Productivity or Endowments? Sectoral Evidence for Hong Kong's Aggregate Growth*

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The present paper provides sectoral evidence that sheds new light on the current debate regarding the sources of growth of the East Asian miracle. We test both the productivity-driven and endowment-driven hypotheses using Hong Kong's sectoral data. The results show that most of the growth of the service sector is driven by rapidly-accumulating capital endowments, and not by productivity growth. In addition, productivity growth in the manufacturing sector is unimpressive. The manufacturing sector is revealed to be more labor intensive than the service sector and its growth is hindered by the reallocation of resources into the service sector as a result of the growth of capital endowments and imports. Overall, sectoral evidence supports the endowment-driven hypothesis.

Keywords: East Asian miracle; endowments; productivity; Rybczynski elasticity.

JEL classification codes: F14, F43, O47, O53.

I. Introduction

The history-defying growth of the four East Asian newly industrialized economies (NIEs) in the past 3 decades has fascinated economists and policy-makers around the world. After more than a decade of extensive research based on the aggregate statistics of the economies, the literature has offered two hypotheses regarding the 'economic miracle': the productivity-driven and the endowment-driven hypotheses. To date, there is still an ongoing debate regarding which of the two is the more important source of growth of these economies. The goal of the present paper is to provide consistent sectoral evidence that might substantiate or invalidate these aggregate findings, and to shed new light on the debate.

The productivity-driven hypothesis originated from the new growth theory, which emphasizes the role of productivity growth and its determinants. Romer

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(1990) shows that endogenous productivity growth, affected by firms' profit-seeking investment decision, human capital accumulation and trade, is the main source of long-run economic growth. Grossman and Helpman (1990, 1991) show how free trade between countries could affect the endogenous rate of productivity growth through increases in input variety and knowledge spillovers, and have effects on long-term growth. Finally, focusing on the East Asian NIEs, Lucas (1988, 1993) introduces the effect of trade on productivity growth through a learning-by-doing mechanism. Therefore, this school postulates that the growth of the four East Asian NIEs is a result of export-led productivity growth.

To provide a theory of sustainable long-run growth that is consistent with the empirical findings, Findlay (1996) and Ventura (1997) formalize the endowment-driven hypothesis. Ventura shows that in a general equilibrium setting, a small open economy can sustain high growth through the Rybczynski effects of factor accumulation. Given that factor prices are equalized through the free trading of goods, when an economy experiences growth in a factor, say capital, the capital-intensive industries in the economy will grow at the expense of the noncapital-intensive industries. Reallocation of resources across sectors makes it possible to defy diminishing returns to factor accumulation as long as the economy is not completely specialized. Therefore, for this school, the East Asian miracle is driven by the rapid growth of factor endowments sustained by international trade, and it can continue as long as the economies remain small and open.

In terms of empirical evidence, there is overwhelming support for the endowment-driven hypothesis. Using aggregate (primal) growth accounting techniques to infer the growth of primal total factor productivity (TFP), Young (1992, 1995) shows that most of the gross domestic product (GDP) growth of the NIEs could be explained by their aggregate capital accumulation, such that there is little sign of productivity growth in these economies. Young's results are supported by many papers, including Kim and Lau (1994), Krugman (1994), Collins and Bosworth (1996), and Kohli (1997).

It is only recently that the productivity-driven hypothesis has been resurrected by Hsieh (1999, 2002). Hsieh derives the implied (dual) productivity growth of the four East Asian NIEs based on the market factor returns in these economies. He shows that the dual TFP growth is, in general, higher than the primal TFP growth by 1–2 percentage points in these economies, depending on the various measures of rate of returns to capital investment. The difference is especially large for Singapore, which might have inflated aggregate capital investment data in its national accounts, causing a smaller primal TFP growth. Hsieh attributes the discrepancy between the primal and dual TFP growth rates to data issues. So far, this is the only piece of evidence that supports the productivity-driven story.

The central idea of the present paper is simple: if the contribution of productivity is indeed large at the aggregate level, then we should find high productivity growth in the industries in the economy. Conversely, if industry data show that most of the industry growth could be explained by the growth of the aggregate endowments, then it would be consistent with an endowment-driven growth hypothesis at the aggregate level.

To give some structure to the idea, we use a translog production-based GDP function approach similar to Kohli (1991, 1997) and Harrigan (1997). We show that the contribution of an aggregate endowment in GDP is correlated to the industry Rybczynski elasticity, which measures the percentage change of each industry output resulting from a 1 percent increase in that aggregate endowment. On the other hand, the aggregate contribution of productivity is correlated to industry productivity growth. In both cases, the degree of correlation depends on the output share of the industry in GDP.

We study the manufacturing and service industries of Hong Kong, which together cover more than 99 percent of the economy, from 1984 to 1997.[1] During that period, the value of the nominal GDP of Hong Kong jumped fivefold, and the aggregate capital stock more than doubled.[2] At the same time, output share of manufacturing in GDP dropped from 60 to 18 percent, and share of import in GDP increased by nearly 40 percent. The service sector, the remaining majority of the economy, was growing at an average rate of 17 percent annually. A finding of a large and positive Rybczynski elasticity of the service sector with respect to capital and a low productivity growth in the manufacturing sector would be sufficient to reject the productivity-driven hypothesis in favor of the endowment-driven hypothesis at the aggregate level.[3]

The results of our empirical analysis show that the service sector is indeed the more capital-intensive sector, which has benefited tremendously from the rapidly-growing capital endowment of the economy. The estimated Rybczynski elasticity shows that for every 1 percent increase in the capital endowment, output of the service sector increases by more than 2.4 percent. Given that the average annual growth rate of capital endowment is nearly 8 percent, it fully explains all of the output growth of the service sector in the sample period. Therefore, even though the regression results indicate that productivity elasticity of the service sector is positive and significant, given such a large endowment effect, the role of productivity in the service sector is negligible. On the other hand, productivity growth in the manufacturing sector is also found to be minimal: an average of 0.6 percent annually. The manufacturing sector is revealed to be more labor intensive. Its output growth is predominantly hindered by the reallocation of production factors into the service sector as a result of the growth of the aggregate capital endowments and imports.[4]

1. There are insignificant amounts of agriculture and fishing activities in Hong Kong.

2. The labor force of Hong Kong increased by only 20 percent during that period.

3. Given that the service share is growing when the aggregate capital endowment is increasing, a positive Rybczynski elasticity of capital in the service sector would be consistent with the endowment-driven story at the aggregate level.

4. In other words, the manufacturing sector is revealed to be more labor intensive, so it is hurt by the negative Rybczynski effect as the economy becomes more capital abundant. However, a positive Rybczynski elasticity of capital in the growing sector is not sufficient to lead to an aggregate finding

Combining a large and positive Rybczynski elasticity of the service sector with respect to the growing capital endowment with a lackluster productivity growth in the manufacturing sector, the present paper concludes that there is sufficient sectoral evidence to reject the productivity-driven hypothesis in favor of the endowment-driven hypothesis at the aggregate level in Hong Kong. The results are robust to the possible endogeneity of industry productivity and the aggregate capital endowment.

The present paper is organized as follows. We first present some standard growth accounting exercises to provide some background information of the economy of Hong Kong in Section II. A production-based GDP function that includes imports is derived in Section III. Empirical specification utilizing a translog function is developed in Section IV. The relationships between aggregate growth accounting and sectoral elasticities are presented in Section V. The data set used for the empirical analysis is shown in Section VI. The estimations and results are discussed in Section VII. Robustness checks of the estimation are provided in Section VIII. The conclusion is presented in Section IX.

II. Preliminary

We provide some preliminary evidence on the aggregate and sectoral growth patterns in Hong Kong in this section. Table 1 presents a standard aggregate growth accounting exercise from 1984 to 1997. As mentioned earlier, while the nominal value of Hong Kong's GDP increased fivefold in this period such that the average annual growth rate is nearly 13 percent, after removing inflation and the weighted growth of endowments, the implied TFP growth is approximately

Table 1 Aggregate growth accounting, 1984–1997

	Annual growth rate (%)	*Contribution (%)*
Nominal GDP	12.82	100
GDP deflator	9.34	72.85
Capital Stock (share in GDP = 0.579)	7.85	35.45
Labor (share in GDP = 0.421)	1.62	5.32
TFP*	−1.75	−13.63

Note: * TFP = 12.82 – 9.34 – 0.579 * 7.85 – 0.421 * 1.62. GDP, gross domestic product; TFP, total factor productivity.
World Development Indicator (2003).

of endowment-driven growth, unless there is no sign of any industries' productivity growth in the economy. To put it differently, if the Rybczynski elasticity of the service sector with respect to capital is not only positive, it is large enough that most of the growth of the service sector is explained by the growing endowment and leaves little sign of productivity growth, then to support the productivity-driven hypothesis at the aggregate level it would be necessary for the manufacturing sector to have high productivity growth.

−1.75 percent per annum. This number is significantly less than the 2 percent findings of both Young (1995) and Hsieh (2002), which is mainly because of the difference in period coverage.[5]

Table 2 presents results of a sectoral growth accounting exercise, for industries within the manufacturing sector, as well as the manufacturing sector as a whole. Our main data sources and descriptions can be found in Table 3. On average, the manufacturing sector has a 0.6 percent TFP growth per year for the period, and most of the drop in real output of the sector can be explained by the reallocation of resources away from the sector: employment and material exit the sector at a rate of 9.6 percent and 1.7 percent per year, respectively. Within the manufacturing sector, the growth rates of TFP range from 2.4 percent in the paper and print industry to −5.9 percent in the miscellaneous manufactures industry. Most industries observe decline in employment as well as material inputs.

Because of the lack of reliable data, a sectoral growth accounting exercise would not be applicable to the service sector. Nonetheless, we can still infer the productivity growth of the service sector based on information on the growth rates of the aggregate and manufacturing TFP. A back-of-an-envelope calculation based on Jorgenson-style sectoral calculation suggests that the productivity growth of the service sector during this period is −1 percent per annum.[6]

Overall, preliminary evidence indicates that aggregate and sectoral productivity growth has been modest in Hong Kong for the sample period. Therefore, a finding that service sector growth is mainly driven by capital accumulation and productivity growth in manufacturing is negligible would be consistent with the endowment-driven hypothesis regarding Hong Kong aggregate growth.

III. Theoretical Model: A General Equilibrium Setting

This section presents an empirical growth model according to a production-based GDP function. This model has been widely used in the literature to analyze the general equilibrium effects of trade.[7] Unlike the standard growth accounting exercises presented in the previous section, reallocation of resources between sectors are taken into account, such that the growth of sectoral output depends on growth of productivity and prices of all sectors, as well as the growth in *aggregate* endowments. Standard growth accounting exercises only consider

5. These authors only focus on the period 1966 to 1999, and they found 2 percent TFP growth per annum. Given the significant restructuring of the economy, moving from manufacturing to service sector in the 1980s and 1990s, we do not expect the average productivity of the latter period to be the same as the earlier period.

6. Given that aggregate TFP is a share weighted average between manufacturing TFP and service TFP, we can infer the service TFP as $(-1.75\% - 0.47 * 0.6\%)/1.65 = -1.2\%$. Notice that in this calculation we assume that there is not any TFP growth in imports. Share of imports in GDP is −112 percent, which implies that share of service in GDP is 165 percent.

7. See Kohli (1991, 1997) and Harrigan (1997). For an excellent textbook treatment of the GDP function, please refer to Feenstra (2004).

Table 2 Sectoral growth accounting, 1984–1997

Annual average	*Manufacturing† (%)*	*Textiles (%)*	*Paper and printing (%)*	*Chemicals‡ (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*
Total sales growth	2.22	0.28	10.82	0.28	2.22	3.34
Price growth	3.85	3.14	2.59	1.80	5.64	9.25
Capital input growth	1.99	–2.14	8.92	0.61	3.78	2.69
Share of capital in sales	19.20	16.97	25.99	22.86	19.28	15.45
Weighted growth of capital§	0.38	–0.36	2.32	0.14	0.73	0.42
Labor input growth	–9.62	–11.82	0.14	–12.45	–9.55	–6.75
Share of labor in sales	16.77	18.70	20.42	14.65	14.63	15.70
Weighted growth of labor§	–1.61	–2.21	0.03	–1.82	–1.40	–1.06
Material input growth	–1.65	–2.63	6.57	–3.26	–2.72	0.93
Share of material in sales	64.03	64.33	53.59	62.49	66.09	68.85
Weighted growth of materials§	–1.06	–1.69	3.52	–2.03	–1.80	0.64
Primal TFP growth¶	0.59	1.34	2.41	2.11	–1.11	–5.94

Note: All values are the annual averages for 1984–1997.
† Standard Industrial Classification 311/312, 313, 314 (food, beverage and tobacco products) are excluded. ‡ SIC 353/354 (petroleum and coal products) is excluded from the data because of the lack of data prior to 1988. § Weighted growth of input equals input growth times share of input in sales. ¶ Primal TFP growth equals total sales growth minus the growth rate of price, and all the weighted growth of inputs.
TFP, total factor productivity.

Table 3 Data description

Years: 1981–1998.

Product classification system: There are a total of five industries, briefly follows the nine categories of the two-digit level of the Hong Kong Standard Industrial Classification (HSIC). The categories, and their three-digit HSIC constituent parts, are listed below.

Industry	*HSIC (1981–1989)*	*Description*	*HSIC (1990–1996)*	*Description*
Textiles	320/322	Wearing apparel	320/322	Wearing apparel
	323	Leather products	323	Leather products
	324	Footwear	324	Footwear
	325–329	Textiles	325–329	Textiles
Paper and printing	341	Paper products	341	Paper products
	342	Printing and publishing	342	Printing and publishing
Chemicals†	351/352	Chemical products	351/352	Chemical products
	355	Rubber products	355	Rubber products
	356	Plastic products	356	Plastic products
	361–369	Non-metallic mineral	361–369	Non-metallic mineral
Machinery and electronics	371/372	Basic metal	371/372	Basic metal
	380/381	Fabricated metal	380/381	Fabricated metal
	382	Machinery	382	Office machinery
	383	Electrical, electronic products	383	Radio, TV and communication equipment
	384	Electrical, electronic parts	384	Electronic parts
	385	Scientific instruments	385	Electrical appliances
	NA		386/387	Machinery
	NA		388	Transport equipment
	389	Transport equipment	389	Scientific instruments
Miscellaneous manufacture	331	Wood products	331	Wood products
	332	Furniture	332	Furniture
	390/391	Other manufacturing	390/391	Other manufacturing

Share of each industry in total output of manufacturing sector

Source: Survey of the Census of Industrial Production, Hong Kong (SIP).

Prices of goods

Measured by Tornqvist unit value of exports, 1984–1998

Source: Census and Statistical Department, Hong Kong Special Administrative Region.

Growth rate of productivity

Measured by the growth rate of dual total factor productivity, which equals the weighted average of the growth rates of input prices minus the growth rate of output price. Source: SIP.

Capital

Generated by compiling real investment using the perpetual inventory method with a depreciation rate of 10%. Source: SIP.

Labor

Number of Workers. Source: SIP.

Note: †HSIC 353/354 (Petroleum and coal products) is not included because of the lack of data for the first half of our sample.

NA, not available.

sectoral employment of factors and own productivity growth. In order to take into account the reallocation of resources between sectors, elasticities of sectoral output with respect to growth of productivity and prices of all sectors, and with respect to endowments would need to be estimated. The following translog specification allows us to make such estimations.

Consider a neoclassical small open economy with fixed aggregate factor supplies, constant returns to scale production technology, and perfectly competitive goods and factor markets. This economy has two main sectors, manufacturing and service; together there are N industries. Each industry n produces only one good ($\tilde{y}_n$) from primary factors ($\mathbf{v}_n$) and intermediate materials (Z_n),

$$\tilde{y}_{nt} = f_n(\mathbf{v}_{nt}, Z_{nt}), \quad \forall n = 1, \ldots, N.$$

Intermediate materials are sourced both domestically and from overseas. In each period t the final output of each industry n is subjected to a Hicks-neutral productivity progress, A_{nt},

$$y_{nt} = A_{nt}\tilde{y}_{nt}, \quad \forall n = 1, \ldots, N.$$

There are I types of primary factor endowment ($\mathbf{v}$) in the economy. The GDP of the economy is the total value of industry output minus the value of imports, $p_{Mt}M_t$. Given aggregate primary factor endowments, the productivity level, and import and export prices, the general equilibrium of this small open economy is obtained by reallocating resources to maximize its GDP, subject to all the production and resources constraints:

$$GDP^*(\mathbf{p}_t\mathbf{A}_t,\mathbf{v}_t) \equiv \max\left\{\sum_{n=1}^{N+1} p_{nt}A_{nt}\tilde{y}_{nt} : (\tilde{\mathbf{y}}_t, \mathbf{v}_t) \in \mathbf{S}_t \cup \{M_t\}\right\}, \quad (1)$$

where $\mathbf{S}_t \cup \{M_t\} \subset \mathbf{R}^{(N+1)+I}$ is the strictly convex production set in t of its net output vector $\tilde{\mathbf{y}}_t = (\tilde{y}_{1t}, \ldots, \tilde{y}_{Nt}, -M_t)$ and factor endowment vector $\mathbf{v}_t = (v_{1t}, \ldots, v_{It}) \geq 0$. For simplicity of presentation, we treat the *negative* of import demand as the $(N+1)$th output supply of the economy and let $y_{N+1t} = -A_{N+1t}M_t$, with $A_{N+1t} \equiv 1$. Given the multiplicative nature of p_{nt} and A_{nt} in the maximization program, the equilibrium GDP, GDP^*, would depend on $\mathbf{p}_t\mathbf{A}_t$, where $\mathbf{A}_t = diag\{A_{1t}, A_{2t}, \ldots, A_{Nt}, 1\}$ is a diagonal matrix that defines the level of productivity of the economy, and $\mathbf{p}_t$ is the price vector of the economy.[8]

8. The GDP function presented in Equation (1) incorporates two GDP function models developed in Kohli (1991, 1997) and Harrigan (1997). Kohli (1991) shows that the import price is important in explaining the expenditure-based GDP function, and that we can derive import demand from the GDP function. Harrigan (1997) introduces productivity into the production-based GDP function by recognizing the multiplicative nature of prices and productivity in the revenue function. This enables him to model productivity empirically, in a similar way as prices. Therefore, the current GDP model includes the possible terms-of-trade effect or import competition faced by domestic industries, as well as possible efficiency gain resulting from the relocation of the aggregate resources as a response to sectoral productivity shocks.

The second order sufficient conditions also imply that GDP^* is convex in $\mathbf{p}_t$, and $\mathbf{A}_t$.[9]

By the envelope theorem, the output supply of industry equals the gradient of GDP^* with respect to own price, and import demand equals the negative of the gradient:

$$y_n^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = \frac{\partial GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)}{\partial p_{nt}}, \quad \forall n = 1, \ldots, N, \tag{2}$$

$$M_t^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = -y_{N+1t}^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = -\frac{\partial GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)}{\partial p_{Mt}}. \tag{3}$$

Define the share of the output of industry n in GDP as $s_{nt} = \frac{p_{nt}y_{nt}}{\text{GDP}_t}$, then, by construction, the sum of all the industry's shares will be greater than 1, and the share of imports will be negative. By Equation (2) it can be shown that the share of output of industry n in GDP is the elasticity of GDP^* with respect to its price:

$$s_n^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = \frac{\partial \ln GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)}{\partial \ln p_{nt}}, \quad \forall n = 1, \ldots, N+1 \tag{4}$$

$$s_{nt}^* \geq 0, \quad \forall n = 1, \ldots, N, \quad s_{N+1t}^* \leq 0, \quad \sum_{n=1}^{N+1} s_n^* = 1.$$

In addition, given the multiplicative nature of prices and productivity, for every industry n, the elasticities of GDP with respect to p_{nt} and A_{nt} equalize:

$$\frac{\partial \ln GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)}{\partial \ln p_{nt}} = \frac{\partial \ln GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)}{\partial \ln A_{nt}}.$$

In other words, the share of industry n also equals the elasticity of GDP with respect to productivity of n.

Hence, in this general equilibrium framework, the share of industry n in GDP depends not only on its own price and productivity, but also on the prices of all other goods, their productivity, and the aggregate endowments of the economy. Using a similar method, we can also show that the share of factor i in total value added equals the elasticity of total value added with respect to the quantity of i:

$$s_{it}^* = \frac{\partial \ln GDP_t^*}{\partial \ln v_{it}}. \tag{5}$$

Our ultimate objective is to estimate the contributions of productivity and factor endowments to output growth of the industries. One method would be to estimate the elasticities of output with respect to productivity and factor endowments,

9. Notice that with the assumption of a small open economy, $\mathbf{p}_t$ is exogenous and is fixed in the world market. In the context of a large economy, $\mathbf{p}_t$ would depend on domestic output and would not enter the GDP function.

and use the estimated elasticities to construct the corresponding contributions. Specifically, for every industry n and m, $y^*_{nt} = \frac{s^*_{nt} GDP^*}{p_{nt}}$, and $s^*_{nt} = \frac{\partial \ln GDP^*(\mathbf{p}_t \mathbf{A}_t, \mathbf{v}_t)}{\partial \ln A_{nt}}$. Given the shares of n and m, the elasticity of n's output with respect to the productivity of m, ε^A_{nmt}, is a *linear* function of the partial effect, $\frac{\partial s^*_{nt}}{\partial \ln A_{mt}}$:

$$\varepsilon^A_{nmt} \equiv \frac{\partial \ln y^*_{nt}}{\partial \ln A_{mt}} = \frac{1}{s^*_{nt}} \frac{\partial s^*_{nt}}{\partial \ln A_{mt}} + s^*_{mt}, \quad \forall n, m = 1, \ldots, N + 1. \tag{6}$$

Similarly, for every industry n and factor i, the factor elasticity of n with respect to i, ε^f_{nit}, is also *linear* in the partial effect $\frac{\partial s^*_{nt}}{\partial \ln v_{it}}$:

$$\varepsilon^f_{nit} \equiv \frac{\partial \ln y^*_{nt}}{\partial \ln v_{it}} = \frac{1}{s^*_{nt}} \frac{\partial s^*_{nt}}{\partial \ln v_{it}} + s^*_{it}, \quad \forall n = 1, \ldots, N + 1, \forall i = 1, \ldots, I. \tag{7}$$

In the literature, the factor elasticity is known as the Rybczynski elasticity.

Finally, it can be shown that own price elasticity of each industry equals its own productivity elasticity minus 1, while cross price elasticity of each industry equals its corresponding cross productivity elasticity:

$$\varepsilon^p_{nmt} \equiv \frac{\partial \ln y^*_{nt}}{\partial \ln p_{mt}} = \begin{cases} \varepsilon^A_{nmt} - 1, & \forall n = m \\ \varepsilon^A_{nmt}, & \forall n \neq m \end{cases}. \tag{8}$$

Therefore, our empirical strategy would be first to estimate the partial effects of productivity and factor endowments on the output shares; namely $\frac{\partial s^*_{nt}}{\partial \ln A_{mt}}$ and $\frac{\partial s^*_{nt}}{\partial \ln v_{it}}$. Subsequently, we will construct the elasticities using the corresponding estimated partial effects and shares, according to Equations (6) and (7). Finally, for every industry n, output growth is decomposed as follows:

$$\hat{y}^*_{nt} = \sum_{m=1}^{N+1} \varepsilon^A_{nmt} \hat{A}_{mt} + \sum_{m=1}^{N+1} \varepsilon^p_{nmt} \hat{p}_{mt} + \sum_{i=1}^{I} \varepsilon^f_{nit} \hat{v}_{it}. \tag{9}$$

Notice that, in contrast to the above decomposition, in traditional growth accounting exercises, growth rate of output only depends on growth rate of own productivity, and share weighted average of the growth rates of own factors:

$$\hat{y}^*_{nt} = \hat{A}_{nt} + \sum_{i=1}^{I} s_{int} \hat{v}_{int}.$$

Therefore, unlike the right-hand side of Equation (9) where all variables are exogenous, the growth of sectoral factors and their shares should reflect changes of productivity and prices of all sectors, as well as the changes in aggregate endowments. This makes sectoral decomposition harder to distinguish the different sources of growth.

IV. Empirical Specification

To implement the model empirically, let us assume that $GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t)$ is a translog function of productivity, prices, and factor endowments, with productivity and prices of goods entering multiplicatively. Let n and m be the indices for industries and i and j be the indices for factors:

$$\begin{aligned}\ln GDP^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = a_{00} &+ \sum_{n=1}^{N+1} a_{0n}\ln(A_{nt}p_{nt}) + \frac{1}{2}\sum_{n=1}^{N+1}\sum_{m=1}^{N+1} a_{nm}\ln(A_{nt}p_{nt})\ln(A_{mt}p_{mt}) \\ &+ \sum_{i=1}^{I} b_{0i}\ln v_{it} + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} b_{ij}\ln v_{it}\ln v_{jt} \\ &+ \sum_{n=1}^{N+1}\sum_{i=1}^{I} c_{ni}\ln(A_{nt}p_{nt})\ln v_{it}, \qquad (10)\end{aligned}$$

with the usual symmetry and homogeneity restrictions:

$$\begin{aligned}&a_{nm} = a_{mn},\quad b_{ij} = b_{ji},\quad \forall n,m = 1,\ldots, N+1,\quad \forall i,j = 1,\ldots, I,\\ &\sum_{n=1}^{N+1} a_{0n} = 1,\quad \sum_{m=1}^{N+1} a_{nm} = 0,\quad \sum_{i=1}^{I} c_{ni} = 0,\quad \forall n = 1,\ldots, N+1,\\ &\sum_{i=1}^{I} b_{0i} = 1,\quad \sum_{j=1}^{I} b_{ij} = 0,\quad \sum_{n=1}^{N+1} c_{ni} = 0,\quad \forall i = 1,\ldots, I. \qquad (11)\end{aligned}$$

Therefore, the share of industry n in total value added can be derived as the elasticity of GDP^* with respect to p_{nt} based on Equation (10) and the above restrictions:

$$s^*_{nt}(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = a_{0n} + \sum_{m=1}^{N+1} a_{nm}\ln(A_{mt}p_{mt}) + \sum_{i=1}^{I} c_{ni}\ln v_{it},\quad \forall n = 1,\ldots, N+1, \qquad (12)$$

with a_{nm} and c_{ni} representing the partial effects of productivity and factor endowments on output shares, $\frac{\partial s^*_{nt}}{\partial \ln A_{mt}}$ and $\frac{\partial s^*_{nt}}{\partial \ln v_{it}}$, respectively. In other words, for every industry n, m, and factor i, we can estimate the partial effects, a_{nm} and c_{ni}, by regressing output share of n on the levels of productivity, price indices, and factor endowments, as shown in Equation (12).

However, two obvious problems are associated with the estimation of Equation (12). The first problem is the non-stationarity of the level of productivity and prices, which causes the ordinary least squares (OLS) estimates to be inefficient. The second problem is the lack of randomness of the model: With full information on the economy, Equation (12) presents a complete model with no error term. Nevertheless, given that neither reliable data on productivity nor prices of the service sector are easily available or constructible, empirically it is impossible to have a full set of productivity and prices for all the industries in both the manufacturing and service sectors to implement Equation (12). By excluding prices and productivity of the service sector from Equation (12), we introduce randomness to the model. However, given that the partial effects, a_{nm} and c_{ni}, are invariant over time, we can get around the non-stationarity problem by taking the first difference of Equation (12).

Specifically, let the industry index for the service sector be $n = 1$. To capture the highly non-stationary property of the level of productivity and price, we assume the log level of the product of the productivity and the price of the service sectors follows a random walk with drift:

$$\ln A_{1t}p_{1t} = \delta + \gamma t + \zeta_t$$
$$\zeta_t = \zeta_{t-1} + u_t,\ u_t \sim \mathcal{N}(0, \sigma^2).$$

Then, by separating the service sector from the first summation of Equation (12), we have:

$$s_n^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = a_{0n} + a_{n1}(\delta + \gamma t + \zeta_t) + \sum_{m=2}^{N+1} a_{nm} \ln(A_{mt}p_{mt}) + \sum_{i=1}^{I} c_{ni} \ln v_{it}, \quad \forall n = 1, \ldots, N+1, \tag{13}$$

with its first difference as

$$\begin{aligned} ds_n^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) &= a_{n1}(\gamma + u_t) + \sum_{m=2}^{N+1} a_{nm}(\hat{A}_{mt} + \hat{p}_{mt}) + \sum_{i=1}^{I} c_{ni}\hat{v}_{it}, \\ &= a_n + \sum_{m=2}^{N+1} a_{nm}(\hat{A}_{mt} + \hat{p}_{mt}) + \sum_{i=1}^{I} c_{ni}\hat{v}_{it} + u_{nt} \\ &\qquad \forall n = 1, \ldots, N+1, \end{aligned} \tag{14}$$

where $a_n = a_{n1}\gamma$, $u_{nt} = a_{n1}u_t$, and the variable $\hat{x}_t$ denotes the growth rate of x.[10] Equation (14) shows that for every industry n, m, and factor i, the change in share of industry n, ds_n^*, depends on the growth rates of productivity, $\hat{A}_{mt}$, output prices, $\hat{p}_{mt}$, and factor endowments, $\hat{v}_{it}$, as well as an industry fixed effect, a_n.

Equation (14) can be further simplified by utilizing the dual definition of TFP,

$$\hat{A}_{mt} \equiv \bar{\hat{w}}_{mt} - \hat{p}_{mt}, \tag{15}$$

where $\bar{\hat{w}}_{mt}$ denotes the weighted average of the growth rates of input prices.[11] Therefore, we can rewrite Equation (14) as:

10. Specifically, $\hat{x}_t \equiv \ln x_t - \ln x_{t-1}$.

11. For example, if there are only four kinds of inputs; namely, labor (L), capital (K), domestic materials (D), and imported materials (M), with input prices equal to w, r, p^D, and p^M, respectively, then:

$$\begin{aligned} \bar{\hat{w}}_{nt} &= \bar{\theta}_{nt}^L \hat{w}_{nt} + \bar{\theta}_{nt}^K \hat{r}_{nt} + \bar{\theta}_{nt}^D \hat{p}_{nt}^D + \bar{\theta}_{nt}^M \hat{p}_{nt}^M \\ \bar{\theta}_{nt}^L &= 0.5 * \left(\frac{w_{nt}L_{nt}}{p_{nt}y_{nt}} + \frac{w_{nt-1}L_{nt-1}}{p_{nt-1}y_{nt-1}} \right) \\ \bar{\theta}_{nt}^K &= 0.5 * \left(\frac{r_{nt}K_{nt}}{p_{nt}y_{nt}} + \frac{r_{nt-1}K_{nt-1}}{p_{nt-1}y_{nt-1}} \right) \end{aligned} \tag{16}$$

$$ds_n^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = a_n + \sum_{m=1}^{N+1} a_{nm}\bar{\hat{w}}_{mt} + \sum_{i=1}^{I} c_{ni}\hat{v}_{it} + u_{nt}, \quad \forall n = 1, \ldots, N+1. \quad (17)$$

Therefore, the change in share of industry n depends on the weighted averages of the growth rates of input prices of all industries and the growth rates of factor endowments. Equation (17) will form the basis of our estimation for a_{nm} and c_{ni}, $\forall n$, m, and i.

For every industry n, m, and factor i, the estimated productivity elasticity and the factor elasticity are, respectively,

$$\varepsilon_{nmt}^A = \frac{a_{nm}}{s_{nt}^*} + s_{mt}^*, \quad \text{and} \quad (18)$$

$$\varepsilon_{nit}^f = \frac{c_{ni}}{s_{nt}^*} + s_{it}^*. \quad (19)$$

V. Multisector Aggregate Growth Accounting

Equations (18) and (19) allow us to reinterpret the traditional aggregate growth accounting as the output share weighted average of the sectoral productivity and Rybczynski elasticities:

$$\sum_{n=1}^{N+1} s_{nt}^*\varepsilon_{nmt}^A = s_{mt}^*, \sum_{n=1}^{N+1} s_{nt}^*\varepsilon_{nit}^f = s_{it}^*. \quad (20)$$

In other words, the aggregate factor share equals the average Rybczynski elasticity of the economy, and the industry share equals the average productivity (price) elasticity.

It can be shown that under such a specification, the growth rate of GDP consists of the following terms:

$$\widehat{GDP}^*(\mathbf{p}_t\mathbf{A}_t, \mathbf{v}_t) = \sum_{n=1}^{N+1} s_{nt}^*\hat{p}_{nt} + \sum_{n=1}^{N+1} s_{nt}^*\hat{A}_{nt} + \sum_{i=1}^{I} s_{it}^*\hat{v}_{it}, \quad (21)$$

where the first summation captures both the domestic price effect and the terms of trade effect à la Kohli (1997). Utilizing the average elasticity interpretation of industry and factor shares, we conclude that the growth rate of GDP depends on the growth rates of industry prices, industry productivity, and aggregate factor endowments. The contribution of these determinants depends on the average productivity and Rybczynski elasticities across all sectors.

$$\bar{\theta}_{nt}^D = 0.5 * \left(\frac{p_{nt}^D D_{nt}}{p_{nt} y_{nt}} + \frac{p_{nt-1}^D D_{nt-1}}{p_{nt-1} y_{nt-1}} \right)$$

$$\bar{\theta}_{nt}^M = 0.5 * \left(\frac{p_{nt}^M M_{nt}}{p_{nt} y_{nt}} + \frac{p_{nt-1}^M M_{nt-1}}{p_{nt-1} y_{nt-1}} \right)$$

$$1 = \bar{\theta}_{nt}^L + \bar{\theta}_{nt}^K + \bar{\theta}_{nt}^D + \bar{\theta}_{nt}^M.$$

For the case of imports, $\bar{\hat{w}}_{kt} = \hat{p}_{kt}$ because A_{kt} is assumed to be 1.

Finally, according to this interpretation, the endowment-driven hypothesis is correct if the majority sector of the economy has a large positive Rybczynski elasticity with respect to the fast-growing endowment and has little productivity growth. Conversely, the productivity-driven hypothesis is correct if the majority sector has large productivity growth and has small or negative Rybczynski elasticity with respect to the fast-growing endowment.

VI. Data

We aggregate the 26 industries in Hong Kong's manufacturing sector into 5 major manufacturing industries. Together with imports and the service sector, there are a total of 7 aggregate industries. However, we consider only two types of primary aggregate factors; namely, labor and capital. Both labor and capital are homogeneous inputs.

Table 3 presents the concordance of the five major manufacturing industries to their Hong Kong Standard Industrial Classifications. From 1976 to 1997, there were two classification regimes, with the break taking place in 1990. As a result of data reporting problems, the food, beverage, tobacco, and petroleum and coal products industries (Standard Industrial Classification (SIC) 311/312, 313, 314, and 353/354) are excluded from the sample. Data sources and the constructions of the variables are in the appendix.

Table 4 presents some summary statistics of the variables used in the regressions. It is clear from the growth in real output and output share in GDP that the manufacturing sector, as a whole, has been shrinking. Among the manufacturing industries, 2 of the largest industries in 1985, textiles/machinery and electronics, dropped from more than 20 percent of GDP in 1976 to less than 7 percent in 1997. The rate of decline is rapid by any measure. On the other hand, the aggregate factor endowments of the economy have been increasing. The growth rate of capital is, on average, nearly 8 percent per year, while the growth rate of labor is 1.6 percent per year.

Evidence of import competition is clearly demonstrated by the growth rate of imports and the change in the import share in GDP. While the value of manufacturing imported materials is dropping as a result of the decline in manufacturing output, imports, as a whole, are certainly increasing. As such, we expect many of the manufacturing industries to be negatively affected by the rising imports.

Finally, the growth rate of productivity of the manufacturing sector shows signs of declining. This is also true at an industry level for machinery and electronics and for miscellaneous manufactures.

VII. Estimations and Results

Equation (22) shows a system of seven equations, and Equation (23) presents the 21 restrictions. For each equation, the dependent variable is the change in share of output in GDP, with u_n being the industry-specific error term. Notice

Table 4 Data at a glance

Variables	*Years*	*Manufacturing† (%)*	*Textiles (%)*	*Paper and printing (%)*	*Chemicals‡ (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*
Growth rate of real output	1985	−6.0682	−4.2574	−3.6711	−9.9102	−7.0832	−5.9565
	1997	−6.6898	−7.0543	10.2951	0.9745	−10.2835	−15.2646
	Mean	−1.6259	−2.8623	8.2323	−1.5203	−3.4195	−5.9101
Output share in GDP	1985	63.3975	26.0510	3.6012	8.0945	23.1072	2.5435
	1997	18.3703	5.7102	3.0152	1.8082	6.9176	0.9191
	Mean	46.6110	17.7564	3.5614	5.1490	18.0762	2.0681
Change in output share	1985	−9.4480	−3.0853	−0.3068	−1.1359	−4.3124	−0.6076
	1997	−3.3320	−0.9576	−0.0969	−0.2837	−1.8875	−0.1064
	Mean	−4.1904	−1.8020	−0.0687	−0.5709	−1.5771	−0.1717
Growth rate of labor input	1985	−5.1498	−5.0099	−0.9816	−4.3604	−7.0656	0.7698
	1997	−12.9138	−20.0259	−3.3155	−2.4379	−13.0069	−10.6848
	Mean	−9.6201	−11.8160	0.1375	−12.4491	−9.5455	−6.7535
Growth rate of capital input	1985	1.0403	−1.4933	5.7958	4.2795	1.5403	2.4435
	1997	0.0670	−7.1892	5.1020	1.0617	3.2378	−4.0387
	Mean	1.9914	−2.1438	8.9152	0.6080	3.7834	2.6861
Growth rate of domestic materials	1985	−0.0183	−0.1383	1.2950	−0.0416	−2.6897	1.2950
	1997	−0.6184	1.0808	−2.4948	−3.5613	−3.5156	−2.4948
	Mean	−4.1495	−10.4167	5.3958	1.3159	0.7093	5.3958
Growth rate of imported materials	1985	−2.4893	−4.1282	−1.7080	−4.1119	−1.0342	−1.7080
	1997	−3.3262	0.0494	−5.1927	−3.8111	−5.8325	−5.1927
	Mean	−0.3556	0.7460	5.6183	−2.9746	−2.4599	−2.1475
Growth rate of output price	1985	−1.2056	−0.3177	2.1132	3.3962	−3.4111	−8.8478
	1997	0.1052	1.6337	−3.3732	−5.4577	−3.7528	14.3940
	Mean	3.8458	3.1427	2.5895	1.8035	5.6426	9.2487

Table 4 (*continued*)

Variables	*Years*	*Manufacturing*† (%)	*Textiles* (%)	*Paper and printing* (%)	*Chemicals*‡ (%)	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*
Growth rate of productivity§	1985	0.6145	–0.9625	0.4368	–5.3264	2.8227	8.4632
	1997	–0.8846	0.4558	6.5895	4.6663	–1.7500	–17.1295
	Mean	0.5967	1.3408	2.4033	2.1025	–1.1075	–5.9419
Aggregate endowments		Labor (%)	Capital (%)	Imports (%)			
Growth rates	1985	0.7911	7.1454	3.5405			
	1997	3.8738	9.4722	5.0481			
	Mean	1.6173	7.8511	15.2178			
Share in GDP	1985	45.8083	54.1917	86.8899			
	1997	42.8246	57.1754	122.4305			
	Mean	42.2041	57.7959	111.9986			

Note: Mean values are the annual averages for the period 1984–1997.
† Standard Industrial Classification 311/312, 313, 314 (Food, Beverage and Tobacco Products) are excluded. ‡ SIC 353/354 (Petroleum and Coal Products) is excluded from the data because of the lack of data prior to 1988. § Productivity is measured as the dual total factor productivity.
GDP, gross domestic product.

that we are not imposing restrictions on the homogeneity in prices in the system, as we do not have a complete set of prices.

$$ds_{nt} = a_n + \sum_{m=2}^{7} a_{nm}\bar{\hat{w}}_{mt} + \sum_{i=1}^{2} c_{ni}\hat{v}_{it} + u_{nt}, \quad \forall n = 1, \dots, 7 \tag{22}$$

$$a_{nm} = a_{mn}, \quad \sum_{m=1}^{2} c_{ni} = 0, \quad \forall n, m, i. \tag{23}$$

Right-hand side variables for each equation include the weighted averages of the growth rates of input prices of all the 5 industries plus import price, and the growth rates of the two aggregate factor endowments. Given that the dependent variable is the change in share of output of 1 of the 7 industries in the sector for each equation, the error terms of the equations will be correlated by construction. Hence, the proper way to implement the empirical model will be to estimate it as a system of six equations using iterative seemingly unrelated regressions.[12] Given that the estimates are neutral to the dropping equation, without further complication, we choose to drop the service sector equation from the system and will recover its coefficients through symmetry and homogeneity restrictions.

Table 5 presents the regression results of the system. Each of the six columns in the table represents the regression result of 1 industry. The dependent variable of each regression is the change in share of the industry in the column, and there are nine explanatory variables for each regression. These explanatory variables are categorized into three groups. The first group consists of the weighted averages of the growth rates of input prices of the various industries as well as the growth rate of import prices. The second group of explanatory variables includes the growth rates of the two aggregate factors. The third group is the industry fixed effects.

At first glance, most of the partial effects of productivity are estimated with precision, while all of the partial effects of factor endowments are not significant. Moreover, all of the partial effects of own price on output are positive and significant, and most of the partial effects of import price on output of the industries are negative and significant. This finding is in line with the theoretical restriction of the model.[13]

Table 6 shows the estimated productivity elasticities of the 5 manufacturing industries, the service sector, and imports. Elasticities for the service sector are obtained by imposing symmetry and homogeneity restrictions. Each cell shows

12. This is equivalent to estimating a system using maximum likelihood estimators. See Barten (1969) for details.

13. To satisfy convexity of GDP function, all the output supply of the industries should be positively related to own price and negatively related to import price, where import is taken as the intermediate input. Therefore, it is necessary that all the partial effects on own price be positive and partial effects on import price be negative.

Table 5 Dependent variables: change in share of output in GDP

Independent variables	*Equation (1) Textiles*	*Equation (2) Paper and printing*	*Equation (3) Chemicals*	*Equation (4) Machinery and electronics*	*Equation (5) Miscellaneous manufacture*	*Equation (6) Imports*
Weighted average of the growth rates of input prices in:						
Textile	0.3612†***	0.0232	−0.0776**	0.3093***	0.0464***	0.6967**
	(0.0975)	(0.0211)	(0.0327)	(0.0969)	(0.018)	(0.3102)
Paper and printing	0.0232	0.1133†***	−0.0647***	0.1145***	−0.037***	0.0927
	(0.0211)	(0.0163)	(0.022)	(0.0251)	(0.013)	(0.0588)
Chemicals	−0.0776**	−0.0647***	0.2741†***	0.0183	0.0157	0.2517**
	(0.0327)	(0.022)	(0.0329)	(0.0383)	(0.0176)	(0.102)
Machinery and electronics	0.3093***	0.1145***	0.0183	0.5196†***	0.0062	0.8368**
	(0.0969)	(0.0251)	(0.0383)	(0.1283)	(0.0238)	(0.3759)
Miscellaneous manufactures	0.0464***	−0.037***	0.0157	0.0062	0.0705†***	0.1123**
	(0.018)	(0.013)	(0.0176)	(0.0238)	(0.0169)	(0.0486)
Imports	−0.6967**	−0.0927	−0.2517**	−0.8368**	−0.1123**	−1.1299†
	(0.3102)	(0.0588)	(0.102)	(0.3759)	(0.0486)	(1.465)
Growth rates of:						
Capital	−0.264	−0.0344	0.076	−0.3376	−0.0815	2.4095
	(0.3812)	(0.0743)	(0.1229)	(0.426)	(0.052)	(1.794)
Labor	0.264	0.0344	−0.076	0.3376	0.0815	−2.4095
	(0.3812)	(0.0743)	(0.1229)	(0.426)	(0.052)	(1.794)
Industry fixed effect	−0.0198	−0.0051	−0.0116	−0.0248	0.0018	−0.1935*
	(0.0223)	(0.0042)	(0.0071)	(0.0251)	(0.0029)	(0.1096)

Note: Estimation method: restricted iterative seemingly unrelated regression (maximum likelihood estimation). Total number of restrictions: 21. Total system observations: 78.
† Own partial effects of productivity. Standard errors are in parentheses.
*, ** and *** indicate significance at 10%, 5% and 1% level, respectively.
GDP, gross domestic product.

Table 6 Elasticity of output with respect to productivity by industry

1% increase in productivity in:	*Effect in terms of percentage change in output in:*						
	Textiles (%)	*Paper and printing (%)*	*Chemicals (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*	*Service (%)*	*Imports (%)*
Textiles	2.2116†***	0.8293	−1.3294**	1.8884***	2.4221***	0.1982**	0.7996***
	(0.549)	(0.5927)	(0.6349)	(0.536)	(0.8689)	(0.0975)	(0.277)
Paper and printing	0.1663	3.2178†***	−1.221***	0.6688***	−1.7544***	0.0014	0.1184**
	(0.1189)	(0.4568)	(0.4263)	(0.139)	(0.6305)	(0.0194)	(0.0525)
Chemicals	−0.3855**	−1.7653***	5.3741†***	0.1529	0.8093	0.1034***	0.2762***
	(0.1841)	(0.6163)	(0.639)	(0.2119)	(0.852)	(0.033)	(0.0911)
Machinery and electronics	1.9224***	3.3944***	0.5367	3.0550†***	0.4828	0.1015	0.9279***
	(0.5456)	(0.7053)	(0.744)	(0.7098)	(1.1484)	(0.1143)	(0.3356)
Miscellaneous manufactures	0.2821***	−1.0188***	0.3251	0.0552	3.4294†***	0.027*	0.1209***
	(0.1012)	(0.3661)	(0.3422)	(0.1314)	(0.8152)	(0.0151)	(0.0433)
Service	1.8465**	0.0664	3.322***	0.9289	2.1599*	1.1682†***	0.8858
	(0.9084)	(0.9019)	(1.0605)	(1.0454)	(1.2094)	(0.4357)	(0.7957)

Note: † Own productivity elasticities. Standard errors are in parentheses.
The productivity elasticity of industry n with respect to industry k equals the share of industry k plus the ratio of the corresponding estimated cross partial effect to the share of industry n.
*, ** and *** indicate significance at 10%, 5% and 1% level, respectively.

the percentage change in output of the industry in the column as a result of a 1 percent change in productivity of the industry in the row.[14]

As highlighted in Table 6, all of the estimated own productivity elasticities are positive and significant. The range of the estimated own productivity elasticities is between 1.2 and 5.4. In addition, all manufacturing industries have estimated own productivity elasticities that are significantly greater than 1. In other words, for each of the 5 industries in the manufacturing sector, a 1 percent increase in own productivity will induce a more than 1 percent increase in the output of the industry. The productivity elasticity of the service sector is positive but not significantly different from 1. Given that own price elasticity equals own productivity elasticity minus 1, the regression result satisfies the specification of the theoretical model that the own price elasticities should be non-negative, as shown in Table 7.

Interestingly enough, imports react positively to productivity growth in all the manufacturing industries, even though the estimated elasticities are less than unity. Therefore, when there is technological progress in the manufacturing sector, we would expect to see an increase in import demand. On the other hand, as shown in Table 7, all of the import price elasticities of the manufacturing industries are negative and significant. For the manufacturing industries, a 1 percent increase in import prices decreases industry output from 3.7 percent to 6.5 percent. For example, from 1984 to 1997, import prices increased by more than 20 percent and, as a result, output dropped by 130 percent in the miscellaneous manufactures industry. Therefore, the rising imports in the sample period have produced some huge negative effects on the output of the manufacturing industries.

Table 8 presents the estimated factor elasticities. These elasticities are also known as the Rybczynski elasticities, which measure growth of output as a result of the growth of the aggregate factor endowments in an economy. Each cell shows the percentage change in output of the industry in the column as a result of a 1 percent growth of the factor in the row.

According to Table 8, the estimated Rybczynski elasticity with respect to aggregate capital is positive and statistically significant in the service sector. In other words, the service sector is revealed to be capital intensive. For every 1 percent increase in the aggregate capital endowments, output of the service sector increases by 2.4 percent. Given that, from 1984 to 1997, the average annual growth rate of Hong Kong's aggregate capital endowments is nearly 8 percent, this would cause the output of the service sector to increase by more than 18 percent annually. Therefore, accumulation of capital endowments alone can explain all of the service sector's growth, leaving no room for productivity.

14. For example, a 1 percent increase in productivity in the textile industry causes the output of the chemicals industry to decrease by 1.33 percent. It also leads to a 1.89 percent increase in the output of the machinery and electronics industry.

Table 7 Elasticity of output with respect to prices by industry

1% increase in price in	*Effect in terms of percentage change in output in:*						
	Textiles (%)	*Paper and printing (%)*	*Chemicals (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*	*Service (%)*	*Imports (%)*
Textiles	1.2116†**	0.8293	−1.3294**	1.8884***	2.4221***	0.1982**	0.7996***
	(0.549)	(0.5927)	(0.6349)	(0.536)	(0.8689)	(0.0975)	(0.277)
Paper and printing	0.1663	2.2178†***	−1.221***	0.6688***	−1.7544***	0.0014	0.1184**
	(0.1189)	(0.4568)	(0.4263)	(0.139)	(0.6305)	(0.0194)	(0.0525)
Chemicals	−0.3855**	−1.7653***	4.3741†***	0.1529	0.8093	0.1034***	0.2762***
	(0.1841)	(0.6163)	(0.639)	(0.2119)	(0.852)	(0.033)	(0.0911)
Machinery and electronics	1.9224***	3.3944***	0.5367	2.055†***	0.4828	0.1015	0.9279***
	(0.5456)	(0.7053)	(0.744)	(0.7098)	(1.1484)	(0.1143)	(0.3356)
Miscellaneous manufactures	0.2821***	−1.0188***	0.3251	0.0552	2.4294†***	0.027*	0.1209***
	(0.1012)	(0.3661)	(0.3422)	(0.1314)	(0.8152)	(0.0151)	(0.0433)
Service	1.8465**	0.0664	3.322***	0.9289	2.1599*	0.1682†	0.8858
	(0.9084)	(0.9019)	(1.0605)	(1.0454)	(1.2094)	(0.4357)	(0.7957)
Imports	−5.0435***	−3.7239**	−6.0075***	−5.7492***	−6.5491***	−0.5999	−3.1288†**
	(1.747)	(1.6522)	(1.981)	(2.0795)	(2.3476)	(0.5389)	(1.3081)

Note: † Own price elasticities. Standard errors are in parentheses. All the cross price elasticities equal the corresponding cross productivity elasticities, while the own price elasticities equals own productivity elasticities minus one.
*, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 8 Elasticity of output with respect to factors by industry

1% increase in:	*Effect in terms of percentage change in output in:*						
	Textiles (%)	*Paper and printing (%)*	*Chemicals (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*	*Service (%)*	*Imports (%)*
Labor	1.9087	1.3877	−1.0537	2.2895	4.3631*	−1.4227	−1.7293
Endowment	(2.1468)	(2.0863)	(2.3869)	(2.3567)	(2.5158)	(0.9128)	(1.6018)
Capital	−0.9087	−0.3877	2.0537	−1.2895	−3.3631	2.4227***	2.7293*
Endowment	(2.1468)	(2.0863)	(2.3869)	(2.3567)	(2.5158)	(0.9128)	(1.6018)

Note: Standard errors are in parentheses. The factor elasticity of industry n with respect to factor m equals the share of factor m plus the ratio of the corresponding estimated partial effect and the share of industry n.

* and *** indicate significance at the 10% and 7% level, respectively.

Most of the manufacturing industries are revealed to be labor intensive, with positive Rybczynski elasticities with respect to aggregate labor endowment and negative Rybczynski elasticities with respect to capital endowment. However, with the exception of the miscellaneous manufactures industry, the elasticities are not precisely estimated. One possibility is that given that most of the manufacturing industries have a concurrent decline in output over the sample period, these elasticities are likely to be highly correlated, which makes it difficult to precisely estimate each individual elasticity. Nevertheless, given the strong positive Rybczynski elasticity with respect to aggregate capital of the service sector, it is safe to infer that, overall, the manufacturing sector is revealed to be labor intensive.

A labor-intensive manufacturing sector would have benefitted from the increase in the aggregate labor endowment. However, given that the average growth rate of the aggregate labor endowment is only 1.6 percent annually, it helps little in offsetting the negative effect of the faster cumulating aggregate capital. Resources are moving into the service sector from the manufacturing sector as a result of the changes in the mix of aggregate endowments that push the economy to be more capital abundant.

Based on the estimated elasticities in Tables 6–8, we can infer the contributions of productivity, prices and endowments in the output growth of each industry according to Equation (9). Table 9 presents the breakdown of contributions. For textiles, and machinery and electronics, the two largest industries in the manufacturing sector, both productivity and endowments contribute to the decline in these industries, and the effects of productivity are larger. However, the roles of productivity and endowments reversed in explaining the decline in the miscellaneous manufactures industry. The drop of the chemicals industry is mainly explained by falling prices, with endowment growth playing an offsetting force to the decline, while the growth in the paper and printing industry mainly originates from increases in productivity and prices. Finally, for imports and the service sector, endowment growth dominates the negative effects of productivity and contributes to the overall growth of the sectors.

In summary, the estimated productivity, prices and factor elasticities suggest that the growth of the capital-intensive service sector is mainly driven by the growth of the aggregate capital endowment, while the growth of the labor-intensive manufacturing sector is mainly hindered by the reallocation of resources into the service sector as a result of the growth of aggregate capital endowment, faltering productivity and rising imports.

We also perform some specification tests on the regression results. All of the industries satisfy the homogeneity hypothesis, which implies that the constant returns to scale assumption is not rejected by the data. However, none of the industries satisfies the symmetry hypothesis.[15]

15. Detailed results on the specification tests are available upon request.

Table 9 Contributions of productivity, endowments and prices by industry

	Effect in terms of percentage change in output in:						
	Textiles (%)	*Paper and printing (%)*	*Chemicals (%)*	*Machinery and electronics (%)*	*Miscellaneous manufactures (%)*	*Imports (%)*	*Service (%)*
Productivity effects	−3.3189	7.3538	0.3358	−0.2913	−22.5985	−0.8009	−1.0946
Endowments effects	−4.0475	−0.7996	14.4195	−6.4211	−19.3476	−18.6313	16.7198
Price effects	8.5809	8.6802	−3.4444	10.4518	18.7894	4.4490	−1.0347
Predicted output growth	1.2145	15.2344	11.3109	3.7395	−23.1567	22.2794	14.5905
Actual output growth	−2.8623	8.2323	−1.5203	−3.4195	−5.9101	13.5485	11.8400

Note: All calculation are based on sample means in Table 3 and elasticity estimates of Tables 5–7. Total factor productivity (TFP) of services −1.2%, which is inferred from aggregate TFP in Table 1 and manufacturing TFP in Table 3. Predicted output growth is the sum of productivity, endowments and prices effects according to Equation (10). Actual output growth of services is inferred from real gross domestic product growth in Table 1 and real output growth of manufacturing and imports in Table 3.

It is not unusual for such regularity conditions to fail in this type of model, and it is necessary to impose such restrictions for the estimation to conform to the model. Failure in symmetry restriction could be as a result of the fact that the sizes of the industries are quite different, ranging from 2 percent of GDP to 112 percent of GDP (including import). Harrigan (1997) has similar findings in the system of equations of the Organization for Economic Cooperation and Development countries.

VIII. Robustness Checks

VIII.1 Endogeneity of total factor productivity

There are at least two reasons why the sectoral growth rates of TFP and the contemporary regression errors could be correlated and cause the estimates to be biased. The first has to do with the measurement of TFP, and the second has to do with the econometric issues associated with the fixity of some inputs. Both of these issues will cause overestimation of industry productivity growth, leading to underestimation of the productivity elasticities.

Specifically, the value of total industry output is used to construct the share of industry in GDP and its changes. By invoking the dual definition of TFP, according to Equation (15), we use data on total cost to construct the growth rate of industry TFP. With the assumption of perfect competition, value of total output equals total cost. Hence, we might have mechanically introduced a spurious correlation between the dependent variable and the growth rates of industry productivity.

In addition, if there is fixity of some inputs in the short run, then a sectoral-specific shock will concurrently affect the sector's share in GDP and the measured sectoral TFP. This is similar to the classical econometric problem of estimating a production function.

We use the lagged growth rate of the industry TFP as an instrumental variable to get around the potential endogeneity issue of the current-period industry TFP growth. As a result, we use the full information maximum likelihood estimation to fit the above system of equations. Although the point estimates of the regression are slightly different, they do not significantly alter the industry productivity and Rybczynski elasticities. Correcting for endogeneity of productivity raises the service sector productivity elasticity from 1.17 to 1.18. We maintain the earlier results that growing capital endowment is the main driving force behind the growth of the service sector, while the manufacturing industries are hurt by the reallocation of resources into the service sector as a result of capital accumulation and import competition.[16]

16. Detailed regression results are available upon request.

VIII.2 Endogeneity of the aggregate capital endowment

Hong Kong is one of the world's most open economies; not just in terms of movement of goods and service, but also in terms of movement of capital, both inward and outward. As such, the aggregate capital stock of the economy could be a result of investors' response to the different rate of returns across countries, as well as across industries. Specifically, a growing sector of a booming economy provides investors with a higher expected rate of return in the future and further attracts investment and causes the aggregate capital endowment to grow. This situation would lead to an overestimation of the Rybczynski elasticity of the growing industry.

Although the standard Heckscher-Ohlin model and Rybczynski theorem call for aggregate capital endowment to be exogenous, with the free trade of goods and service, returns to factors are nevertheless equalized across countries and sectors. Therefore, we could use interest rates as an instrument of the aggregate capital stock, which would capture the exogenous movement of capital as a result of changes in interest rates that are not related to specific industries. A full information maximum likelihood estimation, with the best lending rate of Hong Kong used as the instrument for the aggregate capital endowment, is performed. Once again, while the point estimates are slightly different from those in Table 5, they do not significantly change the industry productivity and Rybczynski elasticities. Correcting for the endogeneity of the aggregate capital endowment reduces the Rybczynski elasticity of the service sector with respect to capital from 2.42 to 2.38. We maintain that the growth of the service sector is predominantly a result of the growth of the aggregate capital endowment.[17]

IX. Concluding Remarks

The present paper sets out to find sectoral evidence that might substantiate the existing aggregate findings in the literature regarding the relative importance of productivity and endowments in the growth of Hong Kong.

Under a general equilibrium framework of a production-based GDP function approach, the present paper links the contributions of aggregate productivity and endowments to industry-level productivity and Rybczynski elasticities. Given the drastic accumulation of aggregate capital stock, a finding of a large Rybczynski elasticity of the majority sectors with respect to capital would be consistent with the endowment-driven hypothesis. In other words, if most of the growth of the majority sectors could be explained by factors other than productivity, then it would be inconsistent with the productivity-driven hypothesis.

The results of an iterative seemingly unrelated regression indicate that most of the growth of the service sector is driven by rapidly-accumulating capital endowments, and not by productivity growth. In addition, productivity growth in

17. Detailed regression results are available upon request.

the manufacturing sector is also unimpressive. The manufacturing sector is revealed to be labor intensive and its growth is hindered by the reallocation of its production factors into the service sector as a result of the growth of capital endowments and imports. Overall, sectoral evidence supports the endowment-driven hypothesis. The results are robust to the corrections of endogeneity of industry productivity and aggregate capital endowment.

In terms of relevancy to the trade literature, this paper is the first to estimate the sectoral Rybczynski elasticities and relate them to the aggregate growth of a small open economy. In terms of relevancy to the growth literature, the sectoral evidence of the paper substantiates the existing endowment-driven findings, which have, so far, been mainly focused on the aggregate statistics.

Appendix

Data sources

Most of the industry-level raw data are from the *Survey of Industrial Production* published by the Census and Statistics Department of Hong Kong from 1976 to 1997. Earlier year data are supplemented by the *Hong Kong Annual Digest of Statistics*, published by the same source. Data from these sources include value of gross output ($p_{nt}y_{nt}$), value of materials purchased ($p^{D}_{nt}D_{\mathrm{nt}} + p^{M}_{nt}M_{nt}$), number of persons engaged (L_{nt}), compensation of employees ($w_{nt}L_{nt}$) and gross addition to fixed assets (value of investment: $p^{I}_{t}I_{t}$).

Hong Kong Annual Digest of Statistics also provides data necessary for the construction of the aggregate factor endowments, which include labor force (L_t) and gross domestic fixed capital formation (value of aggregate investment: $p^{I}_{t}I_{nt}$).

Finally, the Census and Statistics Department of Hong Kong collected detailed Hong Kong trade data at a commodity level from 1984 to 1998.[18] This dataset provides us with information on the value and quantity of import and export by commodities, year, and country of origin/consignment. Given the highly disaggregate nature of the data, it is possible to construct unit value of import and export by industry. Because trade statistics begin in 1984 and the industry data end in 1997, this determined the time dimension of the paper.

Capital stock and factor shares

Both industry and aggregate real investments are inferred by deflating the value of investment by the appropriate GDP deflator of gross domestic fixed capital formation. Capital input is then compiled using the perpetual inventory method from real investment,

$$K_{nt} = K_{nt-1} * (1 - \delta) + I_{nt}, \tag{24}$$

18. The data are purchased by the Pacific Rim Business and Development program at the University of California at Davis, and are only available for students and faculty of UC-Davis.

with the assumption that we correctly specify some base year level of capital stock, K_{n0}. Fortunately, the 1976 *Survey of Industrial Production* publishes the book value of all assets by industry. Taking 1976 as our base year, we compile industry-level capital stock by Equation (24), at a fixed depreciation rate of 10 percent. Log difference of industry capital stock gives us the growth rate of industry capital input.

There are no published data for the aggregate capital stock in the base year. However, aggregate investment series is available from 1972 onwards. We take 1972 as the base year to compile aggregate capital stock. Given the high growth rate of aggregate investment, any underestimation at the beginning of the series would not be significant for the later years, when we want to construct the growth rate of aggregate capital stock, as we need only the growth rates of aggregate capital after 1984 for regression purposes.

There are no published data on the shares of labor and capital of GDP in Hong Kong. Labor share of GDP is constructed as a weighted average of industry's labor shares, with the share of value added, VA_{nt}, of each industry in GDP as the weight, and capital share of GDP is constructed as 1 minus the labor share:

$$\frac{w_t L_t}{GDP_t} = \frac{\sum_{n=1}^{N} w_{nt} L_{nt}}{GDP_t} = \sum_{n=1}^{N} \frac{VA_{nt}}{GDP_t} \frac{w_{nt} L_{nt}}{VA_{nt}}. \tag{25}$$

Industries included in the construction of aggregate labor share are manufacturing, wholesale and retail trades, restaurants and hotels, transport and related service, storage, communication, financing and business service sectors, banking and insurance industries. Together, these industries account for more than 80 percent of the economy.

Export and import prices

Export prices are constructed using Tornqvist price index from the unit value of export commodities:

$$dp_{nt} = \sum_{i_n=1}^{I_{nt}} \bar{\theta}_{i_n t} \left(\ln \frac{p_{nt}^{i_n} Q_{nt}^{i_n}}{Q_{nt}^{i_n}} - \ln \frac{p_{nt-1}^{i_n} Q_{nt-1}^{i_n}}{Q_{nt-1}^{i_n}} \right), \forall n, t, \tag{26}$$

where $i_n = 1, \ldots, I_{nt}$ is the group of common export commodities between year t and $t-1$ in industry n, and $\bar{\theta}_{i_n t}$ is the average share of commodity i_n in the total value of export of industry n between year t and $t-1$.[19]

$$\bar{\theta}_{i_n t} = 0.5 * \left(\frac{p_{nt}^{i_n} Q_{nt}^{i_n}}{\sum_{i_n=1}^{I_{nt}} p_{nt}^{i_n} Q_{nt}^{i_n}} + \frac{p_{nt-1}^{i_n} Q_{nt-1}^{i_n}}{\sum_{i_n=1}^{I_{nt}} p_{nt-1}^{i_n} Q_{nt-1}^{i_n}} \right), \forall i_n, t. \tag{27}$$

19. Commodities imported from different countries, or exporting to different countries, are considered as different commodities.

Therefore, for every year and industry, we need to first identify the group of common export commodities between last and current year, then construct the share of each commodity in the group of common commodities for each of the 2 years, and take the average of the shares to obtain $\bar{\theta}_{i_n t}$. Average share, $\bar{\theta}_{i_n t}$, is the weight used to construct the change in export price of industry n from the change in log unit value of the commodities. In short, the change in industry price equals the weighted average of the change in log unit value of the commodities in the industry. Import prices are constructed in the same way.

There are three different commodity classifications used from 1984 to 1997. Commodities were classified under 6 digits Standard International Trade Classification revision 2 for 1984–1991, 6 digits SITC revision 3 for 1992–1993, and 8 digits Harmonized System for 1994–1998. We first tried to match up the commodities under different classifications by the appropriate concordances. However, the generated price indices presented big swings in 1992 and 1994, which showed that the matching process was not successful. As such, in order to minimize the noise in the data, changes in price of the industry for these 2 years were interpolated from the rest of the years. Finally, with the help of an SITC to Standard Industrial Classification concordance, all the commodities are aggregated using Equation (26) to construct industry-level export price indices.[20]

Domestic versus imported materials

To infer the values of domestic and imported materials from the value of total materials purchased, we need to refer to the input-output tables of Hong Kong, which detail the composition of imported and domestic materials by industry over time. Unfortunately, there is no frequent publication of Hong Kong input-output tables other than those compiled by the Global Trade Analysis Project (GTAP) in 1995.[21]

There are two ways we can make use of the information provided from the input-output table of Hong Kong in 1995. The first is to assume that purchase shares of industry in total imported materials stay constant. In other words, if in 1995, the textile industry purchased 35 percent of the imported chemical products, then we assume that textile industry demands 35 percent of the imported chemical products for all the years. Therefore, the change in the total import of chemical products equals the changes of chemical products materials in all industries, regardless of the intensity of the materials in production.

Alternatively, we assume that within each industry, the expenditure shares of various imported materials in total imported materials stay constant. In other words, total imported materials of each industry can be thought of as a

20. Concordances used in the present paper can be found on the following website maintained by Jon Haveman: http://www.eiit.org/Trade.html

21. The GTAP, which was established in 1992 by Thomas Hertel at Purdue University has a rich global database, which includes individual country input-output tables that account for intersectoral linkages.

Cobb-Douglas function of the different types of imported materials. Therefore, if in 1995 the expenditure share of chemical materials in the total imported materials of textiles was 13 percent, then we assume that the share of chemical materials in total imported materials of textile industry stays at 13 percent for all years. In this way, an increase in the imports of chemicals products will have a different impact on different industries, and the size of the impact depends on the intensity of chemical materials of the industries. The same method applies to domestic materials.[22]

We use the expenditure shares to construct the growth rates of total domestic materials, with the assumption that growth rate of each type of domestic materials equals the growth rate of total domestic sales of the industry in which the materials are originated.[23] Growth rate of the share of domestic materials in total materials is calculated as the difference between the growth rates of total domestic materials ($\widehat{p_{nt}^D D_{nt}}$) and total materials ($\widehat{p_{nt}^Z Z_{nt}}$). Share of domestic materials in total materials is constructed by compiling change in share of domestic materials, and the share of imported materials in total materials is 1 minus the share of domestic materials: $\theta_{nt}^D \equiv \frac{p_{nt}^D D_{nt}}{p_{nt}^Z Z_{nt}} \Rightarrow \hat{\theta}_{nt}^D = \widehat{p_{nt}^D D_{nt}} - \widehat{p_{nt}^Z Z_{nt}}$, and $\theta_{nt}^D = \theta_{t-1}^D \exp(\hat{\theta}_{nt}^D)$.

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22. Detailed data on the expenditure shares are available upon request.
23. Domestic sales of industry n is the difference between total output and exports.

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