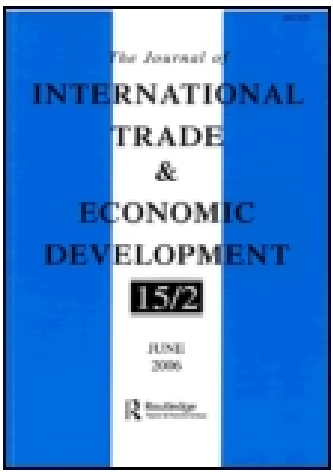

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The Asian miracle: Was it a capital-intensive structural change?

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The Asian miracle: Was it a capital-intensive structural change?

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The Asian miracle has been the focus of much research seeking to understand this extraordinary phenomenon. Ventura (*Quarterly Journal of Economics* 112: 57–84.) offers an explanation for the success of the Asian Tigers in sustaining exceptional growth rates over an extended period based primarily on capital accumulation. 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 only 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.

Keywords: Asian miracle; structural changes; capital accumulation; sustained growth; capital intensity

1. Introduction

For several decades, a few economies in East Asia have enjoyed very high rates of sustained growth exceeding those of virtually all other economies that had comparable productivities and income levels in the early 1960s. 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. In particular, the combination of unusually high investment and export rates has drawn interest in explaining and quantifying their role in the exceptional growth.

The explanations emphasizing investment and exports encounter several difficulties. The empirical research generally indicates that TFP growth in

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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 article examines the empirical validity of Ventura's hypothesis. Using the United Nations Industrial Development Organization (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.

Our findings provide mixed 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.

The article 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 in Section 4. Section 5 describes the structural change, and the indexes we construct to measure its capital intensity. Section 6 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, looking at the accumulation of physical and human capital, technological progress, trade and openness, and other factors.

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), Bosworth and Collins (1996), Hsieh (2000) and other growth accounting studies argue that most of the growth in the East Asian economies may be attributed to capital accumulation and only a small fraction to total factor productivity (TFP) growth. Tilak (2002) emphasizes the role of education in East Asia's technological progress. However, that alone was not enough for sustained growth, and the rapid accumulation of physical capital was required as well.

Growth accounting raises further problems regarding the measurement of TFP growth. Quibria (2002) notes that in open economies such as the Asian, technological advances are largely embodied in equipment imports. Hence, growth accounting probably underestimates productivity growth and attributes the gains from new equipment to input growth instead.[3] Klenow and Rodriguez-Clare (1997) show that TFP estimates often affected by 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.

Governments in the Tigers played an important role in the process of capital accumulation and its allocation among industries. Rodrik (1995) emphasizes the success of the governments in Korea and Taiwan in increasing the private return to capital by subsidizing and coordinating investment decisions. Amsden (1989) describes the policy of the Korean government to capture economies of scale by subsidizing the production of export goods and lowering interest rates, while focusing on large scale conglomerates. Glick and Moreno (1997) observe that growth policies in East Asia included nonneutral subsidies and other measures designed to support selected industries. They also highlight the Korean model of supporting selected infant industries through large-scale enterprises. In Taiwan, the government assisted selected industries and, in Singapore, it

invested in state-owned enterprises and offered incentives for private investment. The World Bank (1993) maintains that governments in these countries intervened to promote not only development in general but also that of specific industries. Selective measures included targeted and subsidized credit to specific industries, and the protection of producers of certain import substitutes.

Empirical studies on the link between trade and growth in the East Asian economies point to the following channels: Increased exports facilitated the imports of capital that embodied new technology (Quibria 2002); Exports promoted learning, because the Tigers had to adopt sophisticated technology to remain competitive and to meet the requirements of western markets (Pack 2001); Outward orientation compensated for low domestic demand (Ades and Glaeser 1999; Bhagwati 1996), or for shortage in foreign exchange (Findlay 1971). Correcting for simultaneity between exports, growth, and investment, Frankel et al. (1996) found that the effect of openness on growth in East Asia was much stronger. Rodrik (1995) argues that outward-oriented policies in the 1960s in South Korea and Taiwan could not by themselves sustain growth.

The various channels of technological progress notwithstanding, the empirical papers generally agree that capital accumulation – not technological progress – was the primary source of growth in the Tigers. This 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 overcomes diminishing returns to capital so its accumulation can support sustained growth. 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: resources are reallocated from labor-intensive to capital-intensive industries. This 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 as the economy is small, their prices in the world do not fall.

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 markets. 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.

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). UNIDO has no data on the initial capital stock, so we use only capital stock estimates constructed for 1980 and later.[4] 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). Data deficiencies reduce our sample to 33 countries (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 in 1980 and 1990 is 0.85 for the entire sample on average, somewhat higher for the Organisation for Economic Co-operation and Development (OECD) (0.93), and lower for the

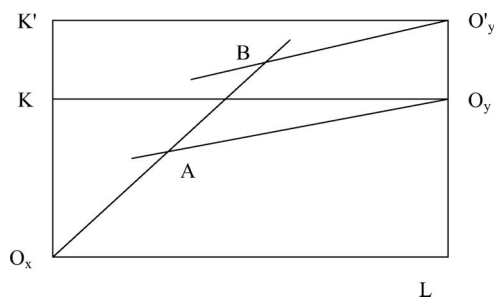

Figure 1. The Rybczynski theorem.

Non-OECD (0.79), and for the Tigers (0.76). 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. Appendix A.2 ranks the industries by their capital-intensity.

5. Structural change

This section describes the scale and some major features of structural change in the sample.[5] It then presents the indexes we construct for the capital intensity of the structural change. These indexes are intended to measure Ventura's argument.

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 1 yield several observations: (a) Scale: Between 1963 and 1990 structural change in the manufacturing sector was substantial in all country-groups, but was significantly more pronounced in the Tigers. The proportion of workers in the 'rising' industries increased by 23% points in the entire sample, yet it increased by 40 points in the Tigers. (b) Rate: The rate of structural change (the average annual change in the employment share of the rising industries)

Table 1. Structural change: changes in the rising industries' share in manufacturing employment.

	Entire sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
Scale[a]				
1963–1990	23	18	25	40
1980–1990	11	8	13	14
Rate[b]				
1963–1980	1.00	0.76	1.06	2.00
1980–1990	1.10	0.80	1.30	1.40
Concentration[c]				
1963–1990	65	61	60	73

Note: Values in parentheses represent number of countries in each country group. [a]The percentage point increase in the share of the rising industries in total manufacturing employment. [b]Average annual percentage point increase in the share of the rising industries. [c]The increase in the share of the top 3 rising industries as a percent of the increase in the share of all rising industries.

in the Tigers was exceptionally high between 1963 and 1980 (2% points per year on average, compared with not more than 1.1% point in the other country-groups). This rate slowed down considerably in the Tigers during the 1980s, 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 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 three industries whose share in employment increased most, account for up to 73% (in the Tigers) of the increase of all rising industries. The degree of concentration is similar among the 'declining' industries.

Which industries account for most of the structural change? Table 2 reports the three industries that were most prominent in experiencing the largest increase or decrease in their share in total manufacturing employment.[6] It 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 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).[7] 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.[8]

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. We offer two approaches for constructing an index of this reallocation. 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 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

Table 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)[a]

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

Note: [a]Averaged just over the countries in which that industry experienced the largest change in employment share. [b]Three industries most prominent in experiencing the largest increase in their share in manufacturing employment. See also Footnote 6. [c]Three industries most prominent in experiencing the largest decrease in their share in manufacturing employment. See also Footnote 6. *While apparel and electric machinery are the top two rising industries in all three Tigers, the third industry is different in each of them: It is plastic products, professional and scientific equipment and transport equipment in Korea, Hong Kong and Singapore, respectively. **No single industry is prominent in terms of the largest change in employment share.

employment. Thus, we calculate the extent to which workers moved into more capital-intensive industries.

The index for the capital intensity of 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 ($i = 1, \ldots, 28$) 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.

Summing $d\_L_i * \mathrm{KL}_i$ 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:

$$\text{Intensity} = \frac{\sum_{i=1}^{28} d\_L_i * \mathrm{KL}_i}{\text{Total\_KL}}$$

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_L_i multiplied by the KL_i of the originating industry) and once upon entering a new industry (a positive d_L_i multiplied by the KL_i of the industry of destination) hence yielding the net effect.

Figure 2 depicts the intensity index for the sample countries during 1963–1980 and 1980–1995.[9] The countries are lined in the same order in both panels and the Tigers are marked in gray. 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

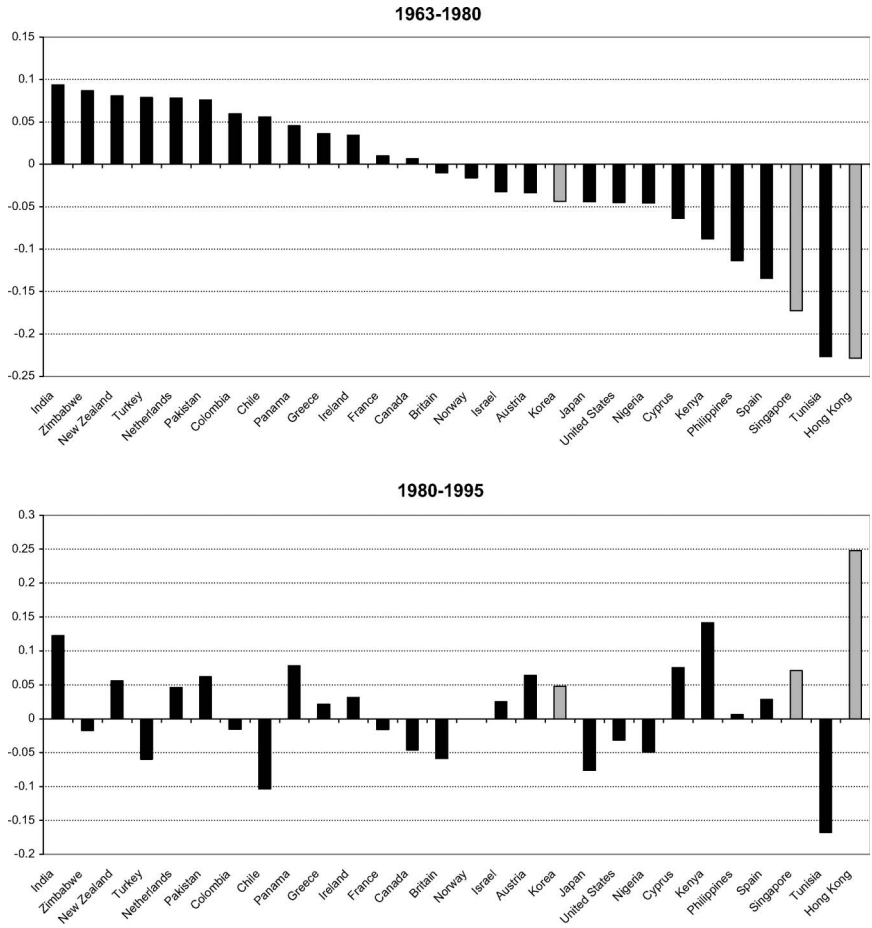

Figure 2. The capital intensity of structural change, 1963–1980 and 1980–1995.

positive one in the second. The shift is strongest in Singapore and Hong Kong: the index there was among the lowest between 1963 and 1980 but among the highest between 1980 and 1995. The extent of the shift in these two economies may in part be due to their very small size. The figure illustrates that while a shift from a negative index to positive one (or *vice versa*) occurred in several countries, it is not a world-wide feature. There is no clear relationship between the sign of the index in a country in the first period and in the second one. Interestingly, the leading industrial countries generally experienced a slightly labor-intensive structural change throughout the period, perhaps moving from industries that are intensive in physical capital to ones that are intensive in human capital.

Table 3. The index of the capital intensity of structural change.

	Entire Sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
1963–1990	0.008	0.001	0.044	−0.131
1963–1980	−0.017	0.003	−0.010	−0.148
1980–1990	0.025	−0.002	0.054	0.017
	Entire Sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963–1995	−0.002	−0.001	0.002	−0.026
1963–1980	−0.020	−0.003	−0.006	−0.148
1980–1995	0.017	0.002	0.008	0.122

Note: Values in the parentheses represent the number of countries in each group. *Australia, Denmark, Finland, Iran, and Zambia are dropped when the sample is extended to 1995.

Table 3 presents the intensity index by country-groups and time periods. 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 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. This is even more pronounced if we consider 1963–1980 versus 1980–1995. 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-abundant 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% during 1963–1980 (compared with 0.9 and 5.7% 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 within manufacturing. By the 1980s however, growth of employment in manufacturing had slowed to just 1% 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 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 capital-intensity of industries had changed over time, or that the composition of sub-industries within each three-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. However, it also implies factor price equalization, which does not hold in reality. The results using these alternative measures (Appendix A.3) are qualitatively similar to the ones just reported here, but are quantitatively milder.

5.2.2. *Decomposing capital accumulation*

A potential disadvantage of the indexes presented above 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 Ventura's 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. Recall that Ventura's argument distinguishes between capital accumulation which serves to increase the capital intensity in each industry, and that 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 into three components: structural change, capital deepening, and the interaction of both. The exercise is limited to 1980–1990 because the 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 and 1990. $\mathrm{KL80}_i$ = 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 and 1990. d_KL = the change in the aggregate capital stock per worker in the manufacturing sector between 1980 and 1990.

Then

$$d\_\mathrm{KL} = \sum_{i=1}^{28} d\_L_i * \mathrm{KL80}_i + \sum_{i=1}^{28} d\_\mathrm{KL}_i * L80_i + \sum_{i=1}^{28} d\_L_i * d\_\mathrm{KL}_i$$

The change in the aggregate capital stock per worker in the manufacturing sector 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

$$\mathrm{frac\_A} = \frac{\sum_{i=1}^{28} d\_L_i * \mathrm{KL80}_i}{d\_\mathrm{KL}}$$

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 is a measure of Ventura's hypothesized effect.

To clarify matters, consider the hypothetical case in which Ventura's effect accounts for all of the capital accumulation in the manufacturing sector. In that case, the capital stock per worker in each industry remains constant throughout the period so that d_KL_i equals zero for each of the industries (hence the second and third terms in the decomposition equation equal zero). The increase in the aggregate capital stock is due exclusively to structural change, i.e. workers moving (d_L_i) from labor-intensive industries (a low $\mathrm{KL80}_i$) to capital-intensive ones (a high $\mathrm{KL80}_i$). Hence frac_A equals 1. At the other extreme, suppose no reallocation of workers among industries takes place that is the relative number of workers in each industry

does not change. Hence d_L_i equals zero for all industries (and the first and last terms in the decomposition equation are zero). In this case, the increase in the overall capital stock reflects just an increase in the capital stock per worker within (at least some of the) industries (capital deepening). This implies that no structural has taken place; Ventura's effect does not account for any of the capital accumulation in the economy, in which case frac_A equals zero.

Table 4 reports the proportion contribution of structural change, capital deepening and their interaction to the increase in the aggregate capital stock per worker, corresponding to the three terms in the decomposition equation. The sum of proportions in each column is 1 by construction. The Table 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% of the increase in the capital per worker in the OECD countries, while its contribution in the Non-OECD and Tiger countries was negligible. The finding is consistent with the previous tables: structural change was substantial in the 1980s (Table 1), but it was only slightly oriented towards more capital-intensive industries (Table 3). 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 (3% during 1980–1995).

The results in Table 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 focuses on the four industries whose share in employment increased most between 1980 and 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 expanded most between 1980 and 1990 were already sizable in Korea by 1980, accounting at that time for

Table 4. The proportion contribution to the increase in the aggregate capital stock per worker in the manufacturing sector, 1980–1990.

	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)

Note: Values in the parentheses are coefficient of variation. *frac_A.

Table 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

Note: *The industries with the largest gains in their share in manufacturing employment in Korea between 1980 and 1990. Values in the parentheses are ISIC codes.

almost 25% of manufacturing employment. That was still significantly lower than their share in the OECD in 1980 – 34%. (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 toward the OECD one. In fact, by 1990 the share of these industries was almost 2% 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% 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). By 1995, these industries accounted for 43% of manufacturing employment. Despite the substantial structural change between 1980 and 1995, its contribution to the increase in the aggregate capital stock was minimal because these industries are not capital-intensive.

6. Conclusion

Ventura (1997) proposes a model that may account for the success of the Asian Tigers in sustaining high and undiminishing growth over an extended period 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. 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, structural change accounts for only a negligible part of capital accumulation in manufacturing in the Tigers during the 1980s.

An overall assessment of our findings suggests that they offer only weak support for Ventura's hypothesis. The major challenge is the finding about the overwhelming role of capital-deepening in the Tigers because the hypothesis draws crucially on their ability to avoid such deepening.

This brings us back to the basic puzzle. How could the Tigers sustain high growth through capital deepening? A possible answer is the importance of capital embodied technological change. If that is the case, then some of the measured increase in capital intensity in any industry should actually be accounted for as technological improvement. Involving a mismeasurement argument, embodied technological change is inherently difficult to test empirically. Note however, that while this explanation suggests a larger role for productivity growth relative to capital accumulation, it may actually offer a refined interpretation of Ventura's hypothesis. Suppose it were possible to decompose industry-level capital deepening into technological improvement and pure capital accumulation. The role of just the later could then be compared with that of structural change in accounting for the overall (technology-adjusted) capital accumulation in manufacturing. This may yield stronger support for Ventura's (technology-adjusted) hypothesis. Further research in that direction depends on devising improved methods of measuring capital accumulation and accounting for technological change embodied in it.

Notes

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.
3. Such a bias may affect our findings regarding the extent of capital deepening within the manufacturing sector in the Tigers and hence our interpretation of the importance of structural change and the validity of Ventura"s hypothesis. We discuss the issue in greater detail in Section 6.
4. 1980 was chosen because for most countries and industries the investment data start only in 1969, and the depreciation rate that we assume – 8% a year – requires the accumulation of 12 years of investment. Changing the rate to 10 or 12% did not change the results presented in the article in any significant manner.
5. Young (1992) analyses 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 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.
6. These are not always the same three industries in all countries in each country-group. Hence, we refer to the industries that experienced the largest change in the largest number of countries in each group. In some countries the industry that experienced the largest change may differ from those listed in the Table.

7. 1995 figures were not available for many of the sample countries.
8. 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 and 1990 (or 1980–1995) ranges between 0.75 and 1.72, substantially higher than the figure for the top rising industries in 1963–1980.
9. The 28 countries for which data are available up to 1995.

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Appendix

A.1. Countries included in the sample

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

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

(*continued*)

(*Continued*).

Industry	ISIC code	Average relative capital intensity
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 and scientific equipment	385	1.20
Glass	362	1.29
Paper	341	1.63
Beverages	313	1.76
Petroleum and 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.3.1. The capital stock per worker in each industry in each country in 1990

	Entire sample (33)	OECD (15)	Non-OECD (15)	Tigers (3)
1963–1990	−0.054	0.001	−0.081	−0.191
1963–1980	−0.017	0.016	−0.025	−0.138
1980–1990	−0.037	−0.015	−0.056	−0.053
	Entire Sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963–1995	−0.044	0.004	−0.066	−0.140
1963–1980	−0.016	0.016	−0.018	−0.138
1980–1995	−0.028	−0.012	−0.048	−0.002

A.3.2. 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)
1963–1990	−0.016	−0.005	0.002	−0.155
1963–1980	0.005	0.007	0.032	−0.136
1980–1990	−0.021	−0.012	−0.030	−0.019
	Entire sample (28)	OECD (12)	Non-OECD (13)	Tigers (3)
1963–1995	−0.038	−0.020	−0.032	−0.131
1963–1980	−0.012	−0.002	0.008	−0.136
1980–1995	−0.026	−0.019	−0.040	0.005

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