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Does the Capital Intensity of Structural Change Matter for Growth?[1]

by

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Abstract

Ventura (1997) offers an explanation for the success of the Asian Tigers in sustaining exceptional growth rates over an extended period based on capital accumulation alone. He points to their ability as export-oriented economies to exploit the accumulated capital to reallocate from labor-intensive to capital-intensive sectors instead of raising the capital intensity within each sector. We test this argument using industry-level data on manufacturing in 33 countries over three decades. The evidence on the argument is mixed. We identify two stages in the evolution of the structural change in the Tigers. It was labor-intensive initially and became capital-intensive in the 1980s. Compared to other countries, the Tigers are exceptional in the extent of their shift from a labor-intensive to a capital-intensive structural change during the sample period. However, structural change in the 1980s accounted for only a negligible part of capital accumulation in manufacturing. When tested in growth regressions the capital-intensity of structural change does not have a significant positive effect on growth. The effect may actually be negative.

Key words: "Asian miracle", structural changes, capital accumulation, sustained growth, capital intensity.

JEL: C31, C33, E22, F43, N15, O47

1. Introduction

In the past four decades, a number of East Asian economies have recorded extremely high rates of sustained economic growth and have achieved spectacular progress in major economic indexes: income per capita, manufacturing exports, the rate of investment, human capital accumulation, labor-force participation rates and the adoption of modern technology. The growth performance of these countries has substantially exceeded those of virtually all other economies that had comparable productivities and income levels in 1960. These four newly industrializing countries: Hong-Kong, Singapore, South Korea, and Taiwan came to be known as the Tigers, and their achievements the "Asian Miracle".

The phenomenal performance of the Tigers has motivated extensive literature seeking to explain it. The combination of unusually high investment and export rates in these countries has drawn much interest in explaining and quantifying their role in the exceptional growth. This research is surveyed in Section 2.

The explanations emphasizing investment and exports encounter several difficulties. The empirical research generally indicates that TFP growth in the Tigers was not very impressive. Diminishing marginal product of capital implies that in the absence of technological progress, high growth rates cannot be sustained over an extended period of time by capital accumulation alone. This point was forcefully made by Krugman (1994) who drew attention to the similarity between the Tigers and the Soviet experience regarding the dominance of the accumulation of physical capital. Another difficulty is that while the Tigers are all export-oriented the precise role of exports in promoting growth remains debatable. Most of all, a unified explanation as to why the *combination* of investment and exports may sustain exceptional growth was desired.

This all makes Ventura's (1997) hypothesis intriguing. Motivated by the East Asian experience, he constructs a model that illustrates how capital accumulation may facilitate sustained growth even in the absence of technological progress. Exports are crucial for that. Extending the Rybczynski theorem he shows that if investments are used to reallocate workers from labor-intensive industries into capital-intensive ones (structural change) instead of increasing the capital stock per worker in each industry (capital deepening), then each industry and the economy as a whole can avoid the

curse of diminishing marginal product. That is of course, provided that producers can sell their ever growing output without forcing prices down. A small open economy that can export any amount without affecting world prices can do just that.

This papers examines the empirical validity of Ventura's hypothesis. Using the UNIDO industry-level investment data set we construct an index of the capital intensity of structural change in the manufacturing sector of 33 countries during 1963-1990.[1] We check whether the Tigers[2] indeed moved into more capital-intensive industries, were they exceptional in doing so, and whether such a transformation accounted for a sizable part of capital-accumulation. We also test the effect of the intensity index in conventional growth regressions.

Our findings provide mix evidence on Ventura's hypothesis. While the Tigers experienced substantial structural change throughout the period, its capital intensity evolved over time. Initially (the 1960s and 1970s) they moved into labor-intensive industries. That is consistent with a Heckscher-Ohlin framework of a labor-intensive economy that is opening to trade. Only later (the 1980s) did structural-change there become more capital-intensive. The later stage is consistent with Ventura's analysis. Indeed, it seems reasonable that his model should apply to countries which have long been open to trade, and have apparently already exploited the benefits of their relative labor abundance. We find that the Tigers differ from other countries in the magnitude of the shift from a labor-intensive to a capital-intensive structural change during the sample period. The shift is even stronger if the period under consideration is extended to 1995. While these findings appear to support Ventura's hypothesis, we calculate that structural change during the 1980s accounted for only a negligible part of capital accumulation in manufacturing in the Tigers, as well as in other countries. Additionally, capital-intensive structural change does not have a positive significant effect in growth regressions. The effect is actually negative in many specifications.

The paper proceeds as follows. Section 2 reviews the literature that has attempted to explain and quantify the sources of East Asian growth. Section 3 provides a simplified illustration of Ventura's argument. The data are discussed briefly in Section 4. Section 5 describes the structural change: its extent and features, and the index we construct to measure its capital intensity. The regressions that test for the

[1] We often expand the sample period through 1995 at the cost of reducing the number of countries in the sample.

[2] We do not have data for Taiwan. Empirical references to the Tigers throughout the paper apply just to the other three countries.

effect of this index on growth are presented in Section 6. Section 7 addresses potential concern regarding our approach of examining structural change within the manufacturing sector rather than among wider sectors. Section 8 concludes.

2. Explaining East Asian Growth - Literature Review

This section reviews some of the literature that has tried to explain and quantify the sources of East Asian growth. Various papers have looked at the accumulation of physical capital, technological progress, trade and openness, human capital and a variety of other factors.

Nelson and Pack (1999) distinguish between two groups of explanations of the Asian miracle. The "accumulation" theories emphasize the role of physical investment in moving these economies "along their production function". The "assimilation" theories, focus on the entrepreneurship, innovation and learning that were essential to these economies if they were to master the new technologies they had been adopting from the advanced industrial nations. These theories consider investment in human and physical capital as a necessary, but far from sufficient, part of the assimilation process.

Much effort has been devoted to assessing the relative importance of physical capital versus technological progress. Young (1992, 1994, 1995) and Kim and Lau (1994) argue that almost all of the growth in the East Asian economies could be attributed to capital accumulation and only a small fraction to total factor productivity (TFP) growth. Others find much higher TFP growth. Tilak (2002) emphasizes the "education miracle" in East Asia. He argues that substantial investment in education, particularly in scientific and engineering skills, was important in facilitating technological progress. However, that alone was not enough for sustained growth and the rapid accumulation of physical capital was required as well. Bosworth and Collins (1996) pay particular attention to the construction of measures of human capital for 80 countries over 1970-1994. They find that TFP growth exhibited an upward trend over the years. This trend implies that the contribution of TFP growth tends to be underestimated. Nevertheless, they conclude that capital accumulation, not TFP growth, was the main source of growth in the miracle economies. Other growth accounting studies e.g., Hsieh (2000) reach a similar conclusion.

Growth accounting raises further problems regarding the measurement of TFP growth. Srinivasan and Quibria (1996) note that in open economies such as the Asian, technological advances are largely embodied in the latest vintages of capital equipment imports. Hence, growth accounting probably underestimates the extent of productivity growth and attributes the gains from new equipment to input growth instead. Klenow and Rodriguez-Clare (1997) show that TPF estimates are highly sensitive to the choice of data on human capital. Both papers conclude, however, that it was capital accumulation - not technological progress - that played the primary role in Asian growth .

Asia's experience provides much motivation for exploring the link between openness and growth. Following an early phase of import substitution, the miracle economies shifted in the 1960s to an outward-oriented strategy of development. Policy measures included lower tariffs and export subsidies, export processing zones, removal of quantitative restrictions on trade, competitive exchange rates and reduced barriers to international investment flows (ADB(1997)). Over the past four decades the share of exports and imports in their GDP has risen dramatically (from 42 percent in 1960s to more than 80 percent in the 1990s).

Theories of export-led growth explain the contribution of exports to growth through several channels. First, exports facilitate the exploitation of economies of scale in poor countries where domestic markets are small (Helpman and Krugman (1985)). Second, exports promote efficiency by increasing the degree of competition (Balassa (1978), Krueger (1980)). Third, exports promote the diffusion of technical knowledge through foreign buyers' suggestions and learning by doing (Grossman and Helpman (1991)). Fourth, exports help to relax the binding foreign exchange constraint to allow increases in imports of capital goods and intermediate goods (Mackinnon (1964)). Ventura offers another channel, reviewed shortly.

Empirical studies on the link between trade and growth in the East Asian economies point to the following channels: Increased exports enhanced their capacity to import inputs that embodied new technology. Access to new technology helped them circumvent the diminishing returns associated with increased accumulation of capital (Quibria (2002)). Nelson and Pack (1999) also emphasize firms' ability to adopt foreign technology. Exports increased the pressure for learning, because the Tigers increasingly had to move toward modern sophisticated technology to remain competitive and to meet the requirements of complex contracts from western

countries (Pack (2001)). Outward orientation helped to alleviate inadequate domestic demand (Ades and Glaeser (1999), and Bhagwati (1996) who notes how domestic demand constrained India) or inadequate availability of foreign exchange (Findlay (1971)). Frankel, Romer, and Cyrus (1996) addressed the problem of simultaneity between exports, growth, and investment and found that after correcting it, the effect of openness on growth in East Asia was indeed much stronger.

Rodrik (1995) argues that the increase in the profitability of exports created by outward–oriented policies in the 1960s was not enough to cause the investment boom that sustained growth. Rather, the boom was the outcome of a number of "strategic" government interventions and favorable initial conditions, such as the presence of an educated labor force and the equality of income and wealth.

The literature reviewed has offered several potential channels of technological progress whether internal (such as learning by doing, investment in education), or external - through trade and openness (such as export-induced incentives, adoption from advanced economies, technological change embodied in imported capital). Yet, the empirical papers generally agree that the accumulation of physical capital - not technological progress - was the primary source of growth in the Tigers. This finding poses a puzzle – the diminishing marginal product of capital implies that, in the absence of technological progress, high growth rates cannot be sustained over an extended period of time by capital accumulation alone. Furthermore, if openness did not contribute much in terms of technological progress – what was its role in ensuring that the accumulation-based growth was sustainable? Ventura's explanation to these questions is presented in the next section.

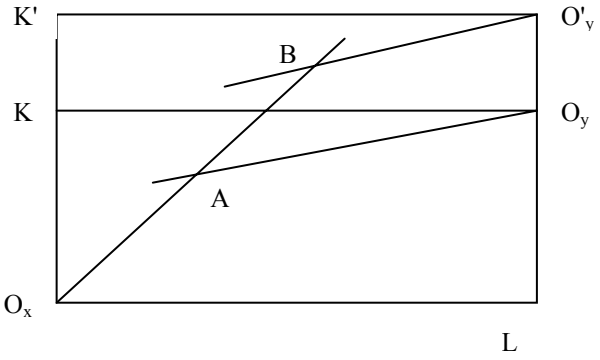
3. Ventura's Argument

Ventura (1997) combines a Ramsey growth model with a weak form of the factor-price equalization theorem. This allows to overcome diminishing returns to capital so its accumulation can sustain growth. The model shows that as the capital stock grows in an open economy, it does not lead to the production of the same goods with more capital-intensive methods, as would occur in a closed economy. Instead, structural change takes place, in which resources are reallocated from labor-intensive to capital-intensive industries. This process ensures that while the capital stock per

worker grows in the economy as a whole, it remains unchanged within each industry. Hence the marginal product of capital – and the rate of growth of output per worker – does not decline. The crucial role of international trade is that it converts the excess production of capital-intensive goods into exports, and if the economy is small relative to world markets, the prices of those goods do not fall in spite of the economy's increased supply. In such a trade-integrated world, diminishing returns apply to the world economy as a whole, and not to individual (small) countries. Returns on capital are the same in each of the integrated economies. The growth rate in each economy is determined by its rate of investment.

We present a simplified illustration of the argument by demonstrating the Rybczynski theorem in an Edgeworth-box diagram. Consider a small open economy that produces two goods: *X* (capital-intensive) and *Y* (labor-intensive). Initial equilibrium is at point A. Now the capital stock of the economy grows. The economy is small and open so the relative price of goods is given by the world markers. Since the prices of goods do not change neither do the returns to capital and labor. This in turn implies that the capital to labor ratio remains the same in each sector. The economy moves to equilibrium in point B producing more of the capital-intensive good and less of the labor intensive one.

Figure 1: The Rybczynski Theorem



4. Data

The UNIDO Industrial Statistics Database (INDSTAT3 2002, Rev. 2) provides annual industry-level data on employment, gross fixed capital formation, and other variables for the 28 industries of the manufacturing sector in a large number of countries beginning in 1963.

We use the UNIDO investment data to construct the net capital stock for each industry in each country, applying the perpetual inventory method described in Acemoglu and Zilibotti (2001). We assume a depreciation rate of 8 percent per year for all industries and countries.[3] UNIDO has no data on initial values of capital stock so in the analysis that follows we use only capital stock estimates constructed for 1980 and later.[4] Missing observations on investment in an industry in certain years are replaced by interpolation, where reasonable. We adjust the nominal investment data to purchasing power US dollars (using the investment PPP exchange rate from Penn World Tables 6.1) and then deflate them into 1995 prices (using the US investment fixed assets deflator). Missing data and criteria we applied to ensure the quality and consistency of the investment data reduce our sample to 33 countries. These are listed in Appendix A.1. Only three of the four Tigers are included as there are no investment data on Taiwan.

The ranking of industries in each country by their capital-intensity is stable over time. Spearman's coefficient for the correlation between the capital-intensity ranks of the industries[5] in 1980 and 1990 is 0.85 for the entire sample on average, somewhat higher for the OECD (0.93), and lower for the Non-OECD (0.79), and for the Tigers (0.76).[6] The correlation is statistically significant in all countries. The stability of the ranking is important since in some of the calculations that follow we use the 1980 capital to labor ratio of industries as a proxy for their capital-intensity in other years as well. The ranking of the industries by their capital-intensity varies

[3] Changing the depreciation rate to 10 or 12 percent per year did not change the results presented in the paper in any significant manner.

[4] 1980 was chosen because for most countries and industries the investment data start only in 1969, and a depreciation rate of 8 percent requires the accumulation of 12 years of investment.

[5] Spearman's coefficient is calculated for each country as follows: the industries are ranked by their capital intensity in 1980 and again in 1990. Pearson's correlation between the ranks (ranks=1,…,28) in the two years is then computed.

[6] Among the Tigers, the rank correlation is particularly low in Hong-Kong (0.59), and Singapore (0.75), while in Korea it is like the OECD average (0.93).

among countries. Appendix A.2 lists the 28 industries ordered by the cross-country average of each industry's relative capital-intensity.

In the discussion that follows, whenever we speak of aggregate capital or employment we refer to the manufacturing sector as a whole – not the overall economy - unless otherwise stated.

5. Structural Change

This section describes the scale and some major features of structural change in the sample.[7] It then presents the indexes we construct for the capital intensity of the structural change. These indexes are intended to measure Ventura's argument and will be used in the growth regressions in Section 6.

5.1 Scale and Features

We use the changes in shares of the various industries in total employment in the manufacturing sector as a measure of the scale of structural change. In particular, define those industries which increased their share in the total employment of the manufacturing sector during a specified period – the "rising" industries of that period. The figures summarized in Table 5.1 yield several observations: *(a) Scale:* Between 1963-1990 structural change in the manufacturing sector was substantial in all country-groups on average, but was significantly more pronounced in the Tigers. The proportion of workers in the "rising" industries increased by 23 percentage points in the entire sample, yet it increased by 40 points in the Tigers. *(b) Rate:* The rate of structural change (defined as the average annual change in the employment share of the rising industries) slowed down considerably in the Tigers during the 1980's, while it accelerated in other developing countries and remained unchanged in the OECD. The difference in the extent of structural change between the Tigers and the other

[7] Young (1992) analyses in detail the industrial transformation in Hong Kong and Singapore. Obviously some of our findings, such as rapid structural transformation, and substantial changes in the principal growth industries over time, even if measured differently, have already been noted by Young. His measure of structural change is also based on shifts in employment across ISIC manufacturing industries, but does not account for differences in capital intensity among them. Hence he does not actually provide an indicator of the capital intensity of structural change, which is at the core of our paper.

countries was thus much more significant in the earlier years of the sample. *(c) Concentration:* Structural change is highly concentrated in a small number of industries. The table indicates that the three industries whose share in employment increased most account for 60 to 73 percent (in the Non-OECD and Tigers respectively) of the increase of all rising industries. The degree of concentration is similar among the "declining" industries, where just three industries account for most of the combined decrease of all industries whose share in employment fell.

Table 5.1: Structural Change - Changes in the Rising Industries' Share in Manufacturing Employment

	Entire Sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
Scale[1] 1963-90	23	18	25	40
1980-90	11	8	13	14
Rate[2] 1963-80	1.00	0.76	1.06	2.00
1980-90	1.10	0.80	1.30	1.40
Concentration[3] (1963-90)	65	61	60	73

1. The percentage point increase in the share of the rising industries in total manufacturing employment.
2. Average annual percentage point increase in the share of the rising industries.
3. The increase in the share of the top 3 rising industries as a percent of the increase in the share of all rising industries.

Which industries account for most of the structural change? Table 5.2 reports the three industries that were most likely to experience the largest increase or decrease in their share in total manufacturing employment. Note the differences between the OECD and Non-OECD countries. In particular the "top" declining industries in the OECD are often the "top" rising ones in the non-OECD countries (apparel and textiles between 1963-1980, apparel and iron and steel between 1980-1990).[8] Somewhat surprisingly, the figures actually suggest a shift to labor-intensive industries in the OECD: capital per worker in the 3 top rising industries was much lower than the sector average (with the exception of food in 1980-1990). However, the declining industries were also generally labor-intensive (iron and steel excluded).

The table illustrates several similarities among the Tigers regarding the industries most involved in structural change and regarding the evolution of the capital intensity of the change over time: in the first sub-period the apparel and

[8] The textiles industry is both a leading rising and a leading declining industry in the Non-OECD between 1963-1980, reflecting the heterogeneity within this group of countries. Note that the textiles industry stands out as a declining industry in all three country-groups in both sub-periods.

electric machinery industries – both very labor-intensive - were among the three top rising industries in each of these countries. However, by the 1980s the non-electric machinery, which is more capital-intensive takes their place. In fact, the apparel and electric machinery lead the declining industries when the 1980-1995 period is considered (not reported in the table).[9] Despite the similarities among the Tigers, they often differ in the specific industries that were most involved in the structural change - as reflected by asterisks in the table.[10]

Table 5.2: The Industries Most Involved in Structural Change, 1963-1980 and 1980-1990
(in parentheses: capital per worker in the industry relative to the entire manufacturing sector)+

	OECD		Non-OECD		Tigers	
1963-1980						
Top 3 rising industries[1]	Non electric machinery Electric machinery Transport equipment	(0.56) (0.62) (0.79)	Apparel Textiles Metal	(0.25) (0.77) (0.79)	Apparel Electric machinery *	(0.31) (0.70)
Top 3 declining industries[2]	Textiles Apparel Food	(0.78) (0.24) (0.88)	Textiles Printing *	(0.86) (1.03)	Textiles Rubber *	(1.23) (0.74)
1980-1990						
Top 3 rising industries[1]	Printing Plastic Food	(0.59) (0.82) (1.08)	Food Apparel Iron & steel	(1.15) (0.24) (2.25)	Non elect. machinery * *	(1.04)
Top 3 declining industries[2]	Textiles Apparel Iron and steel Transport equipment	(0.75) (0.25) (1.90) (0.69)	Textiles * *	(0.87)	Textiles Wood *	(1.01) (0.93)

1. Three industries most likely to experience the largest increase in their share in manufacturing employment.
2. Three industries most likely to experience the largest decrease in their share in manufacturing employment.
* Denotes that no single industry is prominent in terms of the largest change in employment share in the relevant group of countries.
+ Averaged just over the countries in which that industry experienced the largest change in employment share.

Figure 2 plots the proportion change in the employment share of each industry between 1963-1980 (grey squares) and between 1980-1995 (black diamonds) against its 1980 capital stock per worker, in the Tigers.[11] The ISIC code of the

[9] 1995 figures were not available for many of the sample countries.
[10] The relative capital per worker in the other industries which experienced the largest increases in their share in manufacturing employment in the Tigers between 1980-1990 (or 1980-1995) ranges between 0.75 – 1.72, substantially higher than the figure for the top rising industries in 1963-1980. This is well illustrated in Figure 2.
[11] The three most capital-intensive industries in each country are omitted from the plot because their capital stock per worker is 2-10 larger than the next most capital-intensive industry. Including them

industries whose share changed most in each period (regular-type relates to 1963-1980, bold-type to 1980-1995) is also indicated in the graphs (see Appendix A.2 for code definitions).

The figure illustrates several points. There appears to be no straightforward correlation between the change in the industries' employment share and their capital intensity. In particular, there is no positive correlation – even in the later period - as Ventura's hypothesis would seem to suggest. Moreover, the "top" declining or rising industries are neither the most labor-intensive, nor the most capital-intensive ones (except for apparel (322)). However, the figure does reveal a more subtle graphic illustration of the structural change turning from labor-intensive (a Heckscher-Ohlin effect) in the first period into more capital-intensive (a Rybczynski effect) in the second period: The industries which increased their employment share most between 1980-1995 are more capital-intensive than those which increased it most between 1963-1980 (the bold-type codes above the zero line are further to the right than the regular-type codes – especially in Korea and Hong Kong). The industries that declined most between 1980-1995 are more labor-intensive than the declining ones between 1963-1980 (the bold-type numbers below the zero line are further to the left than the regular-type ones – especially in Korea and Singapore). Despite these common trends, the figure also demonstrates how the Tigers differ in the specific industries that experienced the largest changes in employment shares. Finally, note the differences in the range of the vertical axis: changes in the relative importance of particular industries was most dramatic in Singapore (almost 30 percentage points for electric machinery (383) and 15 for rubber products (355) between 1963-1980).

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would distort the proportions of the graphs and obscure the picture regarding all other industries. The changes in the omitted industries' shares in employment are negligible.

Fig. 2: Industries' Capital / Worker and Changes in their Share in Manufacturing Employment

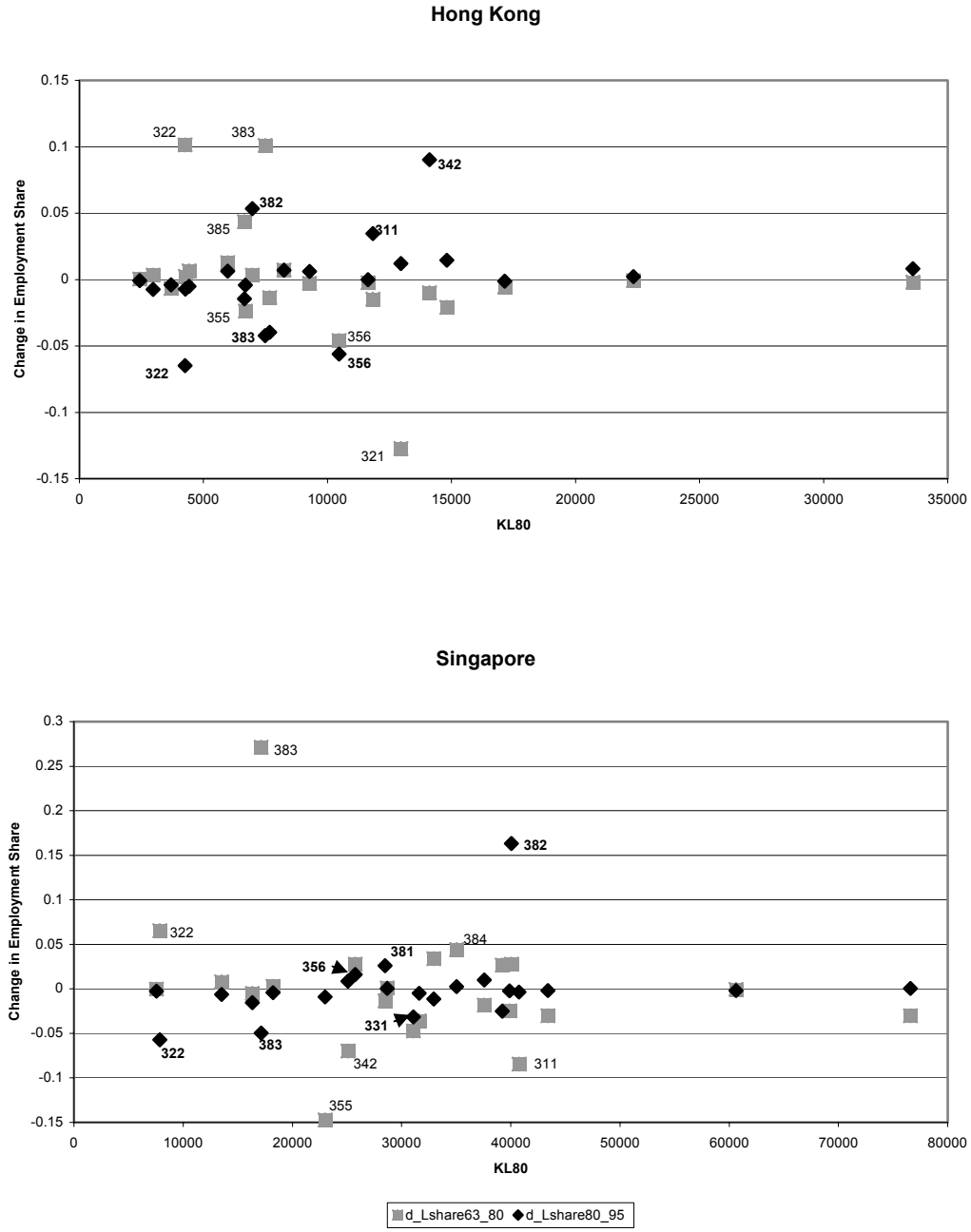
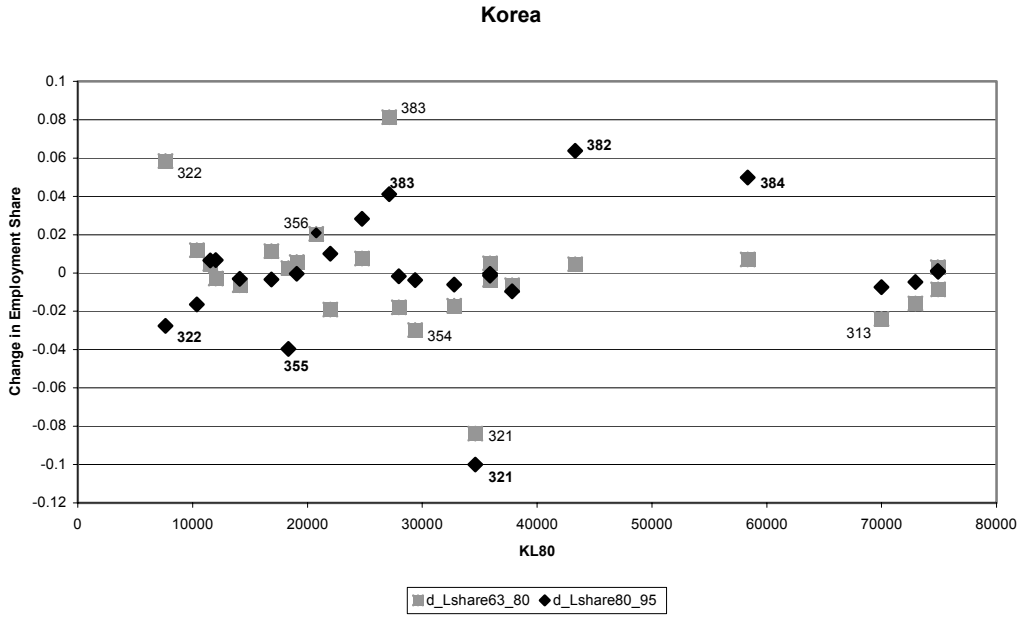


Figure 2- continued



5.2 Measuring Capital-Oriented Structural Change

Ventura's argument is that the Tigers' ability to maintain exceptional growth rates for a long period through capital accumulation was due to their reallocation of labor into more capital-intensive industries, rather than increasing the capital stock per worker within industries. Our objective is to construct an index of this reallocation that would allow us to test the hypothesis.

We offer two approaches for constructing such an index. The first is to obtain a weighted average of the capital intensity of the structural changes, i.e. of the shifts of labor among industries. The second looks at the fraction of capital accumulation that is due to structural change (the shift of workers into more capital-intensive industries) rather than capital deepening (the increase in the capital per worker within industries).

5.2.1 The Capital Intensity of Structural Change

The first approach is to measure the capital intensity of the structural change in the manufacturing sector. The building blocks are the capital per worker in each

industry and the change in the industry's share in total manufacturing employment. These allow us calculate the extent to which workers moved into more capital-intensive industries.

The index for the capital intensity of the structural change is constructed for each country *(j)* for a specified period (T_1-T_0). Country and period subscripts are omitted to simplify notation. Let:

d_L_i = the change in the share of industry i (i=1,…, 28) in total manufacturing employment during the specified period (e.g. 1963-1990). Clearly, $\sum_{i=1}^{28} d\_L_i = 0$.

KL_i = the capital to labor ratio of industry i in 1980.[12]

Summing $d\_L_i * KL_i$ over all industries gives the weighted capital intensity of the *changes* in the shares of the industries in total manufacturing employment. Hence it measures the capital intensity of the structural change. However, this measure would still be misleading in a cross-country comparison since it is sensitive to the level of capital per worker in the country, i.e. its level of development. To normalize the measure we divide it by the aggregate capital to labor ratio in the manufacturing sector of the country. Let:

Total_KL= the aggregate capital to labor ratio in the manufacturing sector in 1980.

The index for the capital intensity of structural change in a country is thus:

$$Intensity = \frac{\sum_{i=1}^{28} d\_L_i * KL_i}{Total\_KL}$$

The index increases with the capital intensity of the structural change. It is positive if the change is capital-intensive, negative if the change is labor-intensive, and equals 0 in the case of a strictly capital-neutral structural change.

This index captures the capital intensity of the structural change because it assigns each shift of labor from one industry to another its proper capital intensity: it counts each labor movement once upon leaving an industry (a negative *d_Li* multiplied by the *KL* of the originating industry) and once upon entering a new

[12] The choice of the 1980 level as the measure of each industry's capital intensity is arbitrary. The year of choice does not matter much because the ranking of industries by their capital intensity is stable over time, as noted earlier. A robustness check with the 1990 level follows shortly.

industry (a positive *d_Li* multiplied by the *KL* of the industry of destination) hence yielding the net effect.

Figure 3: The Capital Intensity of Structural Change, 1963-1980 and 1980-1995

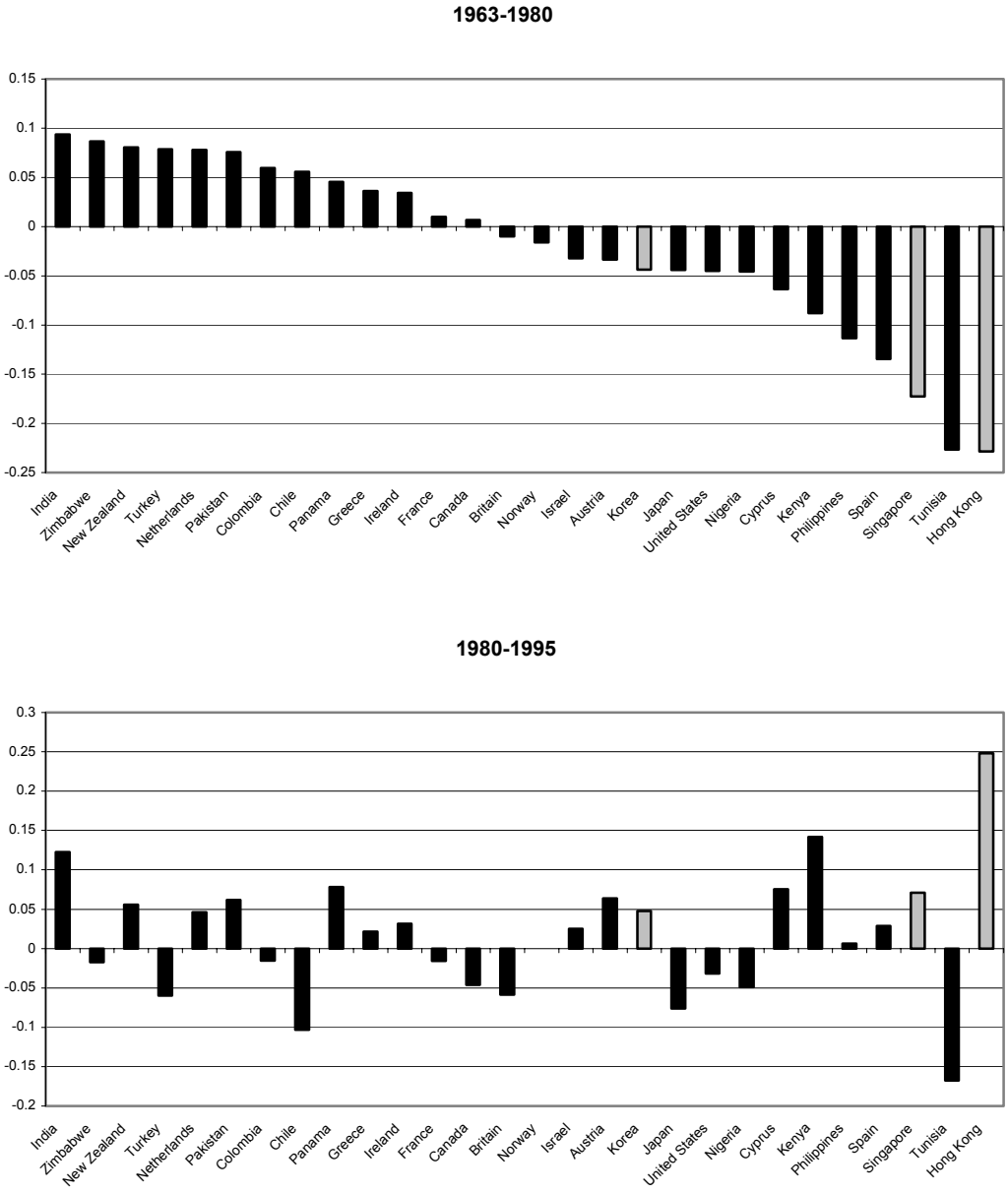


Figure 3 depicts the intensity index for the sample countries during 1963-1980 and 1980-1995.[13] The countries are lined in the same order in both panels to allow an easy comparison of each country in the two periods. The Tigers are marked in grey.

[13] The 28 countries for which data are available up to 1995.

Several points are noteworthy. The Tigers moved from a labor-intensive to a capital-intensive structural change: all three had a negative index in the first period and a positive one in the second. The shift is strongest in Singapore and Hong Kong: the index there was among the lowest between 1963-1980 but among the highest between 1980-1995. The figure illustrates that such a shift from a negative index to positive one (or vice versa) is not a world-wide feature. There is no clear relation between the sign of the index in a country in the first period and in the second one. Interestingly, the leading industrial countries (the sample includes five of the G-7) generally experienced a labor-intensive structural change throughout the period. Three of the five had a negative index in the first period (it was only marginally positive in France and Canada) and all had a negative one in the second period. These countries may have moved from industries that are intensive in physical capital to ones that are intensive in human capital. The issue is beyond the scope of the current paper.

Table 5.3 The Index of the Capital Intensity of Structural Change.

	Entire Sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
1963-90	0.008	0.001	0.044	-0.131
1963-80	-0.017	0.003	-0.010	-0.148
1980-90	0.025	-0.002	0.054	0.017
	Entire Sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963-95	-0.002	-0.001	0.002	-0.026
1963-80	-0.020	-0.003	-0.006	-0.148
1980-95	0.017	0.002	0.008	0.122

*Australia, Denmark, Finland, Iran, and Zambia are dropped when the sample is extended to 1995.

Table 5.3 presents the intensity index by country-groups and time periods. Extending the period to 1995 reduces the sample size but the later years are particularly important for analyzing the Tigers. The table shows that structural change throughout the period (1963-1990) was capital-neutral in the OECD, slightly capital-intensive in the developing countries**,** and labor-intensive in the Tigers. However, it is the breakdown into sub-periods that reveals the important differences between the Tigers and the other countries. The change in the index between the two sub-periods (1963-1980 versus 1980-1990) is negligible in the OECD and very small in the Non-OECD, while it is much larger in the Tigers. The Tigers stand out in the extent of their shift from a markedly labor-intensive structural change in the early years to a capital-

intensive one later. The decisiveness of the Tigers' shift and the difference between them and the other countries are even more pronounced if we consider the sub-periods of 1963-1980 versus 1980-1995 (the index for the Tigers rose from -0.148 to 0.122). These results point to the two stages in the Tigers' development, as noted earlier. Initially they moved into labor-intensive industries as would be expected from labor-intensive countries opening to world trade (a Heckscher-Ohlin effect). Only after this relative advantage had been exploited did they start moving into capital-intensive industries as would be expected from economies that are already integrated in world trade and are now taking advantage of it to grow through capital accumulation (a Rybczynski-Ventura effect).

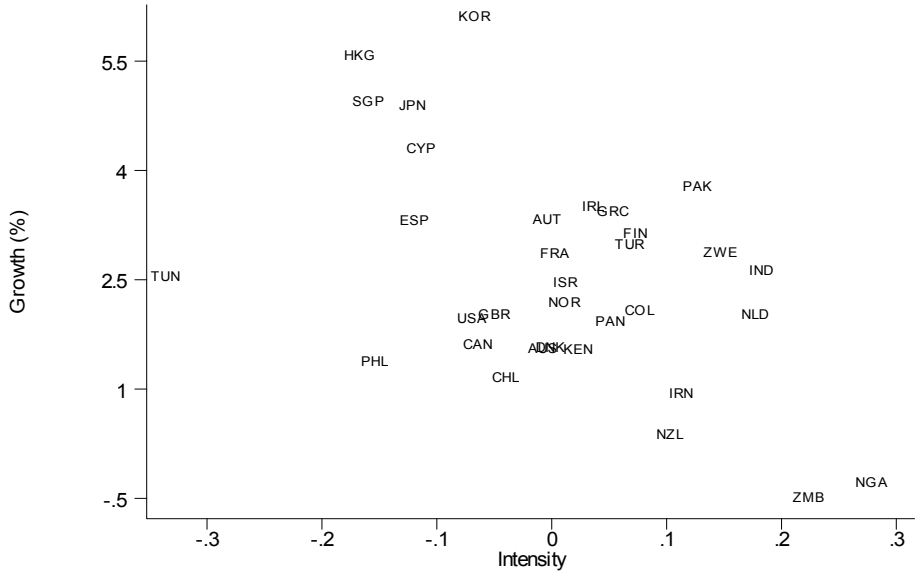
That structural change in the Tigers was first labor-intensive and became somewhat capital-intensive only in the 1980s, should perhaps come as no surprise if we consider the growth in total employment in manufacturing. Manufacturing employment in the Tigers grew at an average annual rate of 9.7 percent during 1963-1980 (compared with 0.9 and 5.7 percent in the OECD and Non-OECD countries respectively). It seems unlikely that these countries could have absorbed so many new workers in increasingly capital-intensive industries: this would require excessive investment rates. By the 1980s however, growth of employment in manufacturing had slowed to just 1 percent a year, so a shift into more capital-intensive industries became feasible. Yet, as we show shortly, investment was then directed primarily at raising the capital stock per worker within industries rather than at reallocating workers to capital-intensive ones.

As noted, the intensity index was constructed using the capital stock per worker in each industry in each country in 1980. We tested the robustness of the findings in Table 5.3 by using two alternative measures of the capital stock per worker in each industry: *(a)* The capital stock per worker in each industry in each country in 1990. This allows for the possibility that the relative position of industries (in terms of their capital-intensity) changed over time, or that the composition of sub-industries within each 3-digit code changed over time (possibly changing the average intensity of that category). *(b)* The average capital stock per worker of an industry in the OECD countries in 1980 was assigned to that industry in each of the sample countries. This allows for the possibility that the capital-intensity of an industry is an industry-specific feature rather than a country- specific one. It brings us closer to the properties of the Heckscher-Ohlin and Rybczynski models that all countries share the

same technologies and that capital per worker in an industry is the same in all countries in equilibrium. The results using these alternative measures (see Appendix A.3) are qualitatively similar to the ones just reported here, but are quantitatively milder. The intensity index still increases in the Tigers over time and the differences between the Tigers and the other countries are still substantial. However, the change in the index between the sub-periods in the Tigers is less dramatic and the level of the index there after 1980 is zero or slightly negative.

Figure 4 plots the average annual growth rate of GDP per worker in the sample countries against the intensity index during 1963-1990. There does not seem to be any clear relation between the two variables. Separate plots for 1963-1980 and 1980-1995 yield a similar result (not presented). Plotting the growth of manufacturing (rather than aggregate) GDP per worker also gives a similar picture.

Figure 4: *Intensity* and Growth of GDP per worker 1963-1990



A rigorous investigation of the growth-intensity relation will follow. Consider, however, the countries with initial conditions similar to those of the Tigers: there are six countries in our sample whose GDP per worker in 1963 was of the same order of magnitude as the Tigers' average.[14] The table in Appendix A.4 divides them into high growth and low growth countries. Data for the Tigers are also presented. Several

[14] GDP per worker in Japan and Iran was very close to Singapore's in 1963. We exclude them from the current discussion. Japan is a developed (OECD) economy. Iran is an oil exporter.

points emerge. There is no apparent relation between intensity and growth even among the countries with similar initial conditions. This holds whether we look at the intensity over the entire period or in sub-periods. The change in intensity over time was actually the same on average in the high- and low-growth countries, and much smaller than in the Tigers. Cyprus, the richest (in 1963) and fastest growing among the six countries considered, exhibited the largest increase in intensity and seems to resemble the Tigers closely. Yet the Philippines, the poorest and slowest growing, also experienced an increase in its intensity similar to that of Cyprus and larger than Korea's. The table also illustrates important differences among the Tigers regarding the intensity index and its evolution over time.

5.2.2 Decomposing Capital Accumulation

A major advantage of the indexes presented above is that they relate to an extended period of time, which is desirable when discussing long term issues such as structural change (and growth). A potential disadvantage is that they may measure Ventura's hypothesis inaccurately. Changes in industries' employment shares are indeed a reasonable proxy for structural change. However, it cannot be ruled out that an increase in an industry's share in employment reflects not just structural change (employment in the industry rises, without changing its capital per worker), but also an unbalanced growth of capital: some of the increase in the industry's employment may be due to investment massive enough so as to raise both the employment and the capital per worker in the industry at the same time. Any change in employment which can be attributed to a change in capital intensity, is not structural change in the strict sense examined in this paper. Hence we would like to distinguish between the two effects.

Rather than calculating the capital-intensity of the structural change, we now ask what proportion of the change in the manufacturing sector's capital stock can be attributed to structural change. This approach is particularly suited to address Ventura's hypothesis because his argument distinguishes between capital accumulation which serves to increase the capital intensity in each industry and would thus be expected to run into diminishing returns, and capital accumulation which is utilized to shift labor into industries that are more capital-intensive. We decompose the change in the aggregate capital stock per worker in the manufacturing sector in

each country between 1980 and 1990 into three components: structural change, capital deepening, and the interaction of both. The exercise is limited to 1980-1990 because the UNIDO investment data do not allow the construction of reliable capital stock estimates prior to 1980, as noted above.

For each country (country subscripts omitted) let:

$L80_i$ = the share of industry *i* in total manufacturing employment in 1980.

d_L_i = the change in the share of industry *i* in total manufacturing employment between 1980 – 1990.

$KL80_i$ = the capital to labor ratio of industry *i* in 1980.

d_KL_i = the change in the capital to labor ratio of industry *i* between 1980 - 1990.

d_KL = the change in the aggregate capital stock per worker in the manufacturing sector between 1980 - 1990.

Then:

$$d\_KL = \sum_{i=1}^{28} d\_L_i * KL80_i + \sum_{i=1}^{28} d\_KL_i * L80_i + \sum_{i=1}^{28} d\_L_i * \sum_{i=1}^{28} d\_KL_i$$

The change in the aggregate capital stock per worker is the sum of three factors: *(a) structural change* - the change in the capital stock due to the reallocation of workers among industries, holding the capital intensity in each industry constant at its 1980 level; *(b) capital deepening* – the change in capital attributable to the change in the capital intensity in each industry, fixing the industry's employment share at its 1980 value*; (c) the interaction* between structural change and capital deepening - the change in an industry's capital intensity which relates just to those workers who joined or left it. Let:

$$frac\_A = \frac{\sum_{i=1}^{28} d\_L_i * KL80_i}{d\_KL}$$

frac_A is the fraction of the change in the aggregate capital stock per worker that is attributable purely to structural change – the shift of workers from labor-intensive industries to capital-intensive ones (or vice versa). This a measure of Ventura's hypothesized effect. The fractions of the change in capital stock attributable to capital deepening and to the interaction term are defined in a similar manner.

Table 5.4: The Proportion Contribution to the Increase in the Aggregate Capital Stock per Worker in the Manufacturing Sector, 1980-1990.
(Coefficient of Variation in parentheses)

	Entire Sample (30)	OECD (14)	Non-OECD (13)	Tigers (3)
Structural Change*	0.026 (11.9)	0.060 (4.0)	-0.006 (73.9)	0.006 (4.5)
Capital Deepening	1.026 (0.3)	0.955 (0.4)	1.086 (0.3)	1.100 (0.1)
Interaction	-0.053 (-5.3)	-0.015 (8.6)	-0.081 (5.0)	-0.106 (0.7)

** frac_A*

Table 5.4 indicates that the increase in the capital stock per worker in the manufacturing sector in the 1980s reflects capital deepening at the industry level, not structural change. Structural change accounted for only 6 percent of the increase in the aggregate capital per worker in the OECD countries, while its contribution in the Non-OECD and Tiger countries was negligible. The finding is consistent the previous tables: structural change was substantial in the 1980s (Table 5.1), but it was only slightly oriented towards more capital-intensive industries (Table 5.3).[15] Extending the period under consideration to 1995 yields similar results for the Tigers. The role of structural change there intensified in recent years, but it still remained very small (it rose from 0.6 percent during 1980-1990 to 3 percent during 1980-1995).[16] The modest magnitude notwithstanding, these findings are in line with the previous observation that the shift to capital-intensive industries in the Tigers began only towards the end of the sample period. Lack of data on investment for many countries, including most OECD ones, prohibits the extension of this calculation through 1995 for the country-groups other than the Tigers.

The coefficient of variation reported in Table 5.4 illustrates that in all country-groups the variation in the contribution of structural change is much larger than that of capital deepening, especially in the less developed countries. It is also considerably larger than the variation in the rate of growth of capital stock per worker in the manufacturing sector overall (not reported in the table). This however does not mean that the extent of structural change is important in explaining differences in capital

[15] The sample in Table 5.4 is smaller because missing data prevent the calculation of the 1990 capital stock in three countries.
[16] Comparing 1980-1995 to 1980-1990, the contribution of structural change to the increase in the capital stock rose in each of the Tigers. The rise was largest in Korea (4 percentage points). The level of the contribution remained marginal in all Tigers: 4.4, 4.0, and 1.7 percent in Hong Kong, Singapore, and Korea respectively.

accumulation: capital-deepening accounts for almost all of the accumulation. The primary difference among countries is not in the relative importance of capital-deepening (versus structural change), rather in its absolute scale.

The results in Table 5.4 on the overwhelming role of capital-deepening versus the negligible one of structural change in accounting for the increase in the capital per worker in the Tigers are somewhat surprising. We take a closer look at Korea to get a concrete sense. Table 5.5 focuses on the four industries whose share in employment increased most between 1980-1990 in Korea. For these industries the table presents most of the components which were used in calculating the proportion contributions above. It also provides the OECD average of these measures. Several points are noteworthy. *(a)* The industries that increased most between 1980-1990 were already sizable in Korea by 1980, accounting at that time for almost 25 percent of manufacturing employment. That was still significantly lower than their share in the OECD in 1980 - 34 percent. *(b)* Their share grew rapidly in Korea during the 1980s while it remained almost unchanged in the OECD resulting in a convergence of the industrial structure of Korea towards the OECD one. In fact, by 1990 the share of these industries was almost 2 percentage points higher in Korea than in the OECD. *(c)* Structural change was overshadowed by capital deepening even among the industries which experienced the largest increase in their share in employment. This share increased by 4.4 percentage points at the most (electric machinery). The increase in capital per worker was much more impressive. In electric machinery it was 2.6 times larger in 1990 than in 1980. *(d)* The increase in capital intensity in these industries in Korea was not extraordinary. The respective figures for the OECD average are of the same order of magnitude. *(e)* The last column shows that the capital intensity of these industries did not change much relative to the manufacturing sector as a whole during the 1980s.

Similar trends in the four industries (rising employment shares and capital intensification) continued in Korea through 1995 (not reported in Table 5.5). By 1995 they accounted for 43 percent of manufacturing employment. Most of the gain in the employment share between 1990-1995 was due to non-electric machinery and transport equipment while the share of electric machinery decreased slightly. Despite the substantial structural change between 1980-1995, its contribution to the increase in the aggregate capital stock was minimal because these industries are not capital-intensive. Finally, note that even the detailed analysis in Table 5.5 cannot rule out the

possibility that there was actually capital-intensive structural change among sub-industries within the 3-digit categories. Such a change would appear as capital-deepening in our computations due to the level of aggregation of the data.

Table 5.5: Employment and Capital Intensity in Selected Industries*: Korea and the OECD 1980-1990

	Employment Share 1980 (%)		Change in Employment Share 1980-1990 (% points)		KL90/KL80		Industry KL Relative to Manufacturing Sector KL (1980, 1990)	
	Korea	OECD	Korea	OECD	Korea	OECD	Korea	OECD
Electric machinery (383)	10.8	8.0	4.4	0.7	2.6	2.0	0.68, 0.90	0.61, 0.74
Non electric machinery (382)	4.0	9.3	3.0	0.4	1.3	1.8	1.09, 0.71	0.57, 0.60
Transport equipment (384)	5.7	9.1	2.5	-0.8	1.9	2.0	1.47, 1.39	0.74, 0.92
Metal products (381)	4.4	7.8	1.5	0.1	1.9	1.5	0.62, 0.61	0.74, 0.66

* The industries with the largest gains in their share in manufacturing employment in Korea between 1980-1990.

6. Growth Regressions

We modify standard growth regressions to assess the effect of the capital intensity of structural change. We consider two types of regressions:

1) Cross-section regressions that examine the growth rates of the 33 countries between 1963-1990.

2) Panel regressions in which the time dimension relates to 5-year periods (1965-1970, …, 1990-1995) for each of the 33 countries (as in Barro (2001)).

The dependent variable is the average growth rate of real per worker GDP during the entire period in the cross-section regressions or during each five-year period in the panel regressions.

Following the growth literature (e.g., Barro (2001)) we include these explanatory variables (period averages unless otherwise stated):[17]

- GDP per worker (capita) at the start of each period to test for conditional convergence.

[17] Data on human capital are from the Barro-Lee data set. Data for all other variables (excluding *Intensity*) are from the Penn World Tables (version 6.1).

- Ratio of investment to GDP during each period, expected to have a positive effect on growth.
- Demographic variables: the log of life expectancy at birth and the log of the fertility rate.
- The ratio of government consumption to GDP.
- Openness to international trade (the ratio of exports plus imports to GDP).
- Measures of initial human capital, expected to have a positive effect on growth.
- Dummy variables for the Tiger countries and for the OECD countries.

We add the index of the capital intensity of the structural change (*Intensity*) to test whether it has a positive effect on growth as Ventura's hypothesis would suggest.

A cross-section regression investigates how differences among countries in the capital intensity of their structural change affect their growth rate over an extended period of time. A panel regression focuses on deviations of a country's intensity index from its average level in that country throughout the sample period. It tests how these shifts affect the country's deviations from its long term growth rate. The cross-section regression may thus be better suited to test Ventura's hypothesis, which relates to long run growth. The panel regressions are more susceptible to short term factors.

6.1 Cross-Section Results

Tables 6.1-6.3 present the main results of the cross section regressions for the entire period (1963-1990) and for the sub-periods 1963-1980 and 1980-1990 respectively. The dependent variable is the growth rate of real per worker GDP. Regressions with per capita GDP yield very similar results and are not reported.

The coefficient on *Intensity* is negative in all specifications. It is generally significant when the entire 1963-1990 period is considered and insignificant in the 1963-1980 sub-sample. The negative effect of *Intensity* is also insignificant for the 1980-1990 when all other right-hand variable are contemporaneous. However, if these variables are introduced with a lag in the 1980-1990 regressions (i.e. at their 1963-

1980 levels), the negative effect of *Intensity* becomes significant. This may indicate endogeneity in the contemporaneous variables.[18]

Table 6.1: Cross-Section Results, 1963-1990

Dependent variable: Growth of GDP per worker

	(1)	(2)	(3)	(4)	(5)
Intensity	-0.032 (-1.97)	-0.037 (-2.23)	-0.008 (-0.72)	-0.037 (-2.69)	-0.025 (-1.86)
Tiger * *Intensity* (dummy interaction)					-0.139 (-2.53)
GDP per worker 1963 (log)	-0.006 (-2.23)	-0.008 (-3.26)	-0.019 (-6.13)	-0.017 (-4.98)	-0.013 (-3.94)
Investment /GDP	0.091 (2.96)	0.114 (4.15)	0.063 (2.53)	0.103 (3.05)	0.098 (3.16)
Openness			-0.009 (-2.64)	-0.007 (-1.56)	-0.015 (-2.83)
Government consumption/GDP		-0.020 (-0.76)			
Total fertility rate (log)				-0.018 (-2.21)	-0.011 (-1.44)
Life expectancy (log)			0.096 (4.10)		
Tiger (dummy)	0.013 (1.69)		0.018 (3.27)		
Constant	0.059 (2.63)	0.077 (3.56)	-0.211 (-2.85)	0.181 (4.41)	0.145 (3.61)
Adjusted R^2 Observations	0.54 33	0.51 33	0.81 33	0.66 33	0.72 33

t-statistic in parentheses

A dummy for the Tigers has a positive and significant effect on growth in most of the equations. The effect of the interaction between the Tiger dummy and *Intensity* is negative and in some specifications significant. In the 1980-1990 sample it is insignificant. An OECD dummy is not significant, neither is its interaction with *Intensity*.

The coefficients of most other variables are of the expected signs and mostly significant - consistent with theory and other empirical studies. The effect of initial per worker GDP and fertility is negative, that of contemporaneous investment – positive. The effect of government consumption is insignificant, consistent with the ambiguity on the matter elsewhere in the literature. Somewhat surprisingly, the effect of initial human capital (measured in several ways) is insignificant, and that of openness is negative. Life expectancy is positively correlated with growth but this

[18] Data constraints do not allow the introduction of lagged variables in the 1963-1990 and 1963-1980 samples.

result should be treated with caution. The causality is dubious on theoretical grounds, and the high multicollinearity between life expectancy and initial per worker GDP erodes its statistical validity.

Table 6.2: Cross-Section Results, 1963-1980

Dependent variable: Growth of GDP per worker

	(1)	(2)	(3)	(4)	(5)
Intensity	-0.014 (-0.56)	-0.021 (-0.85)	-0.031 (-1.63)	-0.044 (-2.07)	-0.022 (-0.98)
Tiger * *Intensity* (dummy interaction)					-0.090 (-2.00)
GDP per worker 1963 (log)	-0.007 (-2.83)	-0.008 (-3.28)	-0.021 (-5.39)	-0.013 (-3.77)	-0.012 (-3.30)
Investment /GDP	0.112 (3.95)	0.123 (4.68)	0.092 (3.39)	0.150 (4.80)	0.147 (4.97)
Openness			-0.010 (-2.26)	-0.014 (-2.84)	-0.018 (-3.51)
Government consumption/GDP		-0.034 (-1.20)			
Total fertility rate (log)				-0.003 (-0.31)	0.002 (0.24)
Life expectancy (log)			0.075 (2.90)		
Tiger (dummy)	0.010 (1.31)		0.008 (1.24)		
Constant	0.072 (3.26)	0.083 (3.81)	-0.110 (1.24)	-0.128 (-2.96)	-0.106 (-2.52)
Adjusted R^2 Observations	0.50 33	0.49 33	0.73 33	0.62 33	0.65 33

t-statistic in parentheses

Table 6.3: Cross-Section Results, 1980-1990

Dependent variable: Growth of GDP per worker

	(1)	(2)	(3)	(4)	(5)
Intensity	-0.062 (-2.05)	-0.052 (-1.96)	-0.079 (-2.46)	-0.089 (-2.60)	-0.078 (-2.43)
GDP per worker 1980 (log)	-0.010 (-1.22)			-0.014 (-2.09)	
GDP per worker 1963 (log)		-0.019 (-2.93)	-0.014 (-2.53)		-0.014 (-2.52)
Investment /GDP (1963-1980)	0.006 (0.12)	-0.007 (-0.15)		-0.021 (-0.50)	-0.045 (-1.11)
Total fertility rate 1963-1980 (log)	-0.024 (-1.79)	-0.043 (-3.23)	-0.031 (-3.03)	-0.034 (-2.88)	-0.036 (-3.23)
Tiger (dummy)			0.032 (3.52)	0.041 (4.07)	0.037 (3.68)
Constant	0.137 (1.52)	0.249 (3.21)	0.185 (2.93)	0.201 (2.61)	0.201 (3.12)
Adjusted R^2 Observations	0.14 33	0.32 33	0.54 33	0.52 33	0.55 33

t-statistic in parentheses

* Government, openness, life expectancy, and the Tiger-I*ntensity* interaction were not significant in any specification.

We further tested the robustness of the cross-section regressions for the entire period and the respective sub-periods as follows: *(a)* We ran the regressions with the two alternative constructions of the *Intensity* index described in Section 5.2.1, using for each industry its 1990 country-specific or its OECD-average capital stock. The results are similar to those reported above. The coefficients on *Intensity* are negative under either construction and often significant. However, the level of significance is lower than obtained using the original measure. *(b)* We extended the sample period to 1995 (instead of 1990). This reduced the sample size to 28 countries, which given the number of explanatory variables, warrants much caution in evaluating the results. The coefficient on *Intensity* remains negative, but usually insignificant (we examined all three constructions of the index). The effect of the Tiger dummy is positive and significant in most specifications. In short the robustness checks do not alter the basic findings reported above.

6.2 Panel Results

The panel consists of up to six five-year periods (1965-1970, …, 1985-1995) for each of the 33 countries.[19] The reference to five-year periods follows Barro (2001). Table 6.4 reports the results of either a fixed effects or a random effects estimation depending on the indication of the Hausman specification test regarding which procedure is the appropriate one in each specification.

The main results from the panel regressions is that the effect of *Intensity* on growth is positive but insignificant. There is no difference in the effect among the OECD, non-OECD and Tiger countries, as indicated by the mostly insignificant interaction term. We use lagged investment rather than its contemporaneous values to avoid likely endogeneity.[20] Limiting the sample period to 1980-1995 yields similar results. Hence, despite the marked increase in *Intensity* in the Tigers (Table 5.3), the regressions (via the interaction term) do not reveal it had any effect on growth there even in those years.

[19] Data were not available for some countries in certain years so the panel is unbalanced.
[20] When contemporaneous investment is used the effect of *Intensity* is positive and significant. However such a specification is susceptible to endogeneity.

Table 6.4: Panel Results (1970-1995)

Dependent variable: Growth of GDP per worker

	(1)	(2)	(3)	(4	(5)	(6)
	random	Random	fixed	fixed	fixed	Random
Intensity	0.029 (1.13)	0.031 (1.15)	0.027 (0.9)	0.033 (1.11)	0.024 (0.82	0.029 (0.88)
Tiger * *Intensity* (dummy interaction)			0.135 (1.79)	0.116 (1.52)	0.116 (1.54)	
GDP per worker (log)	-0.015 (-2.55)	-0.015 (-2.53)	-0.034 (-3.17)	-0.047 (-3.28)	-0.039 (-3.55)	-0.020 (-2.95)
Lagged Investment/GDP	0.101 (3.40)	0.104 (3.23)	0.080 (1.69)	0.096 (2.01)	0.057 (1.22)	0.087 (2.69)
Government consumption/GDP	-0.053 (-1.68)	-0.054 (-1.68)	-0.138 (-2.49)	-0.125 (-2.23)	-0.111 (-1.94)	-0.074 (-2.23)
Lagged total fertility rate (log)	-0.017 (-1.86)	-0.017 (-1.84)		-0.020 (-1.38)		-0.016 (-1.61)
Lagged Openness		-0.001 (-0.21)			0.021 (1.65)	0.020 (0.36)
Initial average years of schooling						0.009 (0.60)
Constant	0.167 (2.63)	0.171 (2.60)	0.347 (3.28)	0.494 (3.30)	0.389 (3.60)	0.213 (3.17)
R^2 Observations	0.16 160	0.16 160	0.15 160	0.16 160	0.17 160	0.17 160

t-statistic in parentheses

* The choice between fixed or random effects estimation for each regression - according to a Hausman specification test.

Following Barro (2001) we also estimated the growth equations using Two Stage Least Squares to overcome potential investment-growth endogeneity (Table 6.5). The capital intensity in this setting may affect growth via two channels: *(a)* Directly – in the growth equation itself. *(b)* Indirectly – through its effect on investment in the first stage equation, which would in turn affect growth in the second stage equation. Table 6.5 shows that the direct effect is positive but insignificant,. The indirect effect is nil - *Intensity* has no effect on investment itself. The TSLS setting therefore does not change the basic result of the panel estimation presented in Table 6.4: the effect of the capital intensity of structural change on growth is positive but insignificant.

Regarding the other explanatory variables, the panel results yield coefficients of the expected signs and similar to those of Barro (2001). However the effect of human capital (measured in several ways) is insignificant in our results. In the TSLS setting none of the measures of human capital have a significant effect on investment in the first stage equation. This implies that physical and human capital are not complementary.

Table 6.5: Panel Results - TSLS Fixed Effects (1970-1995)

Dependent variable - second stage: Growth of GDP per worker (d_Y)
Dependent variable - first stage: Investment/GDP (I/Y)

	(1)		(2)		(3)	
	D_Y	I/Y	d_Y	I/Y	d_Y	I/Y
Investment/GDP	0.212		0.212		0.160	
	(2.22)		(2.24)		(1.49)	
Intensity	0.052	0.036	0.046	-0.074	0.054	0.036
	(1.54)	(0.60)	(1.15)	(-1.11)	(1.62)	(0.61)
Tiger * *Intensity*			0.027	0.439		
(dummy interaction)			(0.30)	(3.23)		
GDP per worker	-0.035	-0.063	-0.037	-0.082	-0.050	-0.09
(log)	(-2.28)	(-2.30)	(-2.23)	(-3.03)	(-2.84)	(-3.13)
Lagged Investment/GDP		0.493		0.497		0.439
		(5.91)		(6.20)		(5.30)
Lagged total fertility rate	-0.022	-0.015	-0.021	0.003	-0.014	0.040
(log)	(-1.45)	(-0.56)	(-1.32)	(0.11)	(-0.88)	(0.15)
Lagged Openness					0.032	0.067
					(1.96)	(2.96)
Initial average years of	0.002	0.002	0.003	0.001	0.004	0.002
schooling	(0.66)	(0.34)	(0.72)	(0.18)	(1.24)	(0.38)
Constant	0.326	0.757	0.335	0.901	0.440	0.914
	(2.04)	(2.87)	(1.99)	(3.49)	(2.50)	(3.50)
R^2	0.20	0.33	0.20	0.39	0.24	0.38
Observations	160	160	160	160	160	160

t-statistic in parentheses

Overall, neither the cross-section nor the panel estimations support the hypothesis that a more capital-intensive structural change promotes growth. This result holds for the sample-countries in general and for the Tigers in particular. In fact, the cross section estimates indicate that capital-intensive structural change may impede growth.

7. Reallocation within Manufacturing – Why?

This paper examined the capital intensity of structural change among industries within the manufacturing sector. Should we have looked at structural change among other sectors instead?

An immediate alternative that comes to mind is the shift from agriculture (traditional, labor intensive) to manufacturing (modern, capital intensive). A second thought reveals that the agriculture-to-manufacturing transformation is not the appropriate empirical framework here. There are several reasons for that. Some arise

from the fact that our paper focuses on the Tiger countries, which are the prime motivation for Ventura's model and the related literature surveyed earlier. Other reasons apply more generally to assessing the hypothesis anywhere, not just in the Tigers. Data on the Tigers for the following arguments are presented in Table 7.1. Data for Taiwan were not available.

Agriculture (a) Agriculture has always been negligible in Hong Kong and Singapore. Hence, in two of the four Tigers the agriculture-to-manufacturing transformation is irrelevant. Even if such a transformation were relevant in Korea (and Taiwan), it cannot be considered a feature of the Tigers as a group.

(b) In Korea agriculture was a dominant sector and its share in employment declined dramatically in recent decades, along with an increase in the share of the labor force employed in manufacturing. Even if were to consider Korea separately from Hong Kong and Singapore, the data suggest that an agriculture-manufacturing analysis is problematic. Between 1970 and 1995 the share of agriculture in employment fell by 36 percentage points, while that of manufacturing increased by 10 percentage points only. The relation between the change in the shares of both sectors is further weakened by the fact that the share of agriculture continued to fall despite the decline in manufacturing between 1990-1995.

(c) There are further reasons why the decline in agriculture is not the appropriate empirical test-case for Ventura's hypothesis even if we limit ourselves to comparing just Korea to other countries. Korean (and the other Tigers') growth is supposedly a unique phenomenon, the decline of agriculture is not; The decline in agricultural employment is to a large extent driven by technological progress and mechanization in this sector, whereas the model we wish to test emphasizes the accumulation of capital in the "rising" sector; Ventura's model stresses the interaction between trade and structural change. Yet the decline in agriculture occurs even in countries that are not particularly open to trade; Moreover, governments tend to intervene in agricultural production and trade (import restrictions, production and export subsidies, etc.) far more than in other sectors. This distorts the response of the agricultural sector to economic fundamentals.

Aggregate Manufacturing: In Ventura's model it is the continuous flow of labor into the capital-intensive sector that sustains growth. If this is true, then the sector's share in employment should rise as long as growth continues. The data indicate that manufacturing as a whole is not the empirical counterpart of that

theoretical sector. While growth was sustained for decades, the share of manufacturing in employment decreased dramatically in Hong Kong, and moderately in Singapore throughout the period. In Korea the share rose initially, but began declining in the 1990s.

Services: Should we look at the expansion of a sector other than manufacturing? Table 7.1 indicates that the financing, insurance, and business services sector expanded substantially in all three Tigers. However, this sector is intensive in human capital, while we are interested in the role of physical capital. Other service sectors which have expanded over time (such as community and social services, not reported in the table) are irrelevant to the discussion. They are generally non-tradable, dominated by the public-sector, and while they probably facilitate growth (e.g., by improving the labor-force), their output does not directly account for growth in the manner implied by the model. Clearly, these services are not intensive in physical capital either.

Table 7.1: Employment in Selected Sectors (as Percentage of Total Employment)

	Agriculture		Manufacturing			Financing, insurance, business services	
	1970*	1995	1970*	1990	1995	1970*	1995
Hong Kong		0.6	45.9	27.7	18.4	6.7	11.8
Singapore	0.5	0.2	29.6	28.9	24.0	5.5	14.9
Korea	48.4	12.4	13.3	26.9	23.5	1.3	8.0

* Hong Kong – 1980.
Source: ILO, Yearbook of Labour Statistics. No data for Taiwan.

There are several advantages to using reallocations of workers *within* the manufacturing sector for testing Ventura's hypothesis. Even if manufacturing as a whole is declining in terms of its share in total employment, it is still reasonable to expect internal flows within the sector such as a shift into capital-intensive industries; Manufacturing is highly tradable, differences in tradability among industries notwithstanding; The large range of industries within the manufacturing sector offers a better micro-based testing-ground for the hypothesis than shifts among a small number of aggregated sectors; It is possible to obtain reliable measures of the capital stock within the manufacturing sector. The availability and reliability of such measures in other sectors (services in particular) are much more questionable; Changes in the distribution of employment among broad sectors such as agriculture-manufacturing-services are closely intertwined with other processes such as

urbanization, technological progress, the rise of the "service economy" etc. The accumulation of physical capital may play a role in that transformation, but it is probably indirect and empirically difficult to isolate. In contrast, reallocations among industries within the manufacturing sector are much more likely to be directly related to the accumulation of physical capital, and can be empirically evaluated in those terms.

8. Conclusion

Ventura (1997) proposes a model which, he argues, may account for the success of the Asian Tigers in sustaining high and undiminishing growth over an extended period of time on the base of capital accumulation without technological progress. The explanation is based on the ability of a small open economy to shift from labor-intensive to capital-intensive industries thus avoiding diminishing returns to capital.

We tested this hypothesis on the manufacturing sector of 33 countries, focusing on three of the Tigers. The findings suggest two stages in the structural change within the manufacturing sector in the Tigers: it was labor-intensive at first, and became capital-intensive later. The first stage is consistent with the theoretical predictions about a labor-intensive economy that opens to trade. The second is consistent with Ventura's prediction about an open economy that is accumulating capital. We found that changes in the Tigers were more dramatic than elsewhere: structural change was more labor-intensive there in the first stage and turned more capital-intensive in the second stage compared to other countries. While the findings about the later period seem to support Ventura's hypothesis, we have shown that structural change accounts for only a negligible part of capital accumulation in manufacturing in the Tigers during the 1980s. Furthermore, growth regressions do not indicate that the capital intensity of structural change has a positive effect on growth.

We explained why we chose to investigate structural change within the manufacturing sector rather than among sectors in the overall economy. Clearly, this choice has certain disadvantages. In particular, it may make it harder to trace the relation between structural change (measured within a single sector) and growth (of

the entire economy). We restricted ourselves to the role of physical capital. The role of human capital within a similar framework may call for further research.

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Appendix

A.1 Countries Included in the Sample

OECD		Non-OECD		Tigers
Australia	Japan	Chile	Pakistan	Hong Kong
Austria	Netherlands	Colombia	Panama	Korea
Canada	New Zealand	Cyprus	Philippines	Singapore
Denmark	Norway	India	Tunisia	
Finland	Spain	Iran	Turkey	
France	United Kingdom	Israel	Zambia	
Greece	United States	Kenya	Zimbabwe	
Ireland		Nigeria		

A.2 The Industries of the Manufacturing Sector

Industries were ordered by ascending capital intensity in the following manner: In each country we calculated the capital per worker in each industry relative to that country's capital per worker in the manufacturing sector in 1980. For every industry this ratio was then averaged over the 33 sample countries. Finally, the industries were ordered by this average ratio.

Industry	ISIC code	Average relative capital intensity
Footwear	324	0.30
Wearing apparel	322	0.33
Furniture	332	0.39
Leather	323	0.56
Electric machinery	383	0.64
Non-electric machinery	382	0.75
Wood	331	0.75
Fabricated metal products	381	0.76
Printing and publishing	342	0.76
Transport equipment	384	0.84
Textiles	321	0.86
Plastic products	356	0.88
Other chemicals	352	0.88
Other manufactured products	390	0.90
Food	311	1.03
Tobacco	314	1.15
Rubber products	355	1.18
Professional & scientific equipment	385	1.20
Glass	362	1.29
Paper	341	1.63
Beverages	313	1.76
Petroleum & coal products	354	1.80
Non-ferrous metals	372	1.82
Non-metallic mineral products	369	2.01
Iron and Steel	371	2.20
Pottery, china, earthenware	361	4.40
Industrial chemicals	351	4.77
Petroleum refineries	353	9.01

A.3 The Index of the Capital Intensity of Structural Change

The index is calculated with two alternative measures of the capital stock per worker in each industry (see Sub-section 5.2.1):

a. The Capital Stock per Worker in Each Industry in Each Country in 1990.

	Entire Sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
1963-90	-0.054	0.001	-0.081	-0.191
1963-80	-0.017	0.016	-0.025	-0.138
1980-90	-0.037	-0.015	-0.056	-0.053
	Entire Sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963-95	-0.044	0.004	-0.066	-0.140
1963-80	-0.016	0.016	-0.018	-0.138
1980-95	-0.028	-0.012	-0.048	-0.002

b. The Average Capital Stock per Worker in Each Industry in the OECD Countries in 1980.

	Entire Sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
1963-90	-0.016	-0.005	0.002	-0.155
1963-80	0.005	0.007	0.032	-0.136
1980-90	-0.021	-0.012	-0.030	-0.019
	Entire Sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963-95	-0.038	-0.020	-0.032	-0.131
1963-80	-0.012	-0.002	0.008	-0.136
1980-95	-0.026	-0.019	-0.040	0.005

*Australia, Denmark, Finland, Iran, and Zambia are dropped when the sample is extended to 1995.

A.4 Intensity and Growth in Selected Countries

	GDP per Worker 1963 (1995 $)	Growth of GDP per Worker 1963-1995 (% per year)	Intensity 1963-1995	Intensity 1963-1980	Intensity 1980-1995	Change in Intensity 1980-95 minus 1963-80
High Growth						
Cyprus	8896	4.3	0.012	-0.064	0.076	0.140
Turkey	5962	2.7	0.019	0.079	-0.060	-0.139
Tunisia	7600	2.4	-0.394	-0.227	-0.168	0.059
Average	*7486*	*3.1*	*-0.121*	*-0.071*	*-0.051*	*0.020*
Low Growth						
Panama	8240	1.9	0.126	0.046	0.078	0.032
Colombia	8633	1.0	0.044	0.060	-0.015	-0.075
Philippines	5627	0.9	-0.107	-0.113	0.006	0.119
Average	*7500*	*1.3*	*0.021*	*-0.002*	*0.023*	*0.025*
Tigers						
Korea	4803	6.1	0.004	-0.044	0.048	0.092
Hong Kong	7375	6.2	0.019	-0.228	0.248	0.476
Singapore	10101	4.3	-0.101	-0.173	0.071	0.244
Average	*7427*	*5.5*	*-0.026*	*-0.148*	*0.122*	*0.270*