive 'proxy' PPPs for a number of OECD countries.

The UVRs, used in this study, match broad ranges of goods while PPPs match a very large number of carefully specified products. As a result, UVRs suffer from problems in correctly measuring quality, especially of technologically advanced products, to a greater extent.[8] But for the same reason, UVRs are more characteristic, especially of developing countries. Expenditure PPPs are based on goods mainly produced in advanced countries, and not in developing countries. Van Ark (1996) suggests that the best way forward in developing industry-PPPs might be to make use of the best elements of each approach, i.e. using UVRs for industries which produce relatively many intermediate goods, produce relatively homogeneous goods and have a relatively high export share, and applying proxy PPPs in industries where product mix and product quality problems are important.
Baily and Gersbach (1995) is a good example of this approach at a detailed industry level. In this study, we restrict ourselves to the use of UVRs because we lack proxy PPPs altogether.

3.1 Industry of Origin Approach

In this paper we derive UVRs by the industry of origin method as used and refined in the International Comparisons of Output and Productivity (ICOP)-project, described in e.g. Maddison and van Ark (1988), van Ark (1993) and Pilat (1994). Following this approach unit value ratios (UVRs) are computed on the basis of Laspeyres and Paasche formulae. On the basis of manufacturing census data, product unit values (uv) are obtained by dividing produced quantity into produced output value. By (bilateral) matching of broadly defined products with similar characteristics between a pair of countries, unit value ratios are derived:

$$UVR_i^{XU} = \frac{uv_i^X}{uv_i^U}$$

with X and U the countries being compared, U being the base country (here the US). UVRs indicate the relative producer price of the matched goods in the two countries. Product UVRs are aggregated according to a stagewise procedure to higher levels i.e. to industry, branch and finally to total manufacturing level. An industry is defined as the lowest level at which economic activities can be compared between countries, which is more or less equivalent to 4-digit industry groups in the International Standard Industrial Classification (ISIC). Branches correspond to 2-digit divisions or a group of 3-digit major industry groups. The computation of industry UVRs is based upon two alternative price indexes: the Laspeyres index, using output weights of the base-country ($UVR^{XU(U)}$) and the Paasche index, using output weights of the other (numéraire) country ($UVR^{XU(X)}$). As not all products in an industry can be matched, it is assumed that the average UVR based on the matched products (1,..., I(M)) is representative for the UVR based on all products in the industry:

[8] See Gersbach and van Ark (1994) dealing with this problem for a limited number of industries using additional industry data.

$$UVR^{XU(U)} = \frac{\sum_{i=1}^{I(M)} UVR_i^{XU} w_i^U}{\sum_{i=1}^{I(M)} w_i^U}$$

at output weights of base country U, and:

$$UVR^{XU(X)} = \frac{\sum_{i=1}^{I(M)} w_i^X}{\sum_{i=1}^{I(M)} \left(w_i^X / UVR_i^{XU} \right)}$$

at output weights of country X. Traditionally branch level UVRs were obtained through a weighted average of the UVRs of industries for which matched products covered more than 25% of the total output value, using the industries' gross value added as weights. The manufacturing sector UVR was derived using branch gross value added (see, for example, van Ark, 1993).

Recently, Timmer (1996) proposed some modifications to the aggregation rules described above. By developing the ICOP industry-of-origin method from a stratified sampling perspective he proposes the following modifications to the original procedure: 1. for aggregation use should be made of output values instead of value added weights and 2. the so-called 25% rule-of-thumb, which determined how industry UVRs were used in the aggregate, should be replaced by a rule based on a statistical test of the reliability of the industry UVR. According to this new rule an industry should have at least two matches, and a coefficient of variation of its average UVR of less than 0.1. If this rule is satisfied, the industry UVR is weighted with its output. If an industry does not apply to this rule, only the matched product value of the industry will be used in the aggregation.

The UVRs for this study are calculated both according to the traditional and the proposed 'new' method. The differences at the total manufacturing level are small, but these can be significant at branch level. In Appendix table B1 a comparison of the traditional and the new UVR method is given. As the new method has a firmer theoretical underpinning, the UVRs according to the new method are used in the remainder of this paper. The geometric average of the Laspeyres and Paasche indices, which is the Fisher index, can be used when a single currency conversion factor is required.

3.2 Unit Value Ratios for 1986 Taiwan/US Comparison

For the product matches, use has been made of the *1987 Census of Manufactures, Industry Series, Bureau of the Census, 1990* for the US, and the *Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, ROC, DGBAS, okt 1988* for Taiwan. Additional data on unit values for Taiwan are obtained from the Mining and Industrial Data Reporting system, which are published in the *Industrial Production Statistics Monthly* (IPSM). In contrast to the census data, the latter unit values are based on a sample of establishments only. We used IPSM data for products for which census data

was not available.[9] The US census gives data for about 11,000 products, but the Taiwanese census for 504 products only. For this reason unit value ratios between the two countries could only be derived for broad product groups like rice, cotton yarns, trousers, steel pipe, color TVs, passenger cars, etc.

The US 1987 unit values were backdated to 1986 using the producer price indices from the Bureau of Labour Statistics.[10] These producer price series are not only available at 4-digit industry level (which are partly published in the US Department of Commerce, *Industrial Outlook 1989*), but for more detailed product groups as well, which are preferably used when product price changes vary around the mean of the industry price change. Taiwanese unit values, which are at market prices, are adjusted to match the US unit values which are at factor cost. For this purpose, we applied industry ratios of output at factor cost to output at market prices derived from the census to the Taiwanese unit values. The UVRs for the 1986 Taiwan-US benchmark comparison are given in Table 3. The Fisher UVR of total manufacturing is lower than the exchange rate. This corresponds with the apparent undervaluation of the controlled exchange rate in 1986. In 1987, the exchange rate appreciated from 38 NT$/US$ to a structurally lower level of 32 NT$/US$. The Fisher UVR for total manufacturing is higher than the PPP for GDP, which is a common finding in ICOP studies of developing countries. The GDP PPP also includes relative prices of services which are generally much lower in developing countries than in developed countries. Use of the exchange rate would lead to an undervaluation of Taiwanese manufacturing output with 28%. Use of the GDP PPP would result in an overvaluation of 23%.

Table 4 gives the details about the matching results. The total number of product matches made is 119, which equals 15% of the US value of output is covered and 26% of the Taiwanese output value. The coefficients of variation in the first columns give an indication of the reliability of the UVRs, as they depend on the degree of price variability and the coverage ratio of the matched products (Timmer, 1996). The table shows that the coefficient of variation for the total manufacturing UVR is 3% for the Laspeyres variant, and 4% for the Paasche variant. Hence the UVRs differ significantly (at 95%) from the exchange rate and the GDP PPP (see Table 3). Branch UVRs are less reliable, especially for other manufacturing and leather products which have coefficients of variation up to 30%. On the other and the UVRs of wearing apparel, machinery and chemicals are relatively reliable according to this indicator.[11]

[9] Anhydrous ammonia, phosphoric acid and carbon black.

[10] Obtained through the Internet on August 8, 1997. Address: http://stats.bls.gov:80/cgi-bin/dsrv?pc.

[11] Another indicator of the sensitivity of the results is to look at the impact of individual product UVRs on the overall manufacturing UVR. Due to the reweighting procedure applied, this impact is determined by the share of the product value in the industry output, the share of the industry in branch output and finally the share of the branch in total manufacturing output. It appears that the 10 products with the highest impact together account for 50% of the impact of all 119 matches for the Laspeyres index, and 38% for the Paasche index. The Laspeyres UVR is heavily dominated by the product match for passenger cars which alone is responsible for 18% of the impact, followed by trucks (6%). Hence these UVRs will have a big impact on the overall results. For example, we matched only Taiwanese 'big passenger car' with the US 'passenger cars' to proxy differences in product mix between cars in both countries. Had we included big *and small* cars in the Taiwanese data (and done the same for trucks) the Fisher UVR in machinery and transport equipment would be reduced by half, and the total manufacturing UVR would go down from 30 NT$/US$ to 27 NT$/US$.

Table 3 *Manufacturing Unit Value Ratios, 1986 Taiwan/US Benchmark.*

	Laspeyres UVR NT$/US$	Paasche UVR NT$/US$	Fisher UVR NT$/US$	Compara-tive Price Level (a)
Food, beverages and tobacco	57	37	46	121
Textile mill products	20	20	20	53
Wearing apparel	14	16	15	40
Leather products	55	47	51	134
Wood products	34	32	33	88
Paper, printing & publishing	18	18	18	49
Chemicals products	31	20	25	66
Rubber and plastic	35	29	32	84
Non-metallic mineral	24	20	22	59
Basic & fabricated metal	35	28	31	82
Machinery & transport equipment	50	32	40	105
Electrical machinery and equipment	21	12	16	43
Other manufacturing	29	28	28	75
Total Manufacturing	40	22	30	78
Exchange rate			38	100
GDP PPP			23	61

Note: (a) Comparative price level is the UVR divided by exchange rate.
Sources: Based on matching procedure described in text. Basic sources are DGBAS, *The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. III* and Bureau of the Census, *US Census of Manufactures, 1987*, Washington DC.
PPP from Yotopoulos and Lin (1993) and exchange rate from DGBAS, National Income in Taiwan, 1994.

Table 4 *Matching Details, 1986 Taiwan/US Benchmark*

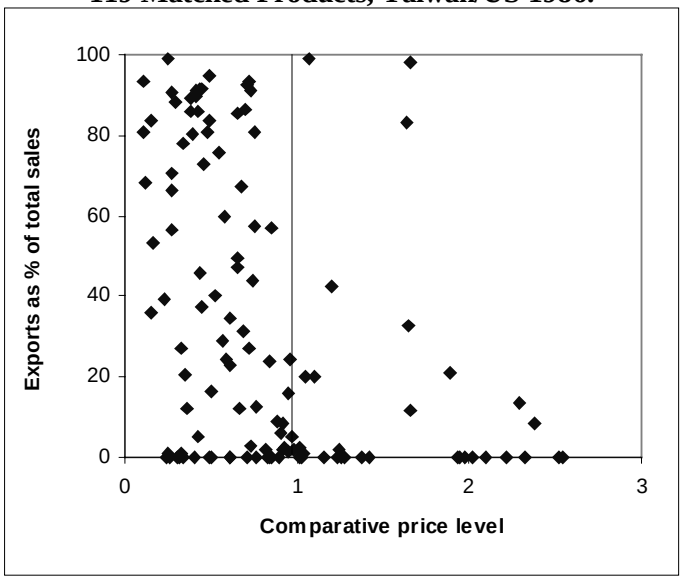
	Coefficient of variation Laspeyres	Coefficient of variation Paasche	Coverage ratio US (%)	Coverage ratio Taiwan (%)	Number of Product Matches
Food, beverages and tobacco	0.07	0.10	18	27	17
Textile mill products	0.11	0.09	44	47	8
Wearing apparel	0.06	0.01	28	95	15
Leather products	0.17	0.20	17	31	3
Wood products	0.05	0.09	12	39	8
Paper, printing & publishing	0.08	0.06	63	79	2
Chemicals products	0.02	0.10	9	6	5
Rubber and plastic	0.10	0.09	5	13	14
Non-metallic mineral	0.08	0.08	10	40	6
Basic & fabricated metal	0.05	0.13	19	23	11
Machinery & transport equipment	0.03	0.09	20	14	4
Electrical machinery and equipment	0.11	0.13	14	28	23
Other manufacturing	0.30	0.23	1	5	3
Total Manufacturing	0.03	0.04	15	26	119

Source: see Table 3.

Another check on the plausibility of the product UVRs is to investigate the relationship between exports and UVRs. Roughly speaking, higher UVRs should lead to lower shares of exports in total output, if the ex factory price is the only determinant of export success which might be a reasonable assumption for trade between a developing and a developed country, but less so for trade between developed countries

which is based more on quality than on price competition.[12] Strictly speaking, products with a UVR higher than the exchange rate should have an export share of zero, while products with a UVR lower than the exchange rate should have a high export share. For Taiwan, the export share of a product in total output is given in the census. Although this covers exports to all countries, and not only to the US, we can use this share as an approximation because the major Taiwanese trade flows are with the US. We divided the 119 UVRs found by the exchange rate to arrive at comparative price levels (CPLs) and plotted these against the export share in total output in figure 2. The data for the Taiwan/US 1986 comparison show the expected pattern: only few products with CPLs above 1 are exported compared to products with CPLs lower than 1. This gives reasonable support to the UVR values found in this study.

Figure 2 Comparative Price Levels and Export Shares for 119 Matched Products, Taiwan/US 1986.



Source: UVRs from matching tables, export shares from DGBAS, Report of Manufacturing Census, Vol. III, 1986.

4. Productivity Benchmark Comparison between Taiwan and the US for 1986

4.1 Comparability of Statistics

For the 1986 benchmark comparison we make use of the manufacturing censuses of both countries. This is necessary to ensure that the output and labour input come from the same source and hence cover the same population of firms, which is a crucial prerequisite for level comparisons. There are a number of inconsistences between the US and the Taiwanese manufacturing censuses. The Taiwanese census covers all establishments which have a fixed location irrespective of their number of employees. The US

[12] Freudenberg and Ünal-Kesenci (1996) compare UVRs and export prices for Germany and France and find that the relationship between the two is strong for most branches.

census includes all establishments with one employee or more. Assuming that the number of manufacturing establishments with no employees in the US is negligible, no adjustment is made.[13]

The biggest possible source of inconsistency is the definition of value added according to the censuses of both countries. In the US census, the concept of value added is broader than the definition applied in the national accounts. The census concept still includes the value of purchased industrial and non-industrial services, including repair and maintenance, advertising, telecommunications and accountancy. Unfortunately, the Taiwanese census value added definition is not clear. From the 1986 Census Vol. III, Table 16, it can be inferred that gross value added is defined as the total value of products minus the sum of total of raw materials consumed, total value of fuel and power consumed, expenses for processing and other expenses. To investigate whether purchases of services are included in the item 'other expenses' we compare the census figures on value added in manufacturing with figures from the Input-Output tables for 1986.

Table 5 shows that intermediate inputs as a percentage of output at factor cost is 74% according to the census, and 75% according to the input-output table. This suggests that the intermediate inputs in the census are comparable to the intermediate inputs in the I/O table, hence they both include industrial and non-industrial services. Consequently, the Taiwanese census concept of value added is different from the US concept. In order to make the two concepts comparable, Taiwanese census figures on intermediate inputs are multiplied by the ratio of service inputs to total intermediate inputs from the I/O table (0.13 for total manufacturing, varying from 0.10 to 0.18 for individual branches) which are then added to original value added in the census. Table 5 also shows that the coverage of the Taiwanese census is incomplete, covering about 89% of value added as given in the input-output table which is close to the figure given in the National Accounts (1,124 bil NT$ at market prices).

Table 5 *Comparison of Input-Output Table and Census Value Added, Taiwan Manufacturing 1986 (mil NT$)*

	Census	Input-Output Table	Census as % of I/O table
Gross Value of Output (market prices)	3,355,520	3,920,569	86
Indirect Taxes	92,051	151,535	61
Gross Value of Output (factor cost)	3,263,469	3,769,034	87
Total Intermediate inputs	2,409,715	2,808,083	86
of which services		376,937	
Value Added NA concept (factor cost)	853,754	960,951	89
Intermediate inputs as % of output (factor cost)	73.8	74.5	

Sources: DGBAS, *1986 Industrial and Commercial Census of Taiwan, Vol III Manufacturing*; and *1986 Input-Output Table*, table 7.

A third problem in comparing the two censuses concerns the concept of employment. In the US *Census Industry Series* only the number of employees in manufacturing establishments are given. In the Taiwan

[13] Self employed workers make up 2.0% of the manufacturing labour force in 1986 (US Dep. of Commerce, NIPA, 1959-1988).

census on the other hand self-employed persons are also included, as well as employment of head offices and auxiliary units. Hence the US employment figures have been scaled up. Firstly, we applied the 1987 ratio of the number of persons working in auxiliary units to persons employed in manufacturing establishments as given in the 1987 *Census, General Summary*, assuming this ratio is the same for 1986. Secondly, we used the 1986 ratio of self-employed to persons employed from the BEA, *National Income and Product Accounts, 1959-1988, vol. II.*

The final inconsistency relates to the differences in the industrial classification schemes of the two countries. To make them comparable the following reclassification of US industries has been made. Metal furniture was moved from the wood products to the metal products branch; houseslippers from leather products to plastic products, and computers from machinery to electrical machinery. The resulting comparable basic data on value of output, value added and employment are given in Table 6. This table also shows the annual hours worked per person employed.

4.2 Benchmark Results

Table 7 shows gross value added, employment and labour productivity in Taiwan as a percentage of that in the US for the 1986 benchmark using the UVRs from Table 3. In 1986, the branches producing textile, leather and rubber and plastic products in Taiwan are big compared to the US both in terms of value added and employment. This related to the export-induced specialization in these branches. On the other hand, the food products, paper, and machinery and transport equipment branches are small. Gross value added (GVA) per person engaged in Taiwanese manufacturing is 26 percent of the US level, with above average performance for the textile products and wearing apparel branches, and below average performance in food products, wood products, machinery, and "other manufacturing" products. GVA per hour is much lower than GVA per person employed as working hours in Taiwan are much longer than in the US in all branches (see Table 6). Aggregate GVA per hour in Taiwan is only 20% of the US level.

Table 6 *Basic Manufacturing Data, Taiwan and US 1986*

	US	US	US	US	US	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan
	Gross Value of Output at factor cost mil US$	Gross Value Added (US census concept) at factor cost (c) mil US$	Persons Engaged (d) '000	Annual Hours Worked per Employee	Gross Fixed Capital Stock mil US$	Gross Value of Output at factor cost mil NT$	Gross Value Added (US census concept) at factor cost (c) mil NT$	Persons Engaged (d) '000	Annual Hours Worked per Employee	Gross Fixed Capital Stock mil NT$
Food products	262,936	91,239	1,358	1,908	160,173	233,575	68,954	139	2,437	205,618
Beverages	45,587	20,952	189	(a)	(a)	21,652	7,953	10	(a)	(a)
Tobacco	6,341	12,725	65	(a)	(a)	25,694	7,009	14	(a)	(a)
Textile mill products	33,013	22,232	676	2,013	48,093	327,252	116,965	291	2,569	279,723
Wearing apparel	57,919	28,451	1,072	1,782	17,437	99,726	36,947	149	2,544	46,335
Leather products	7,600	3,508	133	1,779	3,961	65,025	20,116	72	2,544	16,939
Wood products	79,980	34,746	1,178	1,966	63,077	102,046	39,516	130	2,602	57,179
Paper, printing & publishing	216,424	122,075	2,178	1,866	200,406	127,760	52,516	112	2,557	89,638
Chemicals products	321,969	117,509	1,181	1,945	378,092	462,716	195,372	144	2,424	481,262
Rubber and plastic	73,593	37,340	776	1,984	(b)	331,787	114,662	356	2,592	(b)
Non-metallic mineral	57,274	30,677	558	2,034	64,384	98,849	44,421	108	2,472	115,481
Basic & fabricated metal	254,883	112,865	2,198	1,965	245,175	416,740	148,163	327	2,536	300,227
Machinery & transport equipment	463,159	202,783	3,987	1,949	313,678	283,731	99,477	244	2,469	140,680
Electrical machinery and equipment	249,110	139,771	1,890	1,917	134,476	526,595	171,578	465	2,425	120,271
Other manufacturing	93,796	57,690	1,009	1,922	53,988	150,955	58,676	197	2,432	38,173
Total Manufacturing	2,223,583	1,034,562	18,451	1,930	1,682,941	3,274,102	1,182,325	2,760	2,508	1,891,526

Notes: (a) Food products includes beverages and tobacco for hours worked and capital stock
(b) Chemicals include rubber and plastics for capital stock
(c) US census concept of value added does not exclude services input.
(d) Persons engaged includes selfemployed and employment at head and auxiliary offices.
Sources: GVO, GVA and employment from DGBAS, *The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. III* and Bureau of the Census, *US Census of Manufactures, 1987*, Washington DC; US hours worked and capital stock from data underlying van Ark and Pilat (1993). Taiwan hours from DGBAS, *Monthly Bulletin of Earnings and Productivity Statistics*, Feb. 1995. Taiwan capital stock from appendix Table C3.

Table 7 *Labour Productivity in Manufacturing, Taiwan as % of US, 1986*

	Gross value added census concept (GVA)			Persons engaged	Hours worked	GVA per person	GVA per hour
	at Taiwan prices (1)	at US prices (2)	Geometric average (3)	(4)	(5)	(3)/(4) = (6)	(3)/(5) = (7)
Food products	1.1	1.5	1.3	10.3	13.0	12.4	11.3
Beverages	1.6	1.6	1.6	5.5	(a)	29.8	(a)
Tobacco	3.6	3.6	3.6	22.0	(a)	16.2	(a)
Textile mill products	25.9	26.1	26.0	43.1	55.0	60.4	47.3
Wearing apparel	9.1	8.2	8.6	13.9	19.8	62.0	43.5
Leather products	31.0	31.1	31.1	53.7	76.8	57.8	40.4
Wood products	2.1	2.4	2.2	11.1	14.6	20.2	15.3
Paper, printing & publishing	1.3	1.3	1.3	5.1	7.0	25.1	18.4
Chemicals products	4.8	5.7	5.2	12.2	15.2	42.7	34.2
Rubber and plastic	10.0	15.1	12.3	45.9	59.9	26.8	20.5
Non-metallic mineral	6.0	7.1	6.5	19.4	23.6	33.6	27.7
Basic & fabricated metal	3.8	4.8	4.2	14.9	19.2	28.5	22.1
Machinery & transport equipment	1.0	1.5	1.2	6.1	7.8	20.1	15.9
Electrical machinery and equipment	5.7	10.1	7.6	24.6	31.2	30.9	24.4
Other manufacturing	3.6	3.6	3.6	19.5	24.7	18.4	14.6
Total Manufacturing	2.8	5.2	3.9	15.0	19.4	25.7	19.8

Sources: Tables 3 and 6.

5. Labour Productivity Comparison 1961-1993

To arrive at comparable productivity levels through time, national time series are applied to the 1986 benchmark comparison. This section describes the choice of the data sources used to extrapolate the 1986 labour productivity benchmark. For the US we used time series on value added and employment as given in the National Income and Product Accounts (NIPA).[14] For Taiwan, two alternative series on value added and employment are available.

- Real output

There are two basic ways to construct an index of real output: by deflating nominal value added by an appropriate price index, or by aggregating quantity indices of goods produced into an index of industrial production (IIP). A comparison between the two methods in theory and practice is given in appendix A. For Taiwan differences are found to be considerable.

National accounts (NA) data is based on a host of data sources, including the IIP. Hence it is the preferred source for real value added series. Although constant price series in the NA are constructed at the aggregate manufacturing level for the period from 1961 onwards, detailed industry series are only available from 1981 onwards. For the period 1961-1980 we took the constant price series for aggregate manufacturing from the NA and distributed it over branches.[15] This distribution

[14] See Appendix tables C5 and C6.

[15] See Appendix Table C1 for the resulting time series. To conform the SICC to the ICOP classification, GVA in furniture and fixtures for the period 1981-1994 has been split into metallic and non-metallic furniture using the IIP (Dept. of Statistics MOEA print out, March 1995). To estimate real production of plastics for the period the 1971-1980, the IIP is applied to the 1981 value. 1961 and 1966 are calculated using the real value added of Rubber 1961 and 1966, and applying value added proportions taken from SY 1993, Table 132. Estimates for in between years were obtained by exponential interpolation.

was calculated by deflating current price branch value added series from the NA with branch specific wholesale price indices.[16]

- Labour input

In Taiwan, two labour surveys are held: the Labour force survey (LFS) and the Employee's earnings survey (EES). The LFS is a household survey which has been held since 1963. The EES covers private and public firms and is held since 1972 by DGBAS. It is published in DGBAS, *Monthly Bulletin of Earnings and Productivity Statistics*. We prefer to use the EES as household surveys are much more prone to shifts in reporting of employment between manufacturing and other sectors than establishment surveys. The EES does not include employers, own account workers and family workers. We derived ratios of workers other than employees to employees from the 1976, 1986 and 1991 manufacturing censuses[17] and applied these to the EES number of employees for the period 1974-1993. For the period 1961-1973, the LFS is used to derive growth rates for persons engaged by branch.[18] These growth rates are applied to the 1974 figures from the EES.[19] Hours worked are also available from the EES for the period 1974-1994.[20]

Using these series on real value added and labour input, the 1986 benchmark results are extrapolated over the period 1961 to 1993. The results are given in Table 8.[21] It follows that Taiwan has achieved rapid catch up in all its manufacturing branches during 1961-1986. But in the most recent period, labour productivity is actually declining in a number of branches (wearing appparel, leather, paper and other manufacturing). In 1993, total manufacturing stood at 31% of the US, with textiles having the highest level (69%) and food, paper and other manufacturing the lowest (below 20%).

6. Total Factor Productivity Comparison, 1961-1993

The rapid rise in labour productivity is caused either by an increase in capital per worker or a rise in total factor productivity (TFP). To study the contribution of these two sources to the catch up process of Taiwan relative to the US, estimates of relative capital intensity and TFP are constructed in this section.

[16] Price indices from a print out provided by DGBAS (Third Bureau, March 1995) which is partly published in DGBAS, *Commodity Price Statistics Monthly*. This price index is a weighted average of the domestic wholesale price index, the import price index and the export price index. It would be preferable to exclude the import price index from the series, and to adjust the output price index for changes in input prices as it is used to deflate value added and not gross output. Unfortunately, one is constrained by the available data.

[17] Ratios for other years have been intrapolated.

[18] All taken from DGBAS, printout, 14 December 1995.

[19] The industry furniture and fixtures has been split in metallic and non-metallic furniture using the Yearbook of Earnings and Productivity Statistics 1993 for 1983-1993. 1974-82 is based on the ratio of employees in these industries found in the 1976 manufacturing census.

[20] See appendix table C2 for the resulting series.

[21] Note that these results differ from those shown in Timmer and Szirmai (1997). Their estimate was based on a 1976 benchmark.

6.1 Capital Intensity

Capital input is very hard to measure and different estimates coexist. For the US, we use investment data underlying manufacturing capital stock estimates by van Ark and Pilat (1993) and van Ark (1998). The gross fixed capital stock estimates is based on the perpetual inventory method (PIM), according to which annual investments are cumulated with assumptions on scrapping (in this case, rectangular scrapping) and service lives of the assets (in this case, 45 years for buildings and 17 years for equipment).

Table 8 *Labour Productivity in Manufacturing, Taiwan as % of US, 1961-1993*

	GVA per person (US = 100)				GVA per hour (US = 100)		
	1961	1975	1986	1993	1975	1986	1993
Food , beverages and tobacco	6.7	8.6	12.4	18.9	6.1	11.3	15.7
Textile mill products	21.8	36.3	60.4	69.3	25.9	47.3	54.3
Wearing apparel	11.3	34.4	62.0	53.7	23.5	43.5	39.4
Leather products	2.7	36.4	57.8	31.2	25.0	40.4	22.8
Wood products	11.3	15.3	20.2	30.4	10.1	15.3	24.6
Paper, printing & publishing	10.0	17.6	25.1	19.3	11.4	18.4	14.7
Chemicals products	25.5	50.9	42.7	57.1	37.0	34.2	46.6
Rubber and plastic	3.2	17.7	26.8	34.0	12.6	20.5	27.3
Non-metallic mineral	18.2	23.4	33.6	58.8	17.9	27.7	47.0
Basic & fabricated metal	6.4	16.2	28.5	34.3	11.4	22.1	27.5
Machinery & transport equipment	2.9	18.0	20.1	20.9	13.0	15.9	17.4
Electrical machinery and equipment	6.6	21.4	30.9	36.2	15.8	24.4	29.5
Other manufacturing	2.2	13.0	18.4	15.1	9.4	14.6	12.4
Total manufacturing	11.2	19.3	25.7	31.3	13.7	19.8	25.1

Source: Appendix table D1. For hours worked, see sources Table 6.

For Taiwanese manufacturing one can use series of gross fixed capital stock as published in DGBAS, *The Trends in Multifactor Productivity (TMP), Taiwan Area, Republic of China* (June 1994). This capital stock is estimated with the benchmark extrapolation method and land is excluded. Comparison with the 1991 census data suggests the census is used as a benchmark. DGBAS, *The Report on 1991 Industrial and Commercial Census Taiwan-Fukien Area,* Vol III (Table 10) gives the total gross value of fixed assets in use in 1991, excluding land, as 3,544 bil. NT$ which is almost identical to the 3,537 bil. NT$ given in the TMP[22].

An alternative is to use the investment series in the national accounts in a PIM calculation. The capital stock thus deduced is considerably smaller than obtained above on the basis of the census figures. Assuming an average lifetime of 25 years, the 1991 gross stock of fixed capital is 3,236 bil NT$.[23] During the period 1961-1992, average annual growth is 14.3% according to the NA, compared to only 9.0% according to the TMP. These inconsistencies in results using different sources warrant further investigation. For now, we prefer to use our PIM estimate as it is based on a standard method and on data collected within the national accounts framework. The NA gives only total investment for

[22] TMP gives series at 1986 constant prices. The implicit investment deflator from the national accounts has been used to convert to 1991 prices.

[23] Even assuming an implausible lifetime of 40 years the stock remains smaller (3,343 bil NT$).

individual sectors, such as manufacturing. Hence stocks of different asset types cannot be estimated. As long as the composition of the investment does not change, this will not bias the growth rate of the stock. The results of Young (1995, Table 6.1) who distinguished 5 types of assets shows that this is the case. We use the PIM method and assume a rectangular retirement pattern, that is, assets are scrapped at once at the end of their assumed lifetime. Other more sophisticated mortality functions have been experimented with but the results do not differ much. Much more important are the assumptions about service lives. Here lifetimes are the same as used by van Ark and Pilat (1993, p.42) who based themselves on averages for a number of OECD countries: 45 years for investment in nonresidential structures and 17 years to investment in equipment and vehicles. The service life for the total stock is calculated as a weighted average: 25 years.[24]

To initialize the stock estimate for the benchmark year we follow Young (1995, p.9) who assumes that the growth rate of investment in the first five years is representative of the growth rate of investment prior to the beginning of the series. An alternative is to initialize the stock assuming that the incremental capital output ratio of the period 1951-1953 (about 1) is equal to the capital output ratio in 1951. The results are nearly identical as the capital stock grew rapidly in the early fifties. Note that the benchmark estimate has no influence after 1976. For the distribution of the manufacturing capital stock over the thirteen industries, the shares as given in the TMP are used. Appendix table C3 shows the final results of these calculations.

To express the US and Taiwanese capital stock estimates in the same currency, purchasing power parities are required. Investment PPPs can be obtained from the Penn World Tables (Mark 5.5), but only a conversion factor for total capital formation is given, and not for buildings and equipment seperately. Taiwan does not participate in ICP, hence the quality of the results in PWT 5.5 is graded low (Summers and Heston 1991). We use the direct estimates provided by Yotopoulos and Lin (1993) for 1985 and update these to 1986 using Taiwan and US price indices for capital formation. The resulting PPP of 27 NT$ per US$ is used for all branches. Table 9 gives the gross fixed capital stock in Taiwan manufacturing as a percentage of the US, as well as the capital intensity.

In 1986, capital intensity in Taiwan is 28% of the US level when using persons engaged as the denominator and 22% when hours are used in the denominator. In Table 10 the benchmark comparison is extended through time. From 1961 to 1975 production in all branches has become increasingly more capital intensive, indicating a shift towards modern production methods as new investment embodied new technologies. However, in the period of secondary import substitution, some branches shifted towards less capital intensive production (wearing apparel, leather and electrical machinery) relative to the US. In the most recent period, stagnating labour input and a continuing stream of investments resulted in a new across-the-board wave of capital intensifying. In 1993, capital stock per person in Taiwan was about 47% of the US. This implies that opportunities for further intensification are still abundant. Incidentally, capital intensity in Taiwan in 1993 is about equal to the intensity in US manufacturing in 1961.

[24] The weights are taken from the shares in the total stock taken from the 1991 census, vol. III, Table 10: 31% for structures and 69% for equipment respectively.

Table 9 *Capital Intensity and Total Factor Productivity, Taiwan as % of US, 1986*

	Gross Fixed Capital Stock (GFCS)	GFCS per Person Engaged	GFCS per Hour Worked	Total Factor Productivity Persons Engaged based	Total Factor Productivity Hours Worked based
Food products, beverages and tobacco	4.8	47.4	37.1	20.0	17.4
Textile mill products	21.9	50.7	39.7	75.7	64.4
Wearing apparel	10.0	71.9	50.4	67.0	51.0
Leather products	16.1	29.9	20.9	81.3	62.9
Wood products	3.4	30.8	23.3	29.6	24.5
Paper, printing & publishing	1.7	32.7	23.8	39.4	32.7
Chemicals, rubber and plastic	4.8	18.7	14.4	60.5	53.0
Non-metallic mineral	6.7	34.7	28.6	51.2	45.5
Basic & fabricated metal	4.6	30.9	24.0	44.9	38.4
Machinery & transport equipment	1.7	27.5	21.7	28.5	24.0
Electrical machinery and equipment	3.4	13.6	10.8	56.8	48.2
Other manufacturing	2.7	13.6	10.7	35.3	30.1
Total manufacturing	4.2	28.2	21.7	40.0	34.3

Source: Tables 3 and 6. Relative TFP with Cobb-Douglas production function using average labour shares in gross value added from appendix tables C4 and C8 as weight.

Table 10 *Capital Intensity and Total Factor Productivity, Taiwan as % of US, 1961-1993*

	Capital Stock per Person (US = 100)				Total Factor Productivity (US = 100)			
	1961	1975	1986	1993	1961	1975	1986	1993
Food , beverages and tobacco	8.0	26.1	47.4	68.3	25.4	16.5	20.0	21.3
Textile mill products	6.7	29.4	50.7	113.0	76.2	62.2	75.7	62.8
Wearing apparel	21.4	88.2	71.9	156.5	26.3	37.0	67.0	51.2
Leather products	9.2	34.4	29.9	61.3	7.2	53.3	81.3	36.0
Wood products	8.3	26.2	30.8	86.3	33.3	24.8	29.6	34.6
Paper, printing & publishing	5.9	25.0	32.7	44.2	41.6	32.5	39.4	25.3
Chemicals, rubber and plastic	5.6	16.1	18.7	49.7	106.1	80.6	60.5	58.4
Non-metallic mineral	5.6	18.1	34.7	61.1	91.4	53.7	51.2	66.4
Basic & fabricated metal	3.7	18.9	30.9	44.9	39.3	37.2	44.9	44.1
Machinery & transport equip.	3.8	20.2	27.5	29.7	7.6	29.8	28.5	28.2
Electrical machinery and equip.	8.7	19.3	13.6	17.5	24.2	38.9	56.8	56.6
Other manufacturing	11.5	17.7	13.6	25.6	4.7	23.4	35.3	24.2
Total Manufacturing	7.0	22.4	28.2	47.4	41.0	36.8	40.0	38.4

Source: Table 9 and appendix tables C1-8.

6.2 Total Factor Productivity

For 1986, we made a TFP level comparison between Taiwan and the US. For this we used the Cobb-Douglas function, using the average labour share of Taiwan and the US as weight. In effect, we assumed that both countries have the same production function and are allocative-efficient, so that we measure only the extent to which Taiwan is technically inefficient compared to the US.

$$\ln \frac{TFP^X}{TFP^U} = \ln \frac{Y^X / L^X}{Y^U / L^U} - (1-\alpha_{UX}) \ln \frac{K^X / L^X}{K^U / L^U}$$

with α_{UX} as the unweighted average labour share of Taiwan and the US including wages and salaries paid, and an imputation for earnings of self-employed. The TFP results for the benchmark year 1986 are given in Table 9. In 1986, TFP using persons engaged as the labour input is 40% of the US level, and 34% on a per hour-basis.

The benchmark is extrapolated through time using national series on TFP. Following Jorgenson *et al.* (1987) we construct Törnqvist TFP indices for each country using

$$\ln TFP_t - \ln TFP_{t-1} = (\ln Y_t - \ln Y_{t-1}) - \overline{\alpha}_t (\ln L_t - \ln L_{t-1}) - (1-\overline{\alpha}_t)(\ln K_t - \ln K_{t-1})$$

where $\overline{\alpha}_t = \frac{1}{2}(\alpha_t + \alpha_{t-1})$ and α_t the labour share in year t. Note that we implicitly assume constant returns to scale, profit maximization and perfect competition. No attempt has been made to take into account increases in the quality of the inputs, so that these effects are included in TFP change.

The TFP growth rate for Taiwanese manufacturing is 2.1% annually during 1962-1993. This result is close to that found by Young for manufacturing. Young used the same methodology as we did, but adjusted labour and capital for quality. However, the quality adjustment was only minor, adding only 0.5% growth to the 8.8% growth of inputs during 1966-1990 (Young, 1995, Table 6-1). Hence Young's TFP growth rate of 1.5% for this period is consistent with our finding. Okuda (1994) uses the TFP indices published by DGBAS (1994). For the period 1979-1992, he finds a TFP growth rate of 2.6% using a translog production function with unadjusted capital and labour input. Chen and Tang (1990) use a dual translog function including material inputs for the period 1968-1982. Their capital stock is net of depreciation and builds upon the book value of capital in 1967, which can be considered a weak estimate. Liang (1991) is the most elaborate analysis using translog indices with 5 classes of capital, 4 types of labour and 5 intermediate inputs and energy inputs. His findings for value added-based TFP growth are rather high, which is due to the unusual low growth of the capital stock which is based on book values. Liang shows that the TFP growth rates are distorted when excluding material inputs from the analysis, though the direction of the bias is not clear. In the period 1961-1973, TFP growth based on gross value of output is only one-sixth of TFP growth based on value added. However, after the oil crisis (1973-1981), gross output-based TFP growth is twice as high as value added-based TFP growth.

Table 10 shows the results of the TFP benchmark year extrapolation. It shows clearly that TFP levels in Taiwan relative to the US have been more or less stagnant from 1961 onwards and hence that Taiwanese TFP growth in manufacturing has not been higher than TFP growth of the technological world leader, the US.[25] The level at which the comparative TFP stagnates relative to the US is around

[25] Note that these results differ drastically from those shown in Timmer and Szirmai (1997). Their estimate was based on a 1976 benchmark, and more importantly, they used the capital stock estimates as given in DGBAS, *The Trends in Multifactor Productivity (TMP), Taiwan Area, Republic of China*, June 1994.

40%, which is somewhat higher than the about 30% found for the whole economy by Kim and Lau (1994). These figures make it hard to maintain that "Taiwanese firms are already close to the best practice frontier in existing industries" (Pack, 1992), unless the level of aggregation in this study is too high, and Taiwan is still engaged in lower productivity activities within each branch. Our results confirm the finding of Young (1995) as popularized by Krugman (1994) that growth in Taiwan has been mainly fueled by rapid increases of inputs. However, our estimates also show that one cannot argue therefore that growth must soon come to a halt. Capital intensity in manufacturing is still below 50% the US level, and it is especially low in the heavy-industry branches which rapidly increased their export share in recent years. Hence, opportunities for input driven growth are still abundantly available.

There is a clear tendency towards convergence of branch TFP levels. Branches with relative high TFP levels in 1961 like textiles, chemicals and non-metallic minerals had strong declining trends, while industries with very low relative TFP levels in 1961 like other manufacturing, non-electrical machinery and leather have shown marked catch up with US levels. This indicates that there are also advantages of backwardness at the branch level.

7. Explanations of the TFP Gap

Many scholars have tried to explain differences in TFP growth rates across countries or across industries. For Taiwan, these studies have mainly focused on the impact of differences in output, trade and FDI growth on TFP performance. Chen and Tang (1990) find evidence for Verdoorn's law which claims that output growth is positively related to TFP growth. Chuang (1996) goes one step further and finds strong external effects in Taiwan's two-digit industries which explain the major part of the increasing returns at the aggregate manufacturing level. About half to three-quarters of these external economies are attributed to economy-wide trade-induced learning by doing effects, especially trade in machinery with OECD countries. Okuda (1994) finds a strong negative correlation between TFP growth on the one hand and import penetration and capital intensity on the other, while a small positive effect was found for FDI. The separate effect of the export ratio was not clear. However, a large part of output growth remained unexplained in Okuda's study. Pack (1992) shows a back of the envelope calculation, which suggests that as much as 30% of aggregate TFP growth can be attributed to embodiment of more productive technologies in newly imported equipment, which is an indication of the significance of embodied technology spillovers. Here, we will take a somewhat different angle and try to explain differences in TFP *levels* between Taiwan and the US. We will study three characteristics of Taiwanese industrialization: rapid structural change, the relative small size of its establishments, and the rapid increase in the level of human capital.

7.1 TFP and Structural Change

Section 2 showed that huge changes have taken place in both the input and output distribution of Taiwanese manufacturing. Therefore, in addition to TFP growth within branches, aggregate TFP growth can also increase because of a shift of factor inputs from less productive branches to more

productive branches. When a country liberalizes its international trade, the induced shift of factor inputs according to comparative advantage is assumed to have this positive static effect.[26]

To test this hypothesis for Taiwan, the following decomposition is used. Following Syrquin (1984) the Total Reallocation Effect (TRE) is specified as the difference between aggregate TFP growth and sectoral TFP growth weighted with sectoral shares in aggregate value added, which can be written as:

$$TRE = \frac{1}{Y}\sum_i \dot{L}_i (f_{L_i} - f_L) + \frac{1}{Y}\sum_i \dot{K}_i (f_{K_i} - f_K)$$

with f indicating marginal productivity. The first left hand term indicates the change in TFP generated by labour shifts, the second term by capital shifts. Table 11 gives the results of this decomposition. Note that for this analysis the use of value added figures *at factor cost* is mandatory. [27]

Table 11 shows that indeed there has been a positive static effect from the shifts in factor inputs. Note that these shifts are shifts in factor *shares*. They do not necessarily entail shifts in physical terms within manufacturing when resources are added to manufacturing from outside. The strongest effect is in the early period when Taiwan is embarking on the export driven growth path. During the period 1961-75, relative factor shifts between branches add 0.3 %-point to the average annual aggregate TFP growth of 1.4%. This shift effect is mainly due to a relative shift of capital out of food products towards more productive use in the chemicals and electrical machinery branch. From 1975 to 1986, the effect is less important, adding only an additional 0.1 %-point by primarily shifting inputs from textiles to the metal branch. In the most recent period, labour is shifted out of textiles, wearing apparel and chemicals to metal, machinery and electrical machinery, but the overall effect is slightly negative. But the shift of capital from textiles to mainly chemicals where its marginal productivity is higher creates an additional 0.2 %-point TFP growth. The results indicate that the enormous relative factor shifts which have taken place in Taiwan contribute only little to aggregate TFP growth, but that TFP growth within the individual branches, and not structural change *per se*, has been decisive in growth of TFP in Taiwan, which was at approximately the same rate as the US.

Branch level TFP growth depends in part on reallocations of resources across individual producers. Using micro-level data, Aw, Chen and Roberts (1997) find that resource allocation accounts for more than a third of TFP growth in 9 manufacturing branches during 1981-1991. Most of it involved reallocations through firm turnovers. The remaining two-thirds are due to within-firm productivity growth. "In most industries, the productivity improvements are widespread across the whole distribution of firms, suggesting that it may be less related to individual firm action than it is to common improvements in worker quality and infrastructure." (Aw *et al.*1997)

[26] This is true if comparative advantage depends exclusively on productivity. A country does not necessarily have a comparative advantage in its high productivity industries, when cost levels are relatively high.

[27] Indirect taxes in especially food, beverages and tobacco are much higher than in other branches. This will result in a TFP level in this branch which is much too high in comparison to other branches and subsequent underestimation of the shift effect. Aggregate TFP growth is affected by this choice as well. For 1961-1993, average annual TFP growth is about 0.5% lower at market prices than at factor costs.

Table 11 *Effect on Average Annual TFP Growth in Manufacturing of Factor Input Shifts, Taiwan, 1961-1993 (in percentage)*

	1961-75	1976-85	1986-93	1961-93
Factor shift effect of branch				
Food, beverages and tobacco	-0.54	-0.15	-0.04	-0.29
Textile mill products	0.14	-0.36	-0.37	-0.14
Wearing apparel	0.11	-0.07	-0.28	-0.04
Leather products	-0.03	0.09	-0.03	0.00
Wood products	-0.10	-0.07	-0.12	-0.10
Paper, printing & publishing	-0.19	-0.03	0.10	-0.07
Chemicals, rubber and plastic	0.55	0.01	0.11	0.27
Non-metallic mineral	-0.07	-0.01	-0.01	-0.04
Basic & fabricated metal	0.09	0.53	0.29	0.28
Machinery & transport equip.	0.00	0.01	0.27	0.07
Electrical machinery and equip.	0.34	0.08	0.31	0.25
Other manufacturing	0.00	0.07	-0.07	0.01
Total factor shift effect, of which	0.29	0.11	0.17	0.21
labour shift effect	-0.02	0.12	-0.06	0.01
capital shift effect	0.31	-0.01	0.23	0.19
Total TFPG excluding shift effect	1.40	2.70	2.20	2.01
Total TFPG including shift effect	1.70	2.81	2.37	2.21

Sources: Appendix Tables C1-4, value added is adjusted to factor costs by ratio of factor costs to market prices from DGBAS, Report of Census, 1986.

7.2 TFP and the Size of Firms

The small and medium scale industrial sector is often called the backbone of Taiwan's success, not only in enhancing growth but also equity. This is an inheritance of the past as during colonialization Japanese were in power of large-scale industry, and after independence the Taiwanese government followed an active dispersion policy of industrial activities (Ranis, 1995). Also, there is a traditional inclination of Taiwanese to be a small boss rather than an esteemed employee, resulting in a large number of small family enterprises, combined in a well developed network of subcontracting. The evolution of the average size of manufacturing establishments in Taiwan during 1961-1991 is given in Table 12. It shows an inverted U-shape, with average size first increasing from 9 employees in 1961 to 27 employees in 1976. In this period the basis for the modern industrial sector was laid. However, average size decreased again to 19 employees in 1993. This shows that benefits of economies of scale have not been reaped in the last two decades.

Table 12 *Number of Manufacturing Enterprises and Average Employment Size, Taiwan, 1961-1991*

Year	Number of Enterprises year-end	Persons Engaged per Enterprise
1961	51,567	9
1966	27,709	21
1971	42,636	28
1976	69,554	27
1981	91,564	24
1986	113,805	24
1991	140,572	19

Sources: 1961, 1966 and 1971 calculated from Ho (1978), Table A57; *1976 and 1981* from DGBAS, The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. I, p.71, Table 3-1; *1986* from *ibid.*,Table 19; *1991* from DGBAS, The Report on 1991 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. I, Table 19.

From an international perspective, average Taiwanese firm size is particularly low. Table 13 compares for 6 major branches the median establisment size in 1986 or 1987 for four countries: Japan, South Korea, Taiwan and the US. The median size takes into account the distribution of firm sizes and is defined as the size for which 50% of the total employment is in establishments of a size lower than the median, and 50% in establishments of a size higher than the median size. It shows that the Taiwanese size structure looks much more like that of Japan than that of the US, or South Korea where huge conglomerates have emerged in the process of industrialization. This is not true, however, for the food and textiles branches in which median size in Taiwan is higher than Korea.

Table 13 *Comparison of Median Employment Size of Manufacturing Establishments*

Branch	Taiwan 1986	South Korea 1987	Japan 1987	US 1987
Food, beverages, tobacco	170	92	52	274
Textiles, apparel, leather	167	123	26	233
Chemicals, allied products	121	310	107	240
Basic, fabricated metal	30	146	48	208
Machinery, equipment	196	443	195	633
Other manufacturing	59	80	28	198
Total manufacturing				
Median size	95	166	77	263
Average size	24	18	16	49

Sources: Taiwan calculated from DGBAS, The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, vol. I, Table 45, using average persons engaged per establishment per size class from 1991 Census as weight; *South Korea* from data underlying Pilat (1995); *Japan and US* from van Ark and Pilat (1993), Table 13 with correction for Japan median size total manufacturing.

The impact of a sizable small scale enterprise sector on productivity is still disputed. Labour productivity tends to increase with establishment size since large establishments are more capital

intensive. But the effects on TFP are less clear. Large firms can benefit from economies of scale caused by longer production runs, increased specialization and improved interindustry linkages. They have greater possibilities for in-house R&D activities as well. Based on a large scale survey, Hou and San (1993, p.391) conclude that for "small firms in the more technology-intensive industries in Taiwan, reverse engineering is still the key to acquiring technology. These firms are still far away from becoming an inventor of technology". On the other hand, small firms often choose more socially appropriate capital/labour ratios than larger firms, and are likely to exhibit greater flexibility in movement among product lines and to adjust to changing factor markets more rapidly. Hence, TFP growth in small firms might be higher than in larger firms.

For 1986, a comparison is made of productivity per size class for Taiwan, taking the level of TFP in total manufacturing as 100. Table 14 shows that as expected, labour productivity increases with increasing size. As noted, this is due to the higher capital intensity of larger firms. The anomalous high capital intensity of the smallest class of establishments is caused by the fact that a big part of these small establishments are in the capital intensive fabricated metal industries. To study the effect of size on TFP, a rough estimate has been made using the Cobb-Douglas production function as outlined in section 6.2.[28] The last column of table 14 shows that TFP levels are roughly similar for medium sized firms (with between 10 to 500 employees). But for the smallest firms TFP levels are considerably lower, while for the biggest firms they are higher than average. This can be taken as evidence of increasing returns to scale.

Table 14 *Productivity of Manufacturing Establishments by Size Class, Taiwan 1986*

Size class (employees)	Number of establishments	Value added per worker total = 100	Capital per worker total = 100	TFP total = 100
less than 10	74,489	61	63	79
10-29	26,389	62	41	99
30-49	6,932	64	43	101
50-99	5,606	70	57	95
100-499	4,328	89	75	104
more than 500	492	183	227	118
Total	118,236	100	100	100

Sources: Gross value added, employment and net fixed capital stock at bookvalue from DGBAS, The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. I, Table 6. TFP calculated using Cobb-Douglas production function with total manufacturing labour share (α = 0.53).

As the Taiwanese firm size distribution is much more skewed towards the smallest firms than the US distribution, the difference in size distribution might explain part of the gap in productivity. Table 15 shows the distribution for both countries. Weighting the size class shares of each economy with the TFP levels from table 14, it follows that the impact of differences in size class have a small explanatory

[28] It might seem counterintuitive to assess the impact of firm size on productivity using a production function with constant returns to scale, but in effect the economies of scale will end up in the TFP. Besides, constant returns to scale in the aggregate is not necessarily contradicting non-constant returns to scale at the firm level. This depends on the change in the size distribution of firms.

power. Taiwanese TFP would be 3.4 percentage points higher when it could enjoy the economies of scale enjoyed by the US.[29] Clearly, the difference in size distribution does not go a long way to explain the found productivity gap.

Table 15 *Distribution of Manufacturing Establishments by Size Class, Taiwan 1986 and US 1987*

Size class	Number of establishments		Distribution (in %)	
(employees)	Taiwan 1986	US 1987	Taiwan 1986	US 1987
less than 10	74,489	179,585	63.0	50.0
10-49	33,321	116,339	28.2	32.4
50-99	5,606	28,241	4.7	7.9
100-499	4,328	29,858	3.7	8.3
more than 500	492	4,922	0.4	1.4
Total	118,236	358,945	100.0	100.0

Sources: Taiwan from DGBAS, The Report on 1986 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. I, Table 45; US from Bureau of Census, 1987 Census of Manufactures, General summary, Table 4.

7.3 TFP and Human Capital

If rapid increases in physical capital are not to encounter rapidly diminishing marginal returns, investments in new production technologies and products are necessary to raise productivity. Although the Taiwanese firms were adopting technologies which were not new to the world, successful absorption of technologies which were new to them, and the search for new products and new markets, required a larger pool of skilled workers. The Taiwanese government therefore devoted much efforts to education from early times onwards. Public expenditure on education as a percentage of GNP rose from 2.3% at the end of the 1950s to more than 5.5% in the beginning of the 1990s.[30] As a result, educational levels increased very quickly. In 1965, 80% of the employees in Taiwan had a qualification level of primary school or less, and 23% was even illiterate. In 1995, this percentage had dropped to 30% of which only 3% was illiterate. At the same time, the share of employees who have been educated in college increased from 3% to 19%.

Following Pilat (1995, Table 7), we give a crude illustration of the impact of education levels on productivity. Table 16 gives a comparison of the educational attainment of employees in Taiwan and US manufacturing for 1987. It follows that in the US, a much bigger share of the labour force has had higher education than in Taiwan. By weighting each educational class with its wage level, a labour quality adjustment factor can be calculated, assuming that wage differentials reflect differences in marginal productivity. The quality adjustment factors are given in Table 17.

[29] Only 1.3% when value added shares per size class instead of establishment shares used in the analysis.
[30] Ministry of Education, Education Statistics of the ROC, 1996, Table 17.

Table 16 *Employees in Manufacturing Branches by Educational Attainment, Taiwan and US 1987*

	TAIWAN				US			
	Junior high school or less	Senior high school	Junior college	College and graduate	Junior high school or less	High school (4 year)	College (1-3 year)	College and university (4 year)
Years of education (at least)	8	12	14	16	9	12	13	16
Food, beverages and tobacco	59	28	8	4	27	50	13	10
Textile mill products	72	24	3	1	38	45	8	9
Wearing apparel	76	21	2	1	40	45	8	6
Leather products	72	23	3	2	37	49	3	10
Wood products	76	19	4	1	32	49	12	7
Paper, printing & publishing	51	34	10	5	14	45	19	21
Chemicals, rubber and plastic	65	26	5	3	14	44	17	25
Non-metallic mineral	71	23	4	2	26	46	14	14
Basic & fabricated metal	59	29	9	4	23	48	17	12
Machinery & transport equip.	50	33	11	5	16	43	20	22
Electrical machinery and equip.	51	37	8	4	15	41	20	24
Other manufacturing	63	29	6	3	17	41	19	23
Total manufacturing	61	29	6	3	21	45	17	18

Sources: Taiwan total manufacturing shares for 1993 from Yearbook of Manpower survey statistics Taiwan Area, 1993, Table 50, backdated to 1987 with *ibid.* Table 11. Branch shares estimated by applying branch /total manufacturing ratios for average entries and exits from labourmarket for 1987 to total manufacturing shares. Entry and exits from Yearbook of Labour statistics, Taiwan Area, ROC, Tables 15 and 19; US from Current Population Survey, March 1987, US Department of Labour, Bureau of Labour Statistics.

Table 17 *Quality Adjustment of Labour and Effect on TFP Levels, Taiwan/US Manufacturing 1986*

	TFP Hours Worked based	Labour quality adjustment factor US = 100 (a)	TFP Hours Worked based incl. Labour quality adjustment
Food, beverages and tobacco	17.4	90	18.4
Textile mill products	64.4	88	69.9
Wearing apparel	51.0	89	55.8
Leather products	62.9	88	68.8
Wood products	24.5	87	26.9
Paper, printing & publishing	32.7	83	36.5
Chemicals, rubber and plastic	53.0	77	61.0
Non-metallic mineral	45.5	83	50.8
Basic & fabricated metal	38.4	88	41.7
Machinery & transport equip.	24.0	83	27.4
Electrical machinery and equip.	48.2	81	56.1
Other manufacturing	30.1	79	35.4
Total Manufacturing	34.3	83	38.8

Note: (a) adjustment factor for 1987, calculated by weighting share in each educational class from Table 16 by average relative earnings per educational class for Taiwan and US.
Sources: Table 9 for TFP; US relative earnings from Tabulations from US Dept. of Labour, BLS, Educational Attainments of Workers, March 1987 (October 1987); Taiwan relative earnings from DGBAS, Yearbook of Labour statistics 1987, Table 40.

Taiwanese labour quality levels range between 77% of the US level for chemicals up to 90% in the food branch. Recalculating relative TFP levels using labour input adjusted for quality shows that in 1986, Taiwanese TFP level was 39% of the US instead of 34% (see table 17).[31] This shows that the lower labour quality of Taiwan explains about 7% of the gap in 1986. In earlier years it would undoubtedly explain a bigger part of the gap, and in later years a smaller part, given the extremely rapid increase in Taiwanese educational levels.

Clearly, this calculation gives only a rough indication of the importance of human capital. It does not include the vocational and company training of lowly educated workers which was a widespread phenomenon in Taiwan in the 1970s, and which is still important in recent years. Also it does not distinguish between general and vocational types of education. More importantly, the growth accounting framework used here quantifies only the effects of education on the quality of labour input. As pointed out above, increases in human capital are indispensable in facilitating the adoption of new capital goods and technologies. This effect is not quantifiable within this framework.

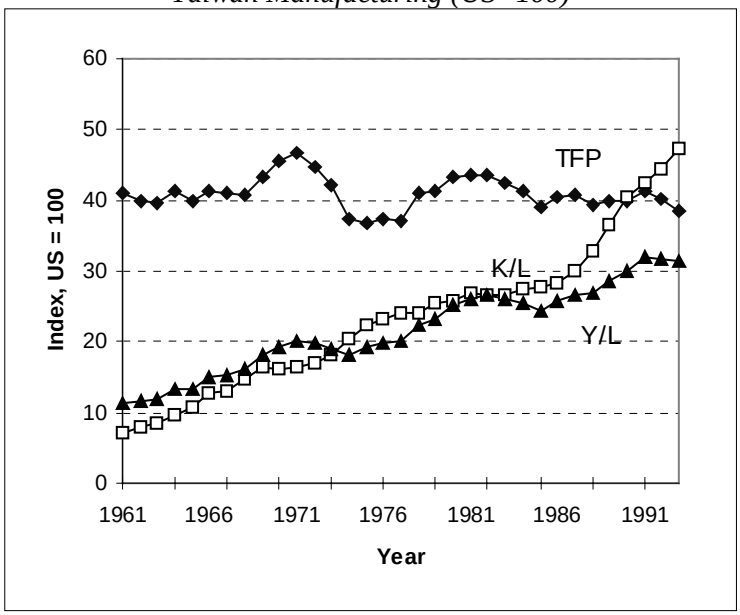
8. Conclusions and Discussion on TFP

Since 1948 Taiwan has undergone a process of rapid industrialization. The conditions for catch up to the productivity levels of advanced economies were favourable at the end of the 1940s. A powerful government initiated and stimulated a process of balanced economic growth. Rapid accumulation of physical and human capital enabled Taiwan to exploit new technologies and produce new products, resulting in rapid catch up in labour productivity with the world productivity leader. This paper shows that in 1961, Taiwan's labour productivity in manufacturing was 11% of the US, increasing to 31% in 1993. Until 1986, aggregate performance was mirrored in branch performance as all branches showed rapid catch up. After 1986, a process of deindustrialization set in as the share of manufacturing in total GDP declined and inflow of labour in the manufacturing sector stagnated. The earlier phenomenon of broad-based manufacturing catch up had come to an end. Labour productivity in aggregate manufacturing still increased relative to the US, but this was not shared by all branches. The increase in labour productivity was driven by a large increase in capital intensity from 7% of the US level in 1961 to 28% in 1986, accelerating afterwards to 47% in 1993 (Figure 3). In 1993, capital intensity in Taiwanese manufacturing was about equal to the capital intensity in US manufacturing in 1961 which shows that there are still plenty of opportunities for further capital intensification. TFP growth in Taiwanese manufacturing averaged 2.2% per year for the period 1961-1993, of which only 0.2% was due to a reallocation of resources between manufacturing branches. In contrast to the catch up in labour productivity and capital intensity, aggregate TFP did not increase relative to the US and stagnated at around 40%. During this period, some branches like wearing apparel and electrical machinery showed catch up with the US, but this was offset by branches like chemicals and paper which were falling behind. Economies of scale do not provide an important explanation of the gap in TFP levels between the US and Taiwan. An adjustment for the relatively small size of Taiwanese manufacturing firms adds

[31] Assuming that the quality adjustment factor found for 1987 is close to that for 1986.

only 3% to the Taiwanese TFP level. Differences in human capital are more important. In 1986, they explained about 7% of the gap.

Figure 3 *Relative Productivity and Capital Intensity Levels in Taiwan Manufacturing (US=100)*



Note: TFP = total factor productivity, K/L=gross fixed capital stock per worker and Y/L=gross value added per worker. *Sources*: see Tables 8 and 10.

The interpretation of these findings is controversial. In the wake of the World Bank study "The East Asian Miracle" (World Bank, 1993) and especially the findings of Young (1995) and Kim and Lau (1994) that "technical progress has played an insignificant role in post war aggregate economic growth of East Asian NICs" (Kim and Lau, 1994, p.264), numerous "old" discussions about the TFP-concept are revived again. Chen (1997) reviews this topic, repeating and stressing the "old" lesson that estimates of TFP are as reliable as the reliability of the underlying data. Especially capital input is difficult to measure, and different estimates can lead to widely different conclusions. This is illustrated by existing estimates for Taiwanese manufacturing. According to DGBAS (1994), gross fixed capital stock in manufacturing increased on average at 9.0% per year during 1961-1992. This estimate is used in TFP-studies by e.g. Chuang (1996), Okuda (1994) and Pack (1992). Using the perpetual inventory method based on investment series from the National Accounts, capital stock appeared to have grown much faster at 14.3% per year. This method is used by Young (1995) and is also preferred in this study. Consequently, TFP growth averages 4.7% per year using the official stock estimates and only 2.2% per year when using the PIM estimate.[32] In the first case rapid catch up with the US has taken place, in the latter case one finds relative stagnation.

Irrespective of the choice of the dataset, the so called "assimilationists" question the usefulness of the growth accounting/ production function approach for studying growth processes. Given the identification problems involved, they are reluctant to separate capital intensification and technical

[32] Using a Cobb-Douglas with α=0.53, gross value added growth of 11.6% per year (from National Accounts 1994) and labour input growth of 5.0% (from Labor Force Survey).

change as measured by TFP (Nelson 1973, Abramovitz 1989). Moreover, they stress the complementarities between physical and human capital accumulation. The crux is that rapid increases in physical capital will encounter rapidly diminishing marginal returns, if investments in new production technologies and products are not made. These technologies are not new to the world, but they are new to the firms introducing them. Successful absorption of technologies, and investigation of new products and new markets requires a growing group of skilled workers and entrepreneurs who learn about and learn to master new technologies used in more advanced countries.Viewed this way, capital intensification is not a mere movement along a prevailing production function, but is a search for an enlargement of the set of production possibilities. This exploration is costly and uncertain, and far from easy or automatic as suggested by the concept of "a movement along a production function"(Nelson and Pack, 1998).

All the same, we believe that there is no inherent contradiction in adhering to the assimilationists' point of view and taking the statistical results from growth accounting exercises, as performed also in this paper, serious. This requires an understanding of the role of the production function as a weighting mechanism in TFP calculations. From an index number perspective, growth of TFP is defined as growth of output minus growth of inputs. It gives an idea of the change in output-per-unit-of-input. As input and output consist of a multitude of different products, the familiar index number problem pops up: how to weight and aggregate different goods. The use of a particular production function is nothing more than applying a certain weighting scheme. However, one does not need to accept the connotative images of easy movements along, or difficult movements of, a production function, while still calculating TFP indices. Therefore the findings of relatively low output-per-unit-of-input figures for Taiwan and other Asian countries (Collins and Bosworth 1996, Lau and Kim 1994, Timmer and Szirmai 1997) are relevant and need to be explained.

A number of possible explanations have been put forward. Firstly, differences in the quality of the capital stock which are not taken into account may be important. In general newer vintages are in place in the US which embody more sophisticated technologies. Further, it is also possible that the growth of the "soft" component of investments, which includes managerial methods and information lags behind the "hard"component in Asian countries. Together with a lagging development of the institutional environment, the financial system and infrastructure the full potential productivity of capital goods might not be realized (Lau and Kim 1994). Another explanation of low TFP might be in the inadequate domestic diffusion of knowledge and new technologies in many developing countries as suggested by Pack (1987) and Pack and Westphal (1986). However, Taiwan is often cited as an example of an economy with a good diffusion practice. Moreover, given the findings of large variations in efficiency between establishments in an industry within developed countries (Caves, 1992), this might not be particularly relevant in this case. However, structural differences between Taiwan and the US below the branch level studied here might be more relevant. On average, Taiwanese firms are still engaged in lower technology activities and products which might generate less output per unit of input than US firms.

A more dynamic explanation stresses the very nature of climbing the technology ladder. Shifting to higher technologies invariably involves "set-up" costs associated with adaptation and adjustment problems and consequently inefficient use, at least in the starting phase. When learning starts to take place, TFP will gradually increase, only to drop again when another shift to a newer technology takes place. Taiwan has been involved in a rapid and continuous process of climbing the technology ladder as was shown in terms of increasing capital intensity, and consequently TFP growth has not been exceptional. Whether this climb has been too fast, allowing insufficient time for learning to take place, is better judged from success on the competitive world market, rather than from TFP. In that respect, Taiwan's industrialization process has been undoubtedly successful.

References

Abramovitz, M. (1989), *Thinking about growth*, Cambridge University Press, Cambridge.

Amsden, A.H. (1989), *Asia's next giant: South Korea and Late Industrialization.* New York: Oxford UP.

Ark, B. van (1993), *International Comparisons of Output and Productivity*, Groningen Growth and Development Centre, Monograph Series No. 1, Groningen.

Ark, B. van (1996), "Issues in Measurement and International Comparison Issues of Productivity-An Overview", Chapter 1 in: *Industry Productivity. International Comparison and Measurement Issues*, OECD Proceedings, OECD, Paris.

Ark, B. van (1998), Technology and Productivity Performance in Germany, *Research Memorandum*, Groningen Growth and Development Centre.

Ark, B. van and D. Pilat (1993), "Productivity Levels in Germany, Japan and the United States", *in: Brookings Papers on Economic Activity, Microeconomics 2*, Washington D.C., December.

Aw, B.Y, X.Chen and M.J. Roberts (1997), "Firm-level Evidence on Productivity Differentials, Turnover, and Exports in Taiwanese Manufacturing", *NBER Working Paper Series* No. 6235.

Baily, M.N. and H.Gersbach (1995), "Efficiency in Manufacturing and the Need for Global Competition", *Brookings Papers on Economic Activity: Microeconomics*, pp.307-358.

Barro, R.J. and X. Sala-i-Martin (1995), *Economic Growth*, Mc Graw-Hill Inc.

Caves, R.E. (ed.) (1992), *Industrial Efficiency in Six Nations*, MIT Press.

Chen, Edward K.Y. (1997), "The Total Factor Productivity Debate: Determinants of Economic Growth in East Asia", in: *Asian-Pacific Economic Literature*, 11(1), pp. 18-38.

Chen,T-J and D-P Tang (1990), "Export Performance and Productivity Growth: The Case of Taiwan" in: *Economic Development and Cultural Change* 38, pp.577-586.

Chuang, Y-C, (1996), "Identifying the Sources of Growth in Taiwan's Manufacturing Industry" in: *Journal of Development Studies*, Vol. 32(3), pp.445-463.

Collins, S.M. and B.P. Bosworth (1996). "Economic Growth in East Asia: Accumulation versus Assimilation". *Brookings Papers on Economic Activity, 2:*135-203.

Dollar, D. and E.N. Wolff (1993), *Competitiveness, Convergence, and International Specialization*, MIT Press, Cambridge, Mass.

Fei, C.H.F., Ranis, G., & Kuo, S.W.Y. (1979), *Growth with Equity. The Taiwan case.*Washinghton: Oxford UP.

Freudenberg, M. and D.Ünal-Kesenci (1996), "French and German Productivity Levels in Manufacturing" in B. van Ark and K. Wagner, *International Productivity Differences. Measurement and Explanations.* North-Holland, Amsterdam.

Gersbach, H. and B. van Ark (1994), "Micro Foundations for International Productivity Comparisons", *Research Memorandum* GD-11, Groningen Growth and Development Centre.

Ho, S.P.S. (1978), *Economic Development of Taiwan, 1860-1970.* Yale University Press, New Haven.

Hooper, P. and E. Vrankovich (1995), "International Comparisons of the Levels of Unit Labour Costs in Manufacturing", *International Finance Discussion Papers*, Number 527, Board of the Governors of the Federal Reserve System, Washington D.C., Oktober 1995.

Hou, C.M. and Gee, S. (1993), "National Systems supporting Technical Advance in Industry: the Case of Taiwan." In R.R. Nelson (Ed.), *National Innovation Systems. A Comparative Analysis* Oxford: Oxford UP.

Jorgenson, D.W. and M. Kuroda (1990), "Productivity and International Competitiveness in Japan and the United States, 1960-85", in: C.R.Hulten (ed.), *Productivity in the U.S. and Japan*, University of Chicago Press.

Jorgenson, D.W., Gollop, F.M. and Fraumeni, B.M. (1987), *Productivity and US Economic Growth*, Cambridge MA, Harvard UP.

Kravis, I.B., A. Heston and R. Summers (1982), *World Product and Income*, John Hopkins, Baltimore.

Krugman, P. (1994), "The Myth of Asia's Miracle", in: *Foreign Affairs*, vol. 73(6), pp. 62-78.

Kuo, S.W.Y. and J.C.H. Fei (1985), "Causes and Roles of Export Expansion in the Republic of China" Chapter 2 in W.Galenson (ed.), *Foreign Trade and Investment. Economic Development in the Newly Industrializing Asian Economies.* University of Wisconsin Press.

Lau, L.J. and J-I Kim (1994), "The Sources of Economic Growth of the East Asian Newly Industrialized Countries." in: *Journal of Japanese and International Economies, 8:*235-271.

Liang, C-Y. (1991), "Energy Productivity and Total Factor Productivity in Taiwan's Seven Industries." In F. Fesharaki & J.P. Dorian (eds.), *Energy Developments in 1990s: Challenges Facing Global/Pacific Markets.* Honolulu, Hawaii: East-West Center.

Maddison, A. and B. van Ark (1988) "Comparisons of Real Output in Manufacturing", *Policy, Planning and Research Working Papers, WPS5*, World Bank, Washington D.C.

Maddison, A. (1995), *Monitoring the World Economy, 1820-1992*, Paris, Development Centre Studies, OECD, 1995.

Nelson, R.R. (1973), "Recent Exercises in Growth Accounting: New Understanding or Dead End?", *American Economic Review*, vol.63, pp.462-8.

Nelson, R.R. and H. Pack (1998), "The Asian Miracle and Modern Growth Theory.", *PolicyResearch Working Paper* 1881, World Bank, Washington DC.

Okuda, S. (1994), "Taiwan's Trade and FDI Policies and Their Effects on Productivity Growth" in: *The Developing Economies*, 32(4), pp.423-443.

O'Mahony, M. (1996), "Conversion Factors in Relative Productivity Calculations: Theory and Practice", Chapter 9 in: *Industry Productivity. International Comparison and Measurement Issues*, OECD Proceedings, OECD, Paris.

Pack, H. (1987), *Productivity, Technology and Industrial Development. A Case Study in Textiles.* New York: World Bank, Oxford University Press.

Pack, H. (1992), "New Perspectives on Industrial Growth in Taiwan." In G. Ranis (Ed.), *Taiwan-From Developing to Mature Economy.* Boulder: Westview Press.

Pack, H. and Westphal, L.E. (1986), "Industrial Strategy and Technological Change: Theory versus Reality." in: *Journal of Development Economics*, vol.22, pp.87-128.

Pilat, D. (1994), *The Economics of Rapid Growth. The Experience of Japan and Korea*, Edward Elgar Publishers, Aldershot.

Pilat, D. (1995), "Comparative Productivity of Korean Manufacturing, 1967-87", in: *Journal of Development Economics*, Vol. 46, pp.123-144.

Ranis, G. and C. Schive (1985), "Direct Foreign Investment in Taiwan's Development", Chapter 3 in: W.Galenson (ed.), *Foreign Trade and Investment. Economic Development in the Newly Industrializing Asian Economies*, University of Wisconsin Press.

Ranis, G. (1973), "Industrial Sector Labour Absorption", *Economic Development and Cultural Change*, Vol. 21, pp.387-408.

Ranis, G. (1995), "Another Look at the East Asian Miracle."in: *World Bank Economic Review,* vol.9(3), pp.509-34.

Riedel, J. (1992), "International Trade in Taiwan's Transition from Developing to Mature Economy", in G.Ranis (ed.) *Taiwan. From Developing to Mature Economy*, Boulder: Westview Press.

Syrquin, M. (1984), "Resource Allocation and Productivity Growth", in: M. Syrquin, L. Taylor, and L.E. Westphal (Eds.), *Economic Structure and Performance - Essays in Honor of Hollis B. Chenery*, Academic Press Inc, Orlando.

Timmer, M.P. (1996), "On the Reliability of Unit Value Ratios in International Comparisons", *Research Memorandum GD-31*, Groningen Growth and Development Centre, December 1996.

Timmer, M. P. and A. Szirmai (1997), Growth and Divergence in Manufacturing Performance in South and East Asia, *Research Memorandum GD-37*, Groningen Growth and Development Centre, June 1997.

World Bank (1993), *The East Asian Miracle. Economic Growth and Public Policy*, Oxford University Press.

Yotopoulos, P.A. and Lin, J. (1993), "Purchasing Power Parities for Taiwan."in: *Journal of Economic Development*, vol.18(1).

Young, A. (1995), "The Tyranny of Numbers: Confronting the Statistical Realities of the East AsianGrowth Experience", in: *The Quarterly Journal of Economics*, vol. 110, pp.641-680.

Appendix A Two Alternative Approaches to Real Value Added Series

There are two different ways to construct constant price series of value added for Taiwan. The first method is to use the Index of Industrial Production (IIP) as compiled by MOEA. In a IIP, changes in product quantities produced are weighted by constant value added weights. The second possibility is to deflate current value added from the National Accounts with a wholesale or other appropriate price index. The difference between the series can be rather substantial which is illustrated in Appendix Table A1.

Appendix Table A1 *Alternative Estimates of GDP Growth Rates in Taiwanese Manufacturing*

	Annual Average Growth Rates of Real GDP		
	National Accounts current price deflated by wholesale price index	Index of Industrial Production	National Accounts constant price
1951-60	12.3	15.8	
1961-72	18.4	18.3	16.0
1973-81	11.3	10.9	10.9
1982-93	10.1	6.4	6.6
1961-93	13.5	12.0	11.2

Sources: Constant and current price GDP from DGBAS, National Income in Taiwan, 1994. IIP from Industrial Production Statistics Monthly,Taiwan Area, ROC and printout MOEA, March 1995. Wholesale price index from DGBAS, Commodity-price Statistics Monthly (Jan 1995, Table 8.2) and print out, DGBAS, Third Bureau, March 1995.

The table shows that the constant price series as published in the National Accounts follows closely the IIP, indicating that estimates of real series in the NA is based on this index. Current NA series deflated by a wholesale price index gives quite different results, especially for the most recent period. For 1982-1993, growth is estimated at 6% by the IIP, but 10% according to the deflated current price series. This big difference in estimates has important implications for productivity analysis and therefore requires an explanation. The theoretical differences between an IIP and a deflated current series will be discussed below.

- The Index of Industrial Production

The Index of Industrial Production (IIP_{0t}) is defined as the ratio of the sum of quantities produced of all goods in year t (Q_{it}^{O}) and their sum in the base year, each good weighted by its value added per unit of produced output in the base year (VA_{i0} / Q_{i0}^{O}). (See MOEA, Industrial Production Statistics Montly, Feb '95, p.7).The number of goods sampled for the construction of this index is denoted by n (i= 1, .., n).

$$IIP_{0t} = \frac{\sum_{i=1}^{n} Q_{it}^{O}\left(\frac{VA_{i0}}{Q_{i0}^{O}}\right)}{\sum_{i=1}^{n} Q_{i0}^{O}\left(\frac{VA_{i0}}{Q_{i0}^{O}}\right)} = \frac{\sum_{i=1}^{n} \frac{Q_{it}^{O}}{Q_{i0}^{O}} VA_{i0}}{\sum_{i=1}^{n} VA_{i0}} = \sum_{i=1}^{n}\left(\frac{VA_{i0}}{\sum_{i=1}^{n} VA_{i0}}\right)\frac{Q_{it}^{O}}{Q_{i0}^{O}} = \sum_{i=1}^{n} w_{i0}\,\frac{Q_{it}^{O}}{Q_{i0}^{O}} \qquad (1)$$

Value added of good i (in the base period 0) is defined as

$$VA_{i0} = Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I}$$

with $Q_{i\,0}{}^{I}$ the quantity of input I, and $P_{i\,0}{}^{I}$ the corresponding price. One can see that the IIP can be rewritten as a quantity index in which the quantity ratios of the goods are weighted by their value added share in total value added in the base year.

Given the definition of value added, the true real value added ratio (at constant base prices, $I_{0\,t}{}^{true}$) would be

$$I_{0t}^{true} = \frac{VA_{it(0)}}{VA_{i0}} = \frac{\sum_{i=1}^{N}(Q_{it}^{O} P_{i0}^{O} - Q_{it}^{I} P_{i0}^{I})}{\sum_{i=1}^{N}(Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I})} \qquad (2)$$

with $VA_{it(0)}$ the value added of good i in period t at base prices, and N the number of all goods produced in the economy. Substituting the definition of VA in the definition of IIP_{ot} in (1) gives

$$IIP_{0t} = \frac{\sum_{i=1}^{n} Q_{it}^{O} \frac{(Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I})}{Q_{i0}^{O}}}{\sum_{i=1}^{n} Q_{i0}^{O} \frac{(Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I})}{Q_{i0}^{O}}} = \frac{\sum_{i=1}^{n} Q_{it}^{O} P_{i0}^{O} - \left(\frac{Q_{it}^{O}}{Q_{i0}^{O}} Q_{i0}^{I}\right) P_{i0}^{I}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I}} \qquad (3)$$

Comparing (2) and (3) it shows that $IIP_{0\,t}$ is only a true estimate of real value added growth if n=N or weaker, the VA-ratio of the non-sampled goods is equal to the VA-ratio of the samples goods. Also the following condition must hold:

$$\frac{Q_{it}^{O}}{Q_{i0}^{O}} Q_{i0}^{I} = Q_{it}^{I} \quad \Leftrightarrow \quad \frac{Q_{it}^{O}}{Q_{i0}^{O}} = \frac{Q_{it}^{I}}{Q_{i0}^{I}} \quad \Leftrightarrow \quad \frac{Q_{it}^{O}}{Q_{it}^{I}} = \frac{Q_{i0}^{O}}{Q_{i0}^{I}} \qquad (4)$$

This assumption should be valid for all goods i. It states that the change in output of good i should be equal to the change in input used for the production of good i (second equation). Or alternatively (looking at the third equation), it is assumed that there is no change in productivity of the inputs between the year 0 and t.

- The deflated current value added index

Another possibility to estimate real value added growth is to deflate current value added figures by an appropriate price index. It is defined as follows.

$$I_{0t}^{defcur} = \frac{VA_{it}}{VA_{i0}} \div \frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}} = \frac{\sum_{i=1}^{N}(Q_{it}^{O} P_{it}^{O} - Q_{it}^{I} P_{it}^{I})}{\sum_{i=1}^{N}(Q_{i0}^{O} P_{i0}^{O} - Q_{i0}^{I} P_{i0}^{I})} \div \frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}} \qquad (5)$$

Current value added is taken from NA and therefore it covers all goods (n = N). However, for the deflator only n goods have been sampled. This index is equal to the true index in (2) if

$$\frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}} \; x \; \sum_{i=1}^{N} Q_{it}^{O} P_{it}^{O} \;=\; \sum_{i=1}^{N} Q_{it}^{O} P_{i0}^{O} \qquad \Leftrightarrow \qquad \frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}} \;=\; \frac{\sum_{i=1}^{N} Q_{it}^{O} P_{it}^{O}}{\sum_{i=1}^{N} Q_{it}^{O} P_{i0}^{O}} \qquad (6)$$

and

$$\frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}} \; x \; \sum_{i=1}^{N} Q_{it}^{I} P_{it}^{I} \;=\; \sum_{i=1}^{N} Q_{it}^{I} P_{i0}^{I} \qquad \Leftrightarrow \qquad \frac{\sum_{i=1}^{n} Q_{i0}^{O} P_{it}^{O}}{\sum_{i=1}^{n} Q_{i0}^{O} P_{i0}^{O}} \;=\; \frac{\sum_{i=1}^{N} Q_{it}^{I} P_{it}^{I}}{\sum_{i=1}^{N} Q_{it}^{I} P_{i0}^{I}} \qquad (7)$$

From (6) follows that N must be equal to n, or weaker, the price index which is computed from a sample of goods is indicative for the real price index for all goods. Furthermore the condition in (6) states that the output price change during the period 0,t using quantity weights from period t (the Paasche price index) is equal to the output price change as indicated by the Laspeyres price index. Correspondingly formula (7) states that the Paasche price change of *inputs* during the period is equal to the Laspeyres *output* price index. Taking these conditions together it follows that the Laspeyres output price index must be equal to the Paasche output price index and to the Paasche input price index.

- Comparison of the two methods

Both methods have to assume that the sampled part of the goods is representative for the non-sampled part. For the IIP 1949 goods are sampled, covering 70% of manufacturing output value in 1993.The sample of prices used in construction of the wholesale price index is smaller and contains 882 goods in 1991. Although the sample for the IIP is bigger it does not automatically follow that it is better in this respect. It is known that variations in quantities are much higher than the variation in prices. An a priori judgment cannot be made on basis of this.

Assuming that Paasche and Laspeyres output price indices differ only slightly, the choice between the IIP and the deflated current price index boils down to the following. Which assumption, constant intermediate goods productivity or equality of Paasche *input* price change and Laspeyres *output* price change, creates the highest bias? Further research is warranted to judge which index of real value added growth is more reliable, and should be used in productivity research.

Appendix B Alternative Matching Results

This appendix gives alternative matching results. Appendix Table B1 gives results for 1986 using alternative aggregation rules. Appendix Table B2 shows the results from a 1976 benchmark used in Timmer and Szirmai (1997).

Appendix Table B1 *Comparison of UVRs Derived by Alternative Aggregation Schemes, 1986 Taiwan/US Benchmark*

	Ratio of UVR by old method to UVR by new method (a)		
	Laspeyres UVR	Paasche UVR	Fisher UVR
Food, beverages and tobacco	0.95	0.99	0.97
Textile mill products	1.00	1.00	1.00
Wearing apparel	1.00	1.00	1.00
Leather products	1.00	1.00	1.00
Wood products	1.00	1.00	1.00
Paper, printing & publishing	1.00	1.00	1.00
Chemicals products	0.98	0.86	0.92
Rubber and plastic	1.12	1.02	1.07
Non-metallic mineral	1.10	0.99	1.04
Basic & fabricated metal	0.93	0.94	0.94
Machinery & transport equipment	1.00	0.58	0.76
Electrical machinery and equipment	0.75	1.06	0.89
Other manufacturing	1.00	1.00	1.00
Total manufacturing	0.93	0.96	0.94

Note: (a) Product UVRs are aggregated to industry, branch and total manufacturing levels. The old method uses gross value added as weights if the coverage ratio of the product matches is higher than 25%. The new method uses gross value of output as weights if the coefficient of variation is lower than 0.1 and at least one match is made. See discussion in section 3.
Sources: Products UVRs from product matches, see section 3.

Appendix Table B2 *Manufacturing Unit Value Ratios, 1976 Taiwan/US Benchmark*

	Laspeyres UVR	Paasche UVR	Fisher UVR	Compara-tive Price Level (a)	Coverage ratio Taiwan (%)	Coverage ratio US (%)	Number of Product Matches
Food manufacturing	36.0	53.4	43.9	115	41.9	15.4	20
Beverages	34.5	34.5	34.5	91	23.6	26.7	1
Tobacco products	25.8	21.9	23.8	63	56.4	89.8	3
Textile mill products	23.2	23.6	23.4	62	45.0	29.4	5
Wearing apparel	24.4	23.8	24.1	63	43.6	17.4	7
Leather products & footwear	13.6	13.2	13.4	35	39.3	59.8	5
Wood, furniture & fixtures	20.0	39.5	28.1	74	52.4	19.8	4
Paper, printing & publishing	33.8	38.4	36.0	95	43.7	14.6	8
Chemical products	43.8	72.3	56.3	148	44.5	40.4	18
Rubber & plastic products	15.4	30.9	21.8	57	30.5	20.1	6
Non-metallic mineral products	11.5	9.3	10.3	27	44.0	11.5	1
Basic & fabricated metal	26.2	31.0	28.5	75	28.2	17.6	13
Machinery & transport equipment	17.9	33.1	24.3	64	13.0	12.3	6
Electrical machinery & equipment	18.5	35.9	25.7	68	24.4	19.1	8
Other manufacturing industries	22.2	39.2	29.5	78	0.0	0.0	0
Total manufacturing	22.2	39.2	29.5	78	35.8	19.7	105
Exchange rate			38.0	100			

Note: (a) Comparative price level is the UVR divided by exchange rate. *Sources:* Based on matching procedure described in section 3. Basic sources are DGBAS, The Report on 1976 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C, Vol. III and Bureau of the Census, US Census of Manufactures, 1977, Washington DC. Exchange rate from DGBAS, National Income in Taiwan, 1994.

Appendix Table C1 Gross Domestic Product at market prices by Manufacturing Branch, Taiwan, 1961-1993, in 1991 million NT dollars

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	19,068	3,576	1,292	200	3,239	5,308	11,082	598	4,637	3,172	1,904	541	517	55,134
1962	20,628	3,672	1,235	158	3,223	5,799	13,412	839	5,198	2,863	2,119	691	519	60,356
1963	23,521	4,441	1,691	139	3,772	5,679	15,974	964	5,594	3,162	2,190	849	618	68,592
1964	24,959	5,746	2,999	149	4,738	6,940	20,679	1,344	6,452	3,584	2,888	1,535	770	82,784
1965	25,674	6,613	2,029	203	5,843	7,842	23,628	1,974	7,315	4,802	5,593	1,977	1,032	94,525
1966	25,468	7,938	2,132	187	5,969	9,218	31,430	2,933	8,620	5,883	6,809	2,955	1,604	111,146
1967	31,611	8,697	2,409	443	6,167	9,148	36,481	3,934	8,979	6,190	9,193	3,952	1,836	129,040
1968	32,625	8,808	2,809	512	7,279	10,937	45,729	5,405	9,201	6,878	11,652	6,902	2,428	151,164
1969	36,966	12,818	4,718	739	10,146	11,782	53,499	6,985	10,226	8,940	12,882	8,238	4,024	181,964
1970	39,652	18,262	8,346	1,142	11,995	13,154	62,412	10,813	11,941	11,377	13,657	10,472	6,037	219,259
1971	40,668	22,711	14,205	2,314	13,510	16,618	69,297	16,088	13,945	15,792	19,382	14,429	8,469	267,428
1972	39,549	26,590	16,205	2,461	19,787	19,781	91,267	18,751	13,788	21,898	24,594	19,054	9,297	323,021
1973	46,079	32,194	19,718	3,298	21,547	23,614	99,750	23,073	14,151	28,148	26,563	27,969	13,051	379,156
1974	56,310	27,529	20,969	4,929	14,690	20,051	79,744	20,293	17,186	20,848	30,791	25,199	20,125	358,664
1975	51,428	35,990	17,369	5,241	15,275	21,063	82,009	23,859	17,873	24,178	38,212	24,882	16,904	374,283
1976	68,339	43,595	23,650	5,935	14,678	24,241	87,339	31,349	22,545	35,601	42,205	32,357	26,533	458,368
1977	69,226	47,195	27,935	7,195	14,438	27,121	101,444	29,638	25,438	37,586	51,888	37,507	40,808	517,420
1978	74,096	57,177	32,692	9,940	20,189	35,861	118,124	38,330	30,165	52,974	59,564	52,865	42,286	624,263
1979	81,277	56,923	35,002	12,948	21,958	40,845	131,309	42,696	29,974	59,570	63,419	56,353	41,080	673,354
1980	85,640	71,711	43,989	14,456	18,539	42,855	128,774	47,310	33,336	70,754	71,249	68,107	43,109	739,829
1981	88,319	78,267	50,644	12,159	19,545	44,527	138,932	50,198	36,108	77,705	85,771	71,577	42,360	796,112
1982	91,977	77,241	58,065	13,936	18,187	41,961	140,260	56,117	35,210	79,067	84,624	70,856	45,723	813,224
1983	104,926	80,560	58,313	16,041	20,185	43,541	155,901	64,543	39,219	93,187	91,381	87,309	51,617	906,723
1984	115,279	91,060	66,989	19,366	23,626	48,714	175,141	76,118	41,471	108,775	99,044	113,378	59,301	1,038,262
1985	125,366	95,875	62,716	21,939	25,976	50,866	182,922	83,797	42,824	113,550	97,394	109,414	59,883	1,072,522
1986	129,877	111,721	67,773	26,554	35,231	61,631	184,900	106,918	45,405	136,326	113,498	142,836	72,485	1,235,155
1987	143,162	116,632	70,699	26,391	39,974	64,107	214,079	119,867	50,507	151,642	138,665	178,438	82,601	1,396,764
1988	142,116	107,332	61,066	24,461	38,005	65,234	226,718	127,554	55,129	170,016	150,335	202,277	85,600	1,455,843
1989	142,395	110,583	60,030	23,128	37,337	66,535	235,236	124,968	59,608	182,370	169,311	217,012	81,101	1,509,614
1990	148,130	103,613	55,437	20,899	29,478	63,338	240,669	117,458	63,551	189,556	176,118	223,563	71,130	1,502,940
1991	149,283	109,533	55,078	20,914	31,874	60,357	263,862	121,669	67,980	213,268	190,796	250,888	68,340	1,603,842
1992	158,160	108,572	49,362	17,109	30,534	59,358	275,146	119,320	72,978	231,781	204,174	263,981	65,319	1,655,794
1993	159,786	101,906	44,519	15,876	27,571	56,737	293,032	115,257	79,640	247,855	206,011	291,319	57,819	1,697,328

Source: 1980-1993: DGBAS, National Income in Taiwan Area of the Republic of China 1994, Jan. 1995.
1961-1979: total manufacturing from *ibid.*. Branch distribution by calculating branch shares in current value divided by wholesale price index, provided by DGBAS, Third Bureau, March 1995

Appendix Table C2 Persons Engaged by Manufacturing Branch Taiwan, 1961-1993, in persons.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	90,288	84,226	30,833	16,307	40,682	34,123	34,003	31,043	32,481	44,965	59,072	21,752	21,375	541,150
1962	90,460	86,551	30,057	16,338	42,142	34,188	34,067	32,449	32,543	46,662	59,185	23,350	22,435	550,426
1963	91,325	90,603	29,134	16,288	44,080	34,084	35,215	33,692	33,743	51,105	57,898	26,383	24,400	567,949
1964	91,733	92,026	28,903	16,159	45,098	33,815	38,028	34,757	34,763	53,656	57,440	27,715	26,225	580,319
1965	98,408	101,644	30,042	17,770	50,406	36,068	39,681	37,814	37,731	60,425	60,160	31,118	29,558	630,826
1966	99,236	105,636	29,115	17,714	52,312	35,955	43,920	40,377	38,909	64,816	58,864	34,121	31,497	652,472
1967	108,581	129,352	33,000	19,467	58,707	40,350	50,038	49,600	43,733	74,730	66,645	46,146	38,291	758,640
1968	106,081	149,324	35,394	19,423	59,254	42,131	46,842	58,777	43,634	74,561	72,653	59,853	41,220	809,148
1969	103,917	171,081	37,489	19,700	59,343	43,568	46,379	68,951	43,203	75,954	78,034	74,457	44,795	866,870
1970	106,494	206,552	42,885	20,956	63,604	47,858	47,262	85,657	46,678	81,981	88,609	96,553	52,380	987,469
1971	104,253	232,966	61,548	19,576	71,031	47,899	47,280	99,269	50,506	86,739	94,645	116,265	53,414	1,085,392
1972	114,441	266,556	77,944	21,274	80,452	49,355	57,757	120,419	57,630	98,015	103,898	149,820	57,906	1,255,467
1973	131,507	286,414	87,460	22,422	91,446	55,165	70,833	146,543	65,701	112,198	126,901	194,197	71,863	1,462,650
1974	134,359	285,768	87,427	22,212	87,981	60,023	81,358	149,446	77,364	113,744	140,742	209,997	74,075	1,524,496
1975	122,751	285,208	89,972	20,918	83,516	57,490	81,466	159,348	76,692	115,877	135,466	172,355	76,176	1,477,236
1976	123,845	308,613	94,529	26,905	95,031	59,890	86,727	184,266	80,065	136,157	144,173	228,238	92,285	1,660,723
1977	128,369	309,855	100,263	34,064	103,676	64,327	89,284	210,168	88,396	157,828	148,319	254,303	99,435	1,788,288
1978	131,796	319,329	104,967	40,521	110,441	67,823	100,369	225,589	93,147	175,729	174,068	291,939	104,912	1,940,629
1979	135,583	319,006	103,286	45,107	111,179	70,168	107,617	231,711	96,122	195,654	189,193	309,637	107,284	2,021,546
1980	139,092	306,791	104,624	46,678	105,652	73,350	116,250	248,118	101,189	211,087	199,196	328,252	114,754	2,095,032
1981	132,484	300,908	120,546	45,786	107,684	79,137	105,692	261,007	105,460	227,541	211,097	315,938	122,873	2,136,152
1982	128,627	292,914	129,622	48,154	106,074	84,488	107,361	272,170	106,198	236,179	205,771	287,710	132,670	2,137,937
1983	128,868	294,021	132,449	56,335	113,177	86,879	109,219	280,803	107,888	253,885	208,264	327,712	141,708	2,241,209
1984	139,278	304,227	144,433	59,028	119,985	93,890	117,298	321,159	112,516	278,508	218,565	408,370	165,702	2,482,958
1985	145,954	314,290	156,746	64,914	118,168	100,315	122,749	334,896	110,873	297,592	225,914	397,804	173,301	2,563,515
1986	144,918	304,875	155,135	69,880	125,975	106,787	125,529	346,864	111,662	317,179	239,903	438,560	189,878	2,677,144
1987	144,100	297,316	145,563	71,888	130,230	111,605	129,467	350,440	111,275	334,402	259,282	478,085	199,962	2,763,614
1988	136,798	287,366	141,264	71,140	128,928	116,570	133,720	349,346	109,429	349,715	268,063	487,248	194,177	2,773,765
1989	134,859	264,070	125,502	65,178	120,342	118,115	135,849	321,770	107,030	358,381	273,604	474,057	182,504	2,681,261
1990	136,520	225,785	110,583	56,180	99,428	116,205	136,873	276,031	102,424	349,615	275,527	460,961	165,552	2,511,686
1991	135,582	213,101	107,068	53,112	89,691	117,512	135,444	263,630	100,663	355,974	278,007	456,319	161,027	2,467,129
1992	138,422	209,637	98,956	50,080	79,760	122,560	138,505	255,079	102,753	373,204	290,942	463,954	154,537	2,478,389
1993	139,230	203,708	93,135	47,076	70,153	125,277	141,576	243,730	105,706	388,295	302,268	466,072	139,135	2,465,361

Sources: 1974-1993 employees from DGBAS, Monthly Bulletin of Earnings and Productivity Statistics, various issues. Industry breakdown for some branches with DGBAS Yearbook of Earnings and Productivity Statistics Taiwan Area of R.O.C., 1993 and DGBAS, The Report on 1976 Industrial and Commercial Census Taiwan-Fukien Area, R.O.C. Adjusted with ratio non-employees/employees found in DGBAS, *ibid.* 1976, 1986 and 1991.

1961-73: extrapolated from 1974 with number of employees from DGBAS, "Printout on Employment in Manufacturing Branches from the Labor Force Survey, 1961-1992", 15 December 1995, controlling for total manufacturing.

Appendix Table C3 Gross Fixed Capital Stock in Manufacturing, Taiwan, in 1991 prices, million NT$, Midyear

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products (a)	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	14,113	8,059	1,134	572	3,191	3,296	12,273		3,884	2,836	2,744	1,330	1,827	55,259
1962	15,541	9,083	1,281	631	3,576	3,677	13,712		4,391	3,237	3,069	1,541	2,014	61,754
1963	17,079	10,177	1,480	706	4,093	4,106	15,701		4,910	3,688	3,471	1,827	2,242	69,479
1964	19,567	12,004	1,798	817	4,832	4,796	18,979		5,688	4,375	4,072	2,190	2,601	81,718
1965	22,320	14,595	2,191	940	5,667	5,628	22,675		6,782	5,224	4,835	2,686	3,011	96,554
1966	25,419	17,935	2,705	1,080	6,662	6,622	27,334		8,477	6,261	5,875	3,409	3,476	115,256
1967	29,940	22,682	3,556	1,275	8,313	7,967	34,844		11,103	7,793	7,443	4,761	4,141	143,818
1968	34,613	28,225	4,749	1,462	10,351	9,463	44,465		13,425	9,732	9,331	6,664	4,899	177,379
1969	39,194	35,314	6,054	1,639	12,169	11,264	54,946		15,294	11,992	11,736	8,840	5,703	214,145
1970	44,652	44,014	8,895	1,855	14,237	13,903	67,642		17,956	14,938	14,996	12,374	6,569	262,031
1971	49,471	52,546	12,799	2,080	16,397	17,104	81,043		20,676	18,178	18,433	16,418	7,440	312,585
1972	55,663	63,109	16,114	2,439	19,386	21,237	98,411		24,224	22,770	23,068	21,013	8,801	376,235
1973	62,269	77,957	19,125	2,837	22,659	25,170	118,783		28,078	28,683	28,601	28,264	10,384	452,809
1974	68,854	100,863	22,636	3,301	26,399	29,163	143,993		31,946	36,051	35,378	38,133	12,460	549,176
1975	76,142	125,395	26,246	3,784	30,674	34,203	175,897		36,118	50,279	44,791	46,895	15,311	665,734
1976	83,768	143,125	28,909	4,056	34,369	38,361	204,890		40,247	70,595	55,719	52,853	17,739	774,632
1977	90,992	153,227	31,277	4,369	37,767	41,054	229,057		45,273	89,674	64,053	59,293	19,720	865,755
1978	98,096	159,457	33,954	4,949	41,413	43,843	251,545		51,948	103,568	70,250	68,333	21,753	949,109
1979	106,898	169,310	37,204	5,790	46,241	47,972	279,591		61,992	120,173	79,753	80,803	24,043	1,059,768
1980	115,763	181,473	40,246	6,717	50,897	51,790	313,545		75,778	152,267	91,607	95,056	26,143	1,201,281
1981	124,059	199,363	42,685	7,576	54,032	54,767	346,804		89,278	194,012	102,275	106,894	27,814	1,349,560
1982	146,092	218,356	44,744	8,666	56,126	62,406	363,055		91,609	227,768	113,247	112,942	29,139	1,474,150
1983	171,641	238,287	46,474	10,599	57,774	71,414	384,890		93,071	250,476	124,519	115,245	30,754	1,595,144
1984	188,386	266,155	48,074	13,174	59,345	79,688	430,251		103,425	272,848	135,511	119,145	34,200	1,750,205
1985	204,468	284,735	48,812	15,603	60,105	88,535	469,642		113,505	291,941	144,020	122,667	37,792	1,881,825
1986	224,199	305,001	50,522	18,469	62,346	97,738	524,752		125,917	327,358	153,393	131,140	41,622	2,062,456
1987	241,644	327,428	51,686	20,892	64,832	109,729	597,327		136,404	372,456	164,710	144,351	45,273	2,276,732
1988	258,816	350,278	52,178	22,882	67,511	127,323	687,330		146,795	411,773	179,440	158,870	49,117	2,512,314
1989	277,692	369,252	53,757	24,524	72,399	143,989	775,328		158,845	446,942	197,236	177,898	53,942	2,751,804
1990	297,164	380,482	56,283	25,562	79,553	156,659	861,307		172,035	482,280	216,873	201,291	59,518	2,989,007
1991	316,337	388,195	58,303	26,625	87,176	167,331	954,626		185,141	522,761	234,590	229,070	66,545	3,236,699
1992	337,071	395,870	59,956	27,637	94,418	177,077	1,047,142		201,862	571,386	252,754	262,962	73,944	3,502,080
1993	362,300	425,501	64,443	29,706	101,485	190,331	1,125,520		216,972	614,155	271,673	282,645	79,479	3,764,210

Note: (a) Included in Chemicals.

Source: Total manufacturing from PIM estimate with rectangular scrapping after 25 years.Investments from DGBAS, National Income in Taiwan, 1994.
Distribution over branches with DGBAS, The Trends in Multifactor Productivity, Taiwan Area, Republic of China, June 1994

Appendix Table C4 Labour Share in Gross Value Added, Taiwan, 1961-1993.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1962	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1963	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1964	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1965	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1966	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1967	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1968	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1969	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1970	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1971	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1972	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1973	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1974	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1975	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1976	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1977	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1978	0.44	0.53	0.57	0.60	0.55	0.50	0.32	0.66	0.39	0.45	0.73	0.43	0.68	0.51
1979	0.44	0.58	0.65	0.57	0.50	0.51	0.37	0.67	0.44	0.43	0.68	0.48	0.63	0.51
1980	0.47	0.56	0.65	0.60	0.56	0.50	0.40	0.65	0.46	0.48	0.65	0.49	0.66	0.53
1981	0.56	0.56	0.67	0.60	0.63	0.55	0.34	0.62	0.52	0.54	0.65	0.53	0.66	0.55
1982	0.62	0.57	0.72	0.61	0.64	0.54	0.33	0.60	0.53	0.50	0.70	0.57	0.66	0.56
1983	0.53	0.56	0.70	0.64	0.65	0.53	0.31	0.64	0.54	0.49	0.62	0.59	0.62	0.54
1984	0.51	0.56	0.73	0.62	0.67	0.50	0.32	0.73	0.55	0.46	0.64	0.60	0.66	0.55
1985	0.50	0.55	0.76	0.63	0.66	0.50	0.35	0.71	0.53	0.49	0.67	0.59	0.66	0.55
1986	0.54	0.55	0.75	0.65	0.65	0.49	0.31	0.69	0.50	0.46	0.64	0.57	0.64	0.53
1987	0.42	0.62	0.82	0.76	0.64	0.51	0.30	0.66	0.51	0.46	0.67	0.59	0.65	0.53
1988	0.44	0.61	0.90	0.74	0.71	0.52	0.33	0.69	0.50	0.46	0.68	0.62	0.66	0.55
1989	0.45	0.61	0.87	0.77	0.72	0.51	0.36	0.71	0.47	0.49	0.72	0.65	0.72	0.57
1990	0.53	0.55	0.81	0.72	0.76	0.54	0.44	0.67	0.48	0.49	0.70	0.65	0.71	0.58
1991	0.54	0.53	0.85	0.68	0.76	0.52	0.34	0.65	0.48	0.51	0.70	0.66	0.72	0.57
1992	0.53	0.53	0.84	0.74	0.80	0.55	0.40	0.63	0.47	0.53	0.68	0.67	0.76	0.58
1993	0.53	0.53	0.84	0.74	0.80	0.55	0.40	0.63	0.47	0.53	0.68	0.67	0.76	0.58

Source: 1976-1992 from DGBAS, The Trends in Multifactor Productivity, Taiwan Area, Republic of China, June 1994.
1961-1977 same as 1978, 1993 same as 1992

Appendix Table C5 Gross Domestic Product by Manufacturing Branch, United States, 1961-1993, in 1982 million US dollars

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	41,022	6,871	12,021	4,251	13,724	35,720	33,287	6,941	14,634	67,015	79,717	18,063	14,929	348,196
1962	42,722	7,311	12,745	4,610	14,178	37,228	35,747	7,975	15,376	72,125	91,382	20,341	16,195	377,935
1963	45,299	9,267	13,290	4,671	16,561	39,420	38,738	8,691	16,714	76,609	99,909	22,314	16,655	408,135
1964	45,423	9,861	13,732	4,811	19,322	42,907	41,036	9,433	17,818	84,333	107,866	23,566	17,183	437,293
1965	46,979	10,813	15,075	5,095	21,646	44,490	44,171	10,239	18,465	92,121	119,646	28,066	19,054	475,860
1966	49,308	11,748	16,310	5,366	21,789	47,061	46,247	11,128	18,587	99,354	131,825	32,411	21,202	512,334
1967	48,926	11,404	15,956	4,835	21,728	46,821	47,083	11,147	18,051	97,594	131,761	33,663	21,692	510,662
1968	49,905	11,970	16,739	5,051	22,833	49,590	51,665	12,641	18,741	99,687	139,713	35,218	23,470	537,223
1969	51,787	12,246	16,738	4,828	23,133	52,942	52,279	13,882	19,810	102,642	139,090	37,694	25,545	552,617
1970	52,875	12,939	15,613	4,389	22,253	49,812	55,402	12,369	18,999	93,774	124,176	34,786	23,408	520,796
1971	54,711	13,406	15,803	4,391	23,079	51,029	58,686	13,377	19,316	90,593	126,595	34,848	24,137	529,972
1972	57,812	14,344	18,501	4,530	26,790	54,858	61,608	15,272	21,212	98,448	138,795	38,755	26,970	577,894
1973	62,129	14,099	19,964	4,902	28,126	60,296	67,667	17,656	23,556	113,333	155,535	44,394	28,449	640,107
1974	57,095	12,627	18,843	4,716	27,075	57,814	62,634	16,373	22,122	109,614	150,399	41,363	28,462	609,135
1975	58,559	11,860	18,674	4,511	24,787	53,946	61,594	14,807	20,025	88,468	138,953	38,024	28,964	563,172
1976	61,603	14,487	20,090	5,042	27,898	58,922	69,948	15,400	22,328	95,970	154,079	41,961	31,051	618,779
1977	61,200	17,600	20,800	4,800	29,400	62,700	76,500	17,900	22,700	99,400	167,700	50,100	34,100	664,900
1978	66,500	16,600	21,500	4,900	30,400	65,100	77,800	19,000	23,300	106,200	173,900	56,200	33,300	694,700
1979	69,400	17,000	21,300	4,200	32,600	65,800	81,600	19,700	23,500	108,700	173,700	60,200	34,400	712,100
1980	69,400	16,400	21,100	4,300	31,700	62,800	72,900	18,600	21,300	101,900	158,700	63,300	31,600	674,000
1981	68,800	15,800	20,300	4,400	26,700	64,100	75,800	20,800	20,200	103,600	157,500	64,900	35,900	678,800
1982	70,300	14,800	18,900	4,100	25,500	65,100	79,700	19,300	18,200	81,600	141,700	61,800	33,700	634,700
1983	70,700	16,200	20,100	3,800	29,200	68,600	89,500	21,600	19,700	77,700	160,200	64,600	32,600	674,500
1984	69,900	16,000	20,400	3,600	32,500	70,300	98,900	24,700	21,300	88,200	194,300	73,500	38,900	752,500
1985	71,000	15,600	20,100	3,200	31,900	72,700	98,500	26,600	22,200	88,900	217,000	74,300	37,200	779,200
1986	72,600	17,000	21,000	2,700	33,300	74,700	105,700	26,700	22,900	87,000	225,900	74,100	39,700	803,300
1987	71,900	17,400	22,000	3,000	37,800	78,400	114,500	29,500	22,000	93,700	238,600	82,900	40,600	852,300
1988	74,178	17,060	22,765	3,156	36,822	80,598	120,949	29,455	22,897	94,099	256,556	90,878	48,331	897,746
1989	70,494	17,695	23,750	3,133	36,005	80,549	121,963	31,381	23,542	91,479	260,570	96,813	48,141	905,514
1990	73,903	17,811	23,214	3,053	33,808	81,174	117,717	31,533	23,220	92,066	258,375	97,090	48,666	901,630
1991	73,014	17,953	23,178	3,049	31,915	79,222	114,268	32,069	21,101	91,648	248,142	99,924	48,960	884,442
1992	72,053	18,983	23,571	3,290	31,761	79,126	116,300	34,087	22,467	92,716	256,194	98,918	48,376	897,843
1993	72,409	19,462	24,000	3,508	31,273	80,097	114,251	35,669	22,421	99,117	283,085	108,343	48,972	942,609

Source: 1961-1976, US Dept. of Commerce, National Income and Product Accounts of the United States, 1929-82, Washington D.C., 1986 (print out)
1977-1993 from Survey of Current Business, various issues;

Appendix Table C6 Persons Engaged by Manufacturing Branch (not full time equivalent) United States, 1961-1993, in 1000 persons.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	1,890	903	1,234	361	1,059	1,579	1,015	393	594	2,309	3,037	1,455	807	16,636
1962	1,879	914	1,285	362	1,085	1,607	1,019	438	602	2,393	3,230	1,556	829	17,199
1963	1,865	901	1,298	353	1,093	1,617	1,032	447	612	2,420	3,320	1,530	832	17,320
1964	1,872	903	1,318	352	1,133	1,640	1,039	463	627	2,512	3,404	1,510	841	17,614
1965	1,878	936	1,367	358	1,168	1,680	1,068	497	642	2,658	3,645	1,613	888	18,398
1966	1,889	974	1,418	368	1,209	1,742	1,123	541	658	2,819	4,024	1,856	958	19,579
1967	1,902	972	1,409	358	1,187	1,787	1,158	546	646	2,846	4,107	1,915	978	19,811
1968	1,901	1,006	1,425	363	1,217	1,817	1,193	587	651	2,897	4,165	1,933	999	20,154
1969	1,905	1,017	1,434	348	1,254	1,868	1,227	627	674	2,993	4,219	1,984	1,024	20,574
1970	1,891	990	1,384	323	1,213	1,853	1,219	611	657	2,841	3,872	1,871	988	19,713
1971	1,853	966	1,361	304	1,227	1,788	1,177	607	646	2,662	3,596	1,730	943	18,860
1972	1,827	1,005	1,391	302	1,287	1,805	1,165	656	667	2,717	3,738	1,782	986	19,328
1973	1,825	1,037	1,430	301	1,356	1,856	1,195	710	706	2,918	4,055	1,967	1,049	20,405
1974	1,819	991	1,371	283	1,301	1,859	1,219	706	701	2,934	4,134	1,985	1,084	20,387
1975	1,764	873	1,266	252	1,121	1,784	1,215	603	642	2,621	3,806	1,706	1,005	18,658
1976	1,790	922	1,353	272	1,222	1,833	1,246	653	661	2,689	3,904	1,783	1,047	19,375
1977	1,810	916	1,347	268	1,303	1,903	1,283	720	683	2,785	4,104	1,882	1,109	20,113
1978	1,831	920	1,366	272	1,364	1,966	1,308	760	716	2,912	4,387	2,027	1,171	21,000
1979	1,836	896	1,331	259	1,377	2,030	1,326	792	732	2,992	4,637	2,129	1,193	21,530
1980	1,810	859	1,298	244	1,283	2,042	1,324	733	685	2,787	4,446	2,114	1,175	20,800
1981	1,784	834	1,277	252	1,249	2,062	1,330	746	658	2,743	4,454	2,117	1,193	20,699
1982	1,744	759	1,190	232	1,131	2,053	1,290	696	590	2,381	4,052	2,034	1,156	19,308
1983	1,708	755	1,191	216	1,202	2,087	1,246	716	591	2,224	3,829	2,034	1,135	18,934
1984	1,697	761	1,226	199	1,289	2,171	1,238	792	620	2,364	4,151	2,228	1,152	19,888
1985	1,690	714	1,151	176	1,286	2,210	1,227	792	609	2,265	4,226	2,208	1,146	19,700
1986	1,710	716	1,135	158	1,305	2,241	1,195	798	604	2,206	4,131	2,132	1,134	19,465
1987	1,723	738	1,132	153	1,357	2,284	1,194	828	606	2,170	4,117	2,087	1,122	19,511
1988	1,722	740	1,123	153	1,390	2,376	1,226	841	619	2,223	4,194	2,197	1,148	19,951
1989	1,723	732	1,122	148	1,382	2,390	1,233	863	613	2,242	4,226	2,172	1,150	19,995
1990	1,733	704	1,076	142	1,350	2,410	1,254	860	599	2,194	4,139	2,077	1,123	19,661
1991	1,744	681	1,047	131	1,250	2,359	1,248	834	564	2,096	3,955	1,976	1,087	18,973
1992	1,724	682	1,040	125	1,264	2,319	1,241	848	555	2,035	3,809	1,891	1,057	18,590
1993	1,746	689	1,026	125	1,310	2,355	1,229	882	558	2,039	3,734	1,899	1,050	18,642

Sources: 1959-1988: US Department of Commerce, NIPA 1959-1988,vol. 2, Sept. 1992.;
1988-1993 Survey of Current Business, various issues.

Appendix Table C7 Gross Fixed Capital Stock in Manufacturing, USA, in million 1985$, midyear.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	102,473	42,862	6,988	3,776	29,023	80,090	130,551	16,277	40,187	126,587	116,238	28,518	17,243	740,814
1962	102,627	42,470	7,123	3,705	29,580	82,211	134,139	17,154	41,110	128,924	119,590	29,659	18,004	756,296
1963	102,569	41,896	7,480	3,597	30,194	84,116	136,955	17,925	41,712	131,414	122,917	30,532	18,623	769,929
1964	101,840	41,116	7,832	3,480	30,690	85,972	139,849	18,599	42,142	134,817	126,126	31,469	19,081	783,012
1965	100,525	39,370	8,036	3,361	31,235	88,986	144,639	19,576	42,719	138,983	130,584	33,064	19,625	800,703
1966	100,386	38,213	8,364	3,339	32,300	94,306	152,427	21,075	44,072	145,722	138,978	36,095	20,605	835,882
1967	101,602	38,369	8,847	3,399	33,488	100,576	161,150	22,877	45,406	154,846	149,469	39,997	22,049	882,074
1968	102,828	38,223	9,362	3,485	34,386	105,617	169,040	24,698	46,042	162,568	157,921	43,631	23,565	921,365
1969	104,561	38,440	9,970	3,583	35,511	110,251	176,035	26,619	47,095	168,350	165,317	47,144	24,843	957,719
1970	106,813	39,134	10,614	3,632	36,872	115,120	183,043	28,508	48,465	173,746	172,255	50,535	25,991	994,726
1971	108,636	39,694	11,223	3,653	38,197	118,728	190,054	30,033	49,508	178,217	176,916	53,335	27,128	1,025,323
1972	110,603	40,537	11,966	3,646	39,716	121,241	195,925	31,709	50,361	181,694	180,732	56,052	28,215	1,052,397
1973	112,581	41,592	12,713	3,639	41,433	123,324	200,911	33,941	51,200	184,909	184,859	59,436	29,546	1,080,084
1974	114,254	42,354	13,288	3,649	43,607	126,266	207,622	36,374	52,012	188,805	190,293	63,585	31,224	1,113,332
1975	116,660	43,116	13,788	3,646	45,757	131,298	217,027	38,410	53,097	194,787	196,917	67,175	32,764	1,154,441
1976	119,883	43,980	14,308	3,647	47,338	137,456	228,491	40,090	54,243	202,225	203,619	70,020	34,209	1,199,509
1977	123,834	44,970	15,002	3,681	49,332	144,008	240,909	41,784	55,342	209,697	211,628	73,125	35,786	1,249,097
1978	128,299	46,085	15,774	3,751	51,972	151,241	252,204	43,803	57,011	217,670	222,724	77,106	37,403	1,305,042
1979	132,602	46,987	16,335	3,832	54,685	159,294	263,108	46,139	59,007	226,402	236,491	82,382	39,260	1,366,524
1980	136,695	47,758	16,600	3,910	57,138	167,825	274,421	48,232	61,167	234,694	250,676	88,933	41,416	1,429,467
1981	140,606	48,295	16,776	4,004	58,861	174,699	285,519	49,876	62,731	241,773	264,883	95,907	43,524	1,487,455
1982	144,199	48,190	16,924	4,043	59,508	179,092	295,811	50,869	62,997	245,001	276,139	102,555	45,429	1,530,758
1983	147,161	47,606	16,983	4,017	59,589	181,912	303,064	51,182	62,421	243,988	281,596	108,624	47,103	1,555,244
1984	149,860	47,267	17,028	3,985	60,046	184,646	307,740	51,660	62,265	241,882	286,401	115,259	48,716	1,576,755
1985	152,949	47,210	17,033	3,925	60,788	189,468	311,487	52,841	62,663	240,216	295,063	123,309	50,619	1,607,571
1986	155,432	46,670	16,921	3,844	61,210	194,474	313,108	53,794	62,478	237,919	304,394	130,496	52,390	1,633,130
1987	157,762	46,023	16,792	3,791	61,749	198,772	313,564	54,213	62,253	235,706	312,521	137,012	54,017	1,654,175
1988	161,164	45,713	16,717	3,757	62,561	205,523	315,703	54,775	62,461	236,040	320,839	145,033	56,097	1,686,383
1989	165,174	45,238	16,498	3,725	63,302	216,822	320,045	55,507	62,714	238,269	330,023	153,799	58,614	1,729,730
1990	169,578	44,406	16,158	3,689	64,060	230,055	324,291	55,735	62,300	239,841	338,856	162,167	60,953	1,772,090
1991	174,477	43,314	15,712	3,637	64,011	239,411	326,705	55,368	60,956	238,204	344,624	169,098	62,882	1,798,398
1992	179,591	42,454	15,276	3,585	63,436	244,899	327,785	55,342	59,670	234,634	349,400	175,228	64,873	1,816,172
1993	185,245	42,049	14,940	3,542	64,068	251,036	328,991	55,706	59,723	232,187	358,321	183,488	67,058	1,846,353

Source: PIM with rectangular scrapping after service lifes (45 years for buildings and 17 years for equipment).
Investment from data underlying capital stock estimates by Van Ark & Pilat (1993) and van Ark (1998).

Appendix Table C8 Labour Share in Gross Value Added, USA, 1961-1993.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	0.58	0.84	0.84	0.84	0.74	0.74	0.62	0.62	0.74	0.79	0.73	0.73	0.74	0.74
1962	0.58	0.83	0.83	0.83	0.74	0.74	0.63	0.63	0.74	0.79	0.71	0.71	0.74	0.74
1963	0.56	0.83	0.83	0.83	0.73	0.73	0.61	0.61	0.73	0.77	0.69	0.69	0.73	0.72
1964	0.57	0.82	0.82	0.82	0.73	0.73	0.61	0.61	0.73	0.76	0.69	0.69	0.73	0.72
1965	0.57	0.80	0.80	0.80	0.72	0.72	0.59	0.59	0.72	0.74	0.67	0.67	0.72	0.71
1966	0.56	0.80	0.80	0.80	0.72	0.72	0.60	0.60	0.72	0.73	0.71	0.71	0.72	0.72
1967	0.58	0.81	0.81	0.81	0.74	0.74	0.62	0.62	0.74	0.74	0.73	0.73	0.74	0.73
1968	0.58	0.81	0.81	0.81	0.73	0.73	0.61	0.61	0.73	0.77	0.72	0.72	0.73	0.73
1969	0.59	0.82	0.82	0.82	0.73	0.73	0.65	0.65	0.73	0.79	0.75	0.75	0.73	0.76
1970	0.58	0.81	0.81	0.81	0.77	0.77	0.66	0.66	0.77	0.82	0.78	0.78	0.77	0.78
1971	0.58	0.82	0.82	0.82	0.75	0.75	0.64	0.64	0.75	0.81	0.74	0.74	0.75	0.75
1972	0.60	0.82	0.82	0.82	0.73	0.73	0.64	0.64	0.73	0.79	0.75	0.75	0.73	0.75
1973	0.62	0.83	0.83	0.83	0.73	0.73	0.62	0.62	0.73	0.79	0.78	0.78	0.73	0.76
1974	0.64	0.83	0.83	0.83	0.76	0.76	0.68	0.68	0.76	0.76	0.86	0.86	0.76	0.80
1975	0.55	0.81	0.81	0.81	0.73	0.73	0.65	0.65	0.73	0.77	0.82	0.82	0.73	0.76
1976	0.60	0.81	0.81	0.81	0.72	0.72	0.63	0.63	0.72	0.78	0.79	0.79	0.72	0.76
1977	0.62	0.77	0.77	0.77	0.72	0.72	0.64	0.64	0.72	0.80	0.76	0.76	0.72	0.75
1978	0.64	0.80	0.80	0.80	0.71	0.71	0.67	0.67	0.71	0.77	0.78	0.78	0.71	0.76
1979	0.65	0.82	0.82	0.82	0.72	0.72	0.69	0.69	0.72	0.77	0.82	0.82	0.72	0.79
1980	0.65	0.81	0.81	0.81	0.74	0.74	0.73	0.73	0.74	0.79	0.86	0.86	0.74	0.81
1981	0.64	0.81	0.81	0.81	0.75	0.75	0.69	0.69	0.75	0.77	0.85	0.85	0.75	0.80
1982	0.63	0.80	0.80	0.80	0.76	0.76	0.68	0.68	0.76	0.86	0.86	0.86	0.76	0.81
1983	0.59	0.79	0.79	0.79	0.75	0.75	0.64	0.64	0.75	0.87	0.81	0.81	0.75	0.78
1984	0.59	0.82	0.82	0.82	0.72	0.72	0.62	0.62	0.72	0.81	0.79	0.79	0.72	0.76
1985	0.60	0.81	0.81	0.81	0.72	0.72	0.63	0.63	0.72	0.81	0.83	0.83	0.72	0.77
1986	0.59	0.78	0.78	0.78	0.71	0.71	0.59	0.59	0.71	0.76	0.82	0.82	0.71	0.75
1987	0.59	0.79	0.79	0.79	0.70	0.70	0.59	0.59	0.70	0.77	0.78	0.78	0.70	0.74
1988	0.59	0.80	0.80	0.80	0.70	0.70	0.52	0.52	0.70	0.75	0.79	0.79	0.70	0.72
1989	0.58	0.78	0.78	0.78	0.68	0.68	0.53	0.53	0.68	0.73	0.79	0.79	0.68	0.72
1990	0.56	0.78	0.78	0.78	0.70	0.70	0.56	0.56	0.70	0.76	0.81	0.81	0.70	0.73
1991	0.56	0.78	0.78	0.78	0.70	0.70	0.56	0.56	0.70	0.76	0.81	0.81	0.70	0.73
1992	0.56	0.78	0.78	0.78	0.70	0.70	0.56	0.56	0.70	0.76	0.81	0.81	0.70	0.73
1993	0.56	0.78	0.78	0.78	0.70	0.70	0.56	0.56	0.70	0.76	0.81	0.81	0.70	0.73

Sources: data underlying van Ark and Pilat (1993), originally for 6 branches allocated to 13 branches.

Appendix Table D1 Real GDP per person employed by branch of manufacturing, Taiwan as % of USA,1961-1993.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	6.7	21.8	11.3	2.7	11.3	10.0	25.5	3.2	18.2	6.4	2.9	6.6	2.2	11.2
1962	6.9	20.8	10.9	2.0	10.8	10.6	28.8	4.1	19.6	5.3	2.9	7.5	2.0	11.5
1963	7.2	18.6	14.9	1.7	10.4	9.9	31.0	4.3	19.0	5.1	2.9	7.3	2.1	11.8
1964	7.7	22.4	26.2	1.8	11.4	11.4	35.3	5.5	20.5	5.2	3.7	11.7	2.4	13.2
1965	7.1	22.0	16.1	2.1	11.6	11.9	36.9	7.4	21.1	6.0	6.6	12.0	2.7	13.3
1966	6.7	24.4	16.7	1.9	11.7	13.8	44.5	10.3	24.6	6.7	8.2	16.4	3.9	15.0
1967	7.7	22.4	16.9	4.4	10.6	12.6	45.9	11.3	23.0	6.3	10.0	16.1	3.7	15.2
1968	8.0	19.4	17.7	4.9	12.1	13.8	57.8	12.4	23.0	7.0	11.1	20.9	4.2	16.1
1969	8.9	24.3	28.3	7.0	17.1	13.9	69.4	13.3	25.2	9.0	11.6	19.2	6.1	18.0
1970	9.1	26.5	45.3	10.4	19.0	14.9	74.5	18.1	27.7	11.0	11.2	19.3	8.2	19.3
1971	9.0	27.5	52.2	21.3	18.7	17.7	75.3	21.4	28.9	14.0	13.5	20.3	10.5	20.2
1972	7.5	27.3	41.1	20.0	21.8	19.2	76.6	19.5	23.6	16.1	14.8	19.3	9.9	19.8
1973	7.0	32.4	42.4	23.5	21.0	19.1	63.7	18.4	20.2	16.9	12.7	21.1	11.3	19.0
1974	9.1	29.6	45.8	34.6	14.8	15.6	48.9	17.0	22.1	12.8	14.0	19.0	17.5	18.1
1975	8.6	36.3	34.4	36.4	15.3	17.6	50.9	17.7	23.4	16.2	18.0	21.4	13.0	19.3
1976	11.0	35.2	44.3	30.9	12.5	18.3	46.0	21.0	26.1	19.1	17.2	19.9	16.4	19.9
1977	10.9	31.0	47.4	30.7	11.4	18.6	48.8	16.5	27.1	17.4	19.9	18.3	22.6	20.1
1978	10.6	38.8	52.0	35.4	15.1	23.2	50.7	19.8	31.2	21.6	20.1	21.6	24.0	22.4
1979	10.8	36.8	55.6	46.0	15.4	26.1	50.8	21.6	30.5	21.9	20.8	21.2	22.4	23.2
1980	11.0	47.9	67.9	45.7	13.1	27.6	51.6	21.9	33.2	24.0	23.3	22.9	23.6	25.1
1981	11.8	53.7	69.4	39.5	15.7	26.3	59.1	20.1	35.0	23.6	26.7	24.4	19.4	26.2
1982	12.1	52.9	74.1	42.6	14.0	22.7	54.2	21.6	33.7	25.5	27.3	26.8	20.0	26.6
1983	13.4	50.0	68.5	42.1	13.6	22.1	50.9	22.2	34.2	27.4	24.4	27.7	21.4	26.1
1984	13.7	55.7	73.2	47.1	14.4	23.3	47.9	22.1	33.6	27.4	22.5	27.8	17.9	25.4
1985	14.0	54.6	60.2	48.3	16.4	22.4	47.6	21.7	33.2	25.4	19.5	27.0	18.0	24.3
1986	14.4	60.4	62.0	57.8	20.2	25.1	42.7	26.8	33.6	28.5	20.1	30.9	18.4	25.7
1987	16.3	65.1	65.7	48.7	20.4	24.3	44.2	27.9	39.2	27.4	21.5	31.0	19.3	26.6
1988	16.5	63.4	56.0	43.3	20.5	24.0	44.0	30.3	42.7	30.0	21.3	33.1	17.7	26.8
1989	17.6	67.8	59.4	43.6	22.0	24.3	44.9	31.1	45.5	32.6	23.3	33.9	17.9	28.6
1990	17.4	71.0	61.0	45.0	21.9	23.5	48.0	33.8	50.2	33.8	23.8	34.2	16.8	30.0
1991	18.0	76.3	61.0	44.0	25.7	22.2	54.5	34.9	56.6	35.8	25.4	35.9	15.9	32.1
1992	18.7	72.8	57.8	33.7	28.1	20.6	54.3	33.9	55.0	35.6	24.3	35.9	15.6	31.8
1993	18.9	69.3	53.7	31.2	30.4	19.3	57.1	34.0	58.8	34.3	20.9	36.2	15.1	31.3

Source: Table 3 and Appendix Tables C1, C2, C5 and C6.

Appendix Table D2 Capital Stock per person employed by branch of manufacturing, Taiwan as % of USA,1961-1993.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products (a)	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	8.0	6.7	21.4	9.2	8.3	5.9	5.6		5.6	3.7	3.8	8.7	11.5	7.0
1962	8.8	7.5	25.3	10.4	9.1	6.5	6.2		6.3	4.2	4.4	9.7	11.8	7.8
1963	9.5	8.0	29.0	11.7	9.8	7.2	6.7		6.8	4.3	5.1	9.7	11.8	8.5
1964	10.9	9.5	34.5	14.1	11.5	8.4	7.7		7.8	4.9	6.1	10.6	12.5	9.7
1965	11.8	11.3	40.9	15.5	12.3	9.1	8.6		8.6	5.3	7.1	11.8	13.2	10.8
1966	13.4	14.3	51.9	18.5	13.9	10.5	9.6		10.4	6.0	9.2	14.4	14.7	12.7
1967	14.4	14.7	56.5	19.0	14.6	10.9	10.0		11.5	6.2	9.7	13.8	13.7	13.1
1968	16.8	16.4	67.3	21.6	18.0	12.0	12.0		13.9	7.5	10.7	13.8	14.4	14.7
1969	19.1	18.0	76.5	22.2	21.1	13.6	13.5		16.1	9.1	12.2	14.0	15.0	16.3
1970	20.7	17.8	89.1	21.7	21.5	14.5	13.7		16.6	9.6	12.0	13.3	13.7	16.2
1971	22.5	18.1	83.0	24.3	21.6	16.7	13.9		17.0	10.1	12.5	12.8	13.9	16.3
1972	22.4	19.4	79.1	26.1	22.8	19.8	13.7		17.7	11.2	14.5	12.5	15.2	16.9
1973	21.4	22.4	81.0	28.8	23.7	21.3	13.7		18.8	13.0	15.7	13.5	14.7	18.0
1974	22.7	27.3	88.0	31.7	26.1	22.2	15.3		17.7	15.9	17.3	15.8	16.7	20.3
1975	26.1	29.4	88.2	34.4	26.2	25.0	16.1		18.1	18.9	20.2	19.3	17.7	22.4
1976	28.1	32.1	95.2	30.9	27.2	26.5	16.6		19.5	22.3	23.5	16.5	16.9	23.2
1977	28.8	33.3	92.2	25.7	28.1	26.1	16.8		20.1	24.4	26.5	16.8	17.6	24.0
1978	29.6	32.9	92.3	24.4	28.7	26.0	16.7		22.3	25.5	25.2	17.2	18.6	24.2
1979	30.4	33.4	96.7	23.9	30.5	27.0	17.5		25.5	26.2	26.2	18.8	19.5	25.4
1980	30.7	35.1	99.1	24.7	31.6	26.6	17.0		26.7	27.7	25.8	19.2	18.5	25.6
1981	33.1	37.8	88.8	28.7	31.1	25.3	18.2		28.3	31.3	25.8	20.9	17.8	27.0
1982	38.2	38.8	79.9	28.4	29.3	26.2	17.0		25.7	30.3	25.6	21.7	16.0	26.7
1983	43.0	42.5	81.0	27.9	30.0	29.2	16.9		26.0	29.1	25.7	18.4	15.0	26.6
1984	42.6	46.5	78.9	30.7	31.0	30.9	17.2		29.2	31.0	28.5	15.8	14.0	27.3
1985	43.1	45.3	69.3	29.7	31.4	31.9	17.6		31.7	29.9	28.9	15.4	14.1	27.6
1986	47.4	50.7	71.9	29.9	30.8	32.7	18.7		34.7	30.9	27.5	13.6	13.6	28.2
1987	51.0	58.3	78.8	32.3	31.9	35.0	21.2		38.0	33.2	26.5	12.8	13.5	29.9
1988	56.3	65.2	81.7	36.1	33.9	39.1	24.6		42.3	35.9	27.7	13.8	14.8	32.9
1989	59.8	74.7	95.9	41.2	38.3	41.6	29.3		46.2	37.9	29.2	14.8	16.6	36.5
1990	61.9	88.2	111.6	48.2	49.2	43.8	36.0		51.4	40.8	30.4	15.6	19.0	40.6
1991	64.9	94.6	119.5	49.7	55.4	43.5	40.4		54.2	41.8	30.7	16.4	20.5	42.5
1992	65.1	100.2	135.8	53.0	68.8	42.4	45.0		58.2	42.9	30.0	17.1	22.3	44.5
1993	68.3	113.0	156.5	61.3	86.3	44.2	49.7		61.1	44.9	29.7	17.5	25.6	47.4

Note: (a) Included in Chemicals.

Source: Table 9 and Appendix Tables C2, C3, C6 and C7.

Appendix Table D3 Total Factor Productivity by branch of manufacturing, Taiwan as % of USA,1961-1993.

	Food & Beverages Tobacco Products	Textile Mill Products	Wearing Apparel	Leather Products & Footwear	Wood Products, Furniture, Fixtures	Paper Products, Printing & Publishing	Chemicals, Petroleum & Coal Products	Rubber and Plastic Products (a)	Non-Metallic Mineral Products	Basic & Fabricated Metal Products	Machinery and Transport Equipment	Electrical Machinery and Equipment	Other Manufac-turing Industries	Total Manufac-turing
1961	25.4	76.2	26.3	7.2	33.3	41.6	106.1		91.4	39.3	7.6	24.2	4.7	41.0
1962	24.9	69.1	23.7	5.0	30.6	42.1	113.5		91.9	31.1	7.6	25.9	4.2	40.0
1963	25.2	60.2	30.2	4.1	28.4	37.3	114.5		85.1	29.3	7.2	24.9	4.5	39.5
1964	24.6	67.0	49.0	4.0	28.9	39.5	123.5		85.0	27.8	8.7	37.7	5.0	41.3
1965	22.0	62.2	28.1	4.6	28.7	39.5	120.5		82.6	30.9	14.9	36.6	5.6	39.8
1966	19.3	62.7	26.3	3.9	27.4	42.3	139.8		85.6	32.5	17.3	45.1	7.6	41.4
1967	21.4	56.9	25.3	8.9	24.0	37.7	135.4		74.0	29.7	20.7	44.3	7.3	41.0
1968	20.2	47.1	24.3	9.5	25.0	39.2	135.8		65.7	29.3	22.4	56.4	8.3	40.9
1969	21.0	56.7	36.2	13.2	32.9	36.8	137.5		66.1	33.9	22.7	50.7	11.7	43.2
1970	20.3	61.3	53.0	19.4	35.7	37.6	135.9		70.0	39.0	21.7	50.1	16.3	45.7
1971	19.1	62.4	61.9	37.3	34.8	41.0	127.6		71.0	46.7	25.9	51.6	20.5	46.6
1972	15.8	60.5	49.1	34.2	39.8	40.7	130.2		56.7	50.9	27.3	49.5	18.8	44.9
1973	15.2	66.9	49.8	38.5	37.7	39.3	112.5		47.6	50.1	22.9	52.3	21.7	42.1
1974	19.0	54.7	50.8	53.8	25.0	31.3	87.1		53.4	33.9	24.6	42.1	32.2	37.5
1975	16.5	62.2	37.0	53.3	24.8	32.5	80.6		53.7	37.2	29.8	38.9	23.4	36.8
1976	20.0	58.4	46.4	48.1	20.1	32.7	73.5		57.5	40.2	27.5	39.6	29.9	37.3
1977	19.6	50.2	49.8	51.1	18.2	33.4	69.5		58.8	34.8	30.7	36.2	40.6	37.1
1978	18.7	62.9	54.2	60.2	23.9	41.6	76.7		63.9	42.2	31.4	42.4	42.3	41.0
1979	18.7	58.5	56.2	77.7	23.4	45.8	77.4		57.5	41.9	32.2	39.5	38.9	41.2
1980	18.7	73.5	67.6	74.6	19.2	48.3	78.0		59.3	43.0	35.6	40.8	41.5	43.4
1981	19.3	79.0	71.4	61.0	22.9	46.8	76.1		59.7	39.5	40.3	40.8	34.4	43.7
1982	18.6	75.2	78.0	64.7	20.7	39.6	72.5		58.6	41.4	40.4	42.5	36.5	43.6
1983	19.6	68.4	71.9	63.7	19.9	36.7	69.3		59.3	44.4	35.4	46.5	39.9	42.5
1984	20.0	73.5	77.6	68.0	21.0	37.7	65.1		55.9	43.9	31.9	50.0	34.1	41.2
1985	20.2	71.8	65.6	69.1	23.8	35.6	64.0		52.9	41.0	27.4	48.1	34.0	39.0
1986	20.0	75.7	67.0	81.3	29.6	39.4	61.1		51.2	44.9	28.5	56.8	35.3	40.6
1987	21.6	77.7	69.5	66.9	29.4	36.8	59.9		57.1	41.6	30.7	57.5	36.9	40.8
1988	20.6	72.6	59.0	57.9	29.1	34.4	56.9		59.2	43.9	30.0	59.7	32.8	39.3
1989	21.3	73.6	61.3	56.4	30.1	33.6	55.3		60.1	46.3	32.3	58.9	32.1	40.0
1990	20.6	71.6	61.6	55.8	28.1	31.5	57.0		62.4	45.9	32.4	57.5	28.9	39.8
1991	20.8	74.4	60.9	53.8	32.3	29.5	60.0		68.0	47.6	34.3	58.5	26.9	41.4
1992	21.6	69.5	56.5	40.4	33.6	27.5	57.4		63.7	46.6	32.8	57.1	25.8	40.1
1993	21.3	62.8	51.2	36.0	34.6	25.3	58.4		66.4	44.1	28.2	56.6	24.2	38.4

Note: (a) Included in Chemicals.

Sources: Table 9 and Appendix Tables C1-C8.

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