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An Analysis of Growth Attributes

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Abstract: *Since 1997, when the political sovereignty of Hong Kong reverted to China, the integration of the two economies has steadily increased. This article examines the economic and institutional differences between mainland China and Hong Kong, and considers the spillover benefits for the provinces adjacent to Hong Kong. The economic and productivity growth of mainland China and Hong Kong are decomposed into four attributes: input growth, adjusted scale effect, technical progress, and efficiency growth. A stochastic frontier model is used to estimate the growth attributes, and a human capital variable is incorporated in the production function. The empirical study compares the growth, productivity, and efficiency performance of mainland China and Hong Kong.*

The sovereignty of Hong Kong reverted to the People's Republic of China on July 1997, after 155 years of colonial rule by the British. Hong Kong became a Special Administrative Region (SAR) of China. The Basic Law in Hong Kong preserves

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its capitalist market economic structure, but there are great systemic differences between mainland China and Hong Kong. In 1949, mainland China adopted a system of socialist economic principles and central planning as practiced in the former Soviet Union. During the three decades from the 1950s through the 1970s, state planning in mainland China resulted in resource distortion and economic inefficiency (Perkins 1986, 1988). For decades, Hong Kong has practiced a laissez-faire economic system with strong adherence to rights of private property and economic freedom. Through the industrialization process that began in the 1960s, Hong Kong became a mature economy, and by the 1980s had about the same GDP per capita as Japan. It turned from a receiver to a supplier of foreign investment, especially to neighboring economies (Li 2002, 2006).

In the period from the beginning of economic reform in 1978 until 1997, Hong Kong played an important role in China's economic development as financier, facilitator, mediator, and investor, especially in the adjacent Guangdong province (Sung 1991). According to one source, 70 percent of the foreign direct investment (FDI) utilized in Guangdong in 2001 originated in Hong Kong (Li 2006, 370). At the time of sovereignty reversion in 1997, there was still a vast difference in the level of economic development between mainland China and Hong Kong. For example, Hong Kong ranked first, and mainland China ranked 135th, in the 2011 *Index of Economic Freedom*, and the per capita GDP of Hong Kong was 7.4 times higher than that of mainland China in 2006 (Heritage Foundation 2009, 2011). Businesses in Hong Kong operate under a strong legal system, while in mainland China *guanxi* (relationships) is an important form of business behavior (Dixit 2004). With sovereignty reversion, "economic welding" in the form of economic cooperation and integration between China and Hong Kong is expected to increase.

This article examines the different growth attributes of mainland China and Hong Kong in order to further understand the economic dimensions for integration of the two economies. Studies of the growth of total factor productivity (TFP) in the two economies have employed the neoclassical Solow (1957) growth accounting approach (Borenzstein and Ostry 1996; Kalirajan, Obwona, and Zhao 1996; Li 2003, 2006, 2009; Lin 2000; Liu and Li 2006). The few studies that have analyzed economic efficiency in China are largely sector- or enterprise-oriented (Fu 2005; Huang and Kalirajan 1998; Kalirajan and Zhao 1997; Tong 1999; Wu 1995). Regional economic imbalance in China is another area of scholarly concern. The role of input differences in economic growth has also been studied (Cai, Wang, and Du 2002; Chang 2002; Liu and Li 2006; Wan 2004; Yao, Zhang, and Feng 2005; Zhang and Zhang 2003).

However, the neoclassical assumptions of constant returns to scale and optimal production capacity in the Solow (1957) model have been challenged by the output-oriented stochastic frontier-production approach, which argues that deviations between actual and optimal output are possible due to technical inefficiency (Aigner, Lovell, and Schmidt 1977). The stochastic frontier approach assumes nonconstant returns to scale and decomposes TFP growth into three components:

technical progress, technical efficiency change, and scale effect (Kumbhakar and Lovell 2000).

The stochastic frontier-production model is used to analyze and compare the growth attributes of the two economies with the aim of drawing lessons for further integration. In addition to the physical capital and labor variables, a human capital variable is included in the stochastic frontier-production function (Li and Liu 2011). The sample periods for mainland China and Hong Kong are 1986–2006 and 1983–2005, respectively. To determine changes, improvement of efficiency, and technical progress for the two economies, the estimates for the period before 1997 are compared to the whole sample period. The break point of 1997 was chosen to reflect both the sovereignty reversion in 1997 and the Asian financial crisis in the period 1997–1998. Note that the different statistical systems in the two economies may not generate directly comparable empirical results, but the results can still be used for analysis.

Panel data from mainland China and Hong Kong are used in the regression exercise. The data sources and compilation of different variables for the thirty provinces in mainland China, updated to 2006, are similar to those used by Li (2003, 2009), Li, Yun, and Lui (2009), and Liu and Li (2006). The data for Hong Kong used in Li (2006) are updated to 2005, and the construction of human capital, together with the explanation of other data, is discussed in the Appendix. The aggregate data for the Hong Kong economy come from fourteen comprehensive industries grouped into four economic sectors. The tradable goods sector includes agriculture and fishing, mining and quarrying, and manufacturing. The tradable services sector includes import and export trade, restaurants and hotels, air and water transport, other transport services, storage and communications, financing, insurance, real estate, and business services. The nontradable goods sector comprises only construction, electricity, gas, and water. The nontradable services sector covers wholesale and retail, land transport, and community, social, and personal services.

Economic Integration Performance

From 1949 to 1978, mainland China pursued a closed-door economic policy of self-sufficiency, with a socialist ideology characterized by state-ownership and communes. During the same time period, Hong Kong practiced an open-market capitalist economic system and became an international center of finance, trade, and investment. In 2005, for example, total trade flows and foreign direct investment as a percentage of GDP for mainland China were 69.5 percent and 4.1 percent, respectively. The figures for Hong Kong were 385.2 percent and 34.2 percent, respectively (IMF 2007).

There are vast differences in institutional performance between mainland China and Hong Kong, as documented by established world institutions. Mainland China's performance in key institutional indicators is weaker than Hong Kong's, as is shown in Table 1. In 2009 the Chinese Academy of Social Sciences ranked the overall urban competitiveness of 294 cities in the Greater China region, including the four Chinese economies of mainland China, Chinese Taipei, Hong Kong, and Macau. Hong Kong was ranked the most competitive city, followed by Shenzhen, Shanghai, Beijing, Taipei, Guangzhou, Qingdao, Tianjin, Suzhou, and Kaohsiung as the top-ten most competitive cities. Shenzhen and Guangzhou are both located adjacent to Hong Kong (CASS 2009).

Since 1997 the Hong Kong economy has suffered a series of economic shocks and crises, including the Asian financial crisis in 1997–98, the avian flu that occurred in various years, the outbreak of severe acute respiratory syndrome (SARS) in 2003, and the financial tsunami in 2008 (Li 2006). Cooperative agreements have been made between the central government in Beijing and the Hong Kong SAR government since 2003, when the Closer Economic Partnership Agreements (CEPA) were concluded to lower the tariff rates of mainland China for goods and services imported from Hong Kong. Since 2005, the Beijing government has had a visa-free travel policy for mainland residents from major cities and provinces visiting Hong Kong. In 2006, led mainly by Guangdong, a regional Pan–Pearl River Delta (Pan-PRD) body was established consisting of nine southern provinces, the Hong Kong SAR, and the Macau SAR to promote regional development and growth. Hong Kong's status as a financial center status was promoted by the policy on Qualified Domestic Institutional Investor (QDII) announced in 2006, permitting mainland capital to come to Hong Kong, but due to the drastic jump in the financial market in Hong Kong, the policy was shelved in November 2007. In spring 2009, Beijing declared that Hong Kong would become a renminbi trading center.[1]

A closer examination of key economic variables shows that provinces closer to Hong Kong have benefited most from Hong Kong's return to mainland China through spillovers of investment, trade, cross-border consumption, and human capital. In 2007, at least 49.4 percent of Hong Kong's total direct investment in mainland China entered into the nine provinces in the Pearl River Delta (PRD) region. As for the sources of FDI in these nine provinces, Table 2 shows the FDI from Hong Kong and the world in each of the nine provinces. The FDI from Hong Kong is the largest share in each province, though Hong Kong's investment funds in mainland China could have come from elsewhere, including mainland China (Sung 1991). The share of total exports from mainland China to Hong Kong in the nine provinces amounted to at least 74.7 percent in 2007.

Mainland China has become the key destination for Hong Kong resident departures for outbound travel, with the percentage share in Hong Kong's total resident departures amounting to 85 percent or higher between 1999 and 2007 (CSD 2008). The majority of these personal travel trips to mainland China are destined for Guangdong province, which accounted for 94.7 percent in 2007, with Shenzhen city having the largest share in Guangdong (about 58 percent) in 2007. This reflects the geographical proximity and close socioeconomic ties between Hong Kong and Guangdong province. Other than leisure-travel trips, knowledge spillover from Hong Kong to mainland China has also been important. A total of 218,200 Hong Kong residents were working in China in the third quarter of 2008,

Table 1

Institutional Performance: Mainland China and Hong Kong

Institutional establishment (2005)	Mainland China	Hong Kong
Corruption perception index	3.2	8.3
Voice and accountability	16.8	55.1
Political stability	46.4	73.7
Government effectiveness	47.8	82.5
Regulatory quality	44.5	87.7
Rule of law	40.5	80.0
Control of corruption	36.2	83.7
Property right protection	30.0	90.0
Regulatory scores	30.0	90.0
Economic freedom (2009)	Mainland China	Hong Kong
Economic Freedom Index	53.2	90.0
Business freedom	51.6	92.7
Trade freedom	71.4	95.0
Fiscal freedom	70.6	93.4
Government size	88.9	93.1
Monetary freedom	72.9	86.2
Investment freedom	30.0	90.0
Financial freedom	30.0	90.0
Property rights	20.0	90.0
Freedom from corruption	35.0	83.0
Labor freedom	61.8	86.3

Sources: Heritage Foundation 2009; Transparency House 2005; World Bank 2005.

equivalent to 6.2 percent of the total employed population of Hong Kong. Of the total of Hong Kong residents working in mainland China, 87.8 percent work in Guangdong province, and 62.9 percent are employed in the two Guangdong cities of Shenzhen and Dongguan. Outside Guangdong province, Shanghai is the more popular city, employing 4.9 percent of the total population.

A statistical report published by the Census and Statistics Department in Hong Kong in 2009 reviewed how Hong Kong residents working in mainland China supplement the shortage of specialized human capital in mainland China (CSD 2009). Middle-aged workers, 40 to 49 years old, form the largest group. In educational attainment, those with a secondary and sixth-form education are the largest group. This implies that labor mobility from Hong Kong to mainland China is more significant at the higher educational level than other levels. Manu-

Table 2

Foreign Direct Investment and Export Flows

	1985			1995			2007		
	Hong Kong	World	Hong Kong/ World (%)	Hong Kong	World	Hong Kong/ World (%)	Hong Kong	World	Hong Kong/ World (%)
FDI from Hong Kong and world to nine PRD provinces (actually utilized, US$million)									
Fujian	9.6	11.8	81.6	25.0	403.9	62.	170.2	406.1	41.9
Guangdong	45.0	51.5	87.4	797.3	1,018.0	78.3	830.3	1,712.6	48.5
Guangxi	1.3	1.3	100.0	37.2	67.0	55.6	16.0	68.4	23.4
Hainan	2.1	2.1	97.9	56.4	105.5	53.5	n/a	112.0	n/a
Jiangxi	n/a	0.5	n/a	n/a	28.8	n/a	178.9	310.4	57.5
Hunan	n/a	n/a	n/a	32.3	48.8	66.2	153.3	327.1	48.1
Sichuan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	149.3	n/a
Guizhou	n/a	n/a	n/a	n/a	5.7	n/a	n/a	12.7	n/a
Yunnan	n/a	0.2	n/a	n/a	22.5	n/a	15.8	39.5	40.1
Nine provinces	57.9+	67.3+	86.1+	948.2+	1,700.2+	55.8+	1,368.7+	3,137.9	43.6+
Nation	95.6	195.6	48.9	2,018.5	3,752.1	53.8	2,770.3	7,476.8	37.1
Exports from nine PRD provinces to Hong Kong and world (US$1,000 million)									
Fujian[3]	0.2	0.5	40.3	4.1	9.3	43.9	3.6	49.9	7.2
Guangdong[1]	2.1	3.0	72.1	48.4	55.7	87.0	129.9	369.2	35.2

(*continued*)

Table 2 (*continued*)

	1985			1995			2007		
	Hong Kong	World	Hong Kong/ World (%)	Hong Kong	World	Hong Kong/ World (%)	Hong Kong	World	Hong Kong/ World (%)
Guangxi[3]	0.2	0.4	43.6	1.2	2.2	53.3	0.4	5.1	8.2
Hainan[1]	n/a	n/a	n/a	0.4	0.8	53.5	0.4	1.8	23.0
Jiangxi[2]	0.1	0.3	33.2	0.8	1.4	52.5	0.6	5.5	11.3
Hunan[1]	n/a	n/a	n/a	0.3	1.1	31.8	0.8	6.5	12.5
Sichuan[1]	n/a	0.2	n/a	n/a	1.9	n/a	1.5	8.6	17.8
Guizhou[1]	n/a	0.0	n/a	n/a	0.4	n/a	n/a	1.5	n/a
Yunnan[3]	n/a	0.1	n/a	n/a	1.2	n/a	0.4	4.7	9.2
Nine provinces	2.6+	4.5+	57.4+	55.3+	74.1	74.6+	137.8+	452.9	30.4+
Nation	7.2	27.4	26.3	36.0	148.8	24.2	184.4	1,217.8	15.1

Sources: National Bureau of Statistics 1985, 1995, 2007; Statistical yearbooks of the nine provinces, various years. All national data are based on customs statistics; data for provinces to 1998 are from Ministry of Foreign Trade, Beijing.

Notes: [1] Hong Kong was largest export destination in 2007. [2] Hong Kong was second-largest export destination in 2007. [3] Hong Kong was third-largest export destination in 2007.

facturing and wholesale/retail services have attracted more people than other industrial groups. Although only 5.4 percent of people in Hong Kong are engaged in manufacturing, 41.7 percent of Hong Kong residents working in mainland China are in manufacturing. In terms of occupations, most Hong Kong residents working in mainland China are managers, administrators, and professionals. The total percentage represented by these groups is 86.5 percent, much higher than the total percentage represented by these groups employed in Hong Kong (36.4 percent). The 2009 report also shows that 17.1 percent of Hong Kong residents working in China are employers.

A large proportion of Hong Kong residents working in China are engaged at the upper end of the occupational hierarchy. For example, the median monthly earnings of Hong Kong residents working in mainland China have reached HK$20,000 (US$2,564), but the median earnings in Hong Kong in the same period were HK$10,500 (US$1,346). Knowledge spillover from Hong Kong to mainland China was an important factor in the economic integration process in the period after sovereignty reversion.

Stochastic Frontier Model and Output Growth Decomposition

This article considers the four sources of output growth: input growth, adjusted scale effect, technical progress, and technical-efficiency change (Li and Liu 2011). The adjusted scale effect shows the combined effect from the input elasticity of physical capital, labor, and human capital. Technical progress shows the rate of technological change and is indicated by an outward shift in the economy's production-possibility frontier. Technical-efficiency change refers to a movement from a position within the production-possibility frontier toward the production frontier.

A conventional production function shows how a producer maximizes output from inputs. The estimates of the output, cost, and profit functions are based on the assumption that producers are operating optimally and efficiently. However, Kumbhakar and Lovell (2000) have pointed out that such an estimation technique fails to deal with variations in production efficiency because not all producers are successful in solving their optimization problems. The stochastic frontier analysis assumes that deviations from the efficient frontier can be either a realization of inefficiency or a random shock (Coelli, Rao, and Battese 1998; Farrell 1957; Stevenson 1980).

The estimation model with a production-frontier function without the random component, as suggested in Aigner et al. (1977), can be stated as:

$$y_i = f(x_i; \beta) \cdot TE_i, \tag{1}$$

where y_i is the observed scalar output and x_i is a vector of inputs for ith firm, β is a $k \times 1$ vector of parameters to be estimated, and TE_i denotes the technical efficiency defined as the ratio of observed output to maximum feasible output (Aigner and Chu 1968). Let $y_i = f(x_i; \beta) \exp(-u_i)$. Then

$$TE_i = \frac{y_i}{f_i} = \exp(-u_i), \tag{2}$$

where u_i is supposed to measure technical inefficiency and when $u_i \geq 0$, then $TE \leq 1$ (Battese, Coelli, O'Donnell, and Rao 2005). Such an output-oriented measure of technical efficiency takes a value between zero and one. It measures the output of the *i*th firm relative to the stochastic frontier output that could be produced by a fully efficient firm utilizing the same vector of inputs. The technical efficiency TE_i can be derived using the estimates from the stochastic frontier-production model. If $TE_i = 1$, then the firm is technically efficient.

The specification of technical inefficiency in Equation (1) may also capture other random shocks that are either beyond the control of the firm or not directly attributable to the underlying technology. The random shocks affecting the production process can be included in the production-frontier function by adding a two-sided error term (Aigner and Chu 1968). The stochastic frontier production now becomes:

$$y_i = f(x_i; \beta) \exp(-u_i) \exp(\nu_i), \tag{3}$$

where $\exp(\nu_i)$ denotes the stochastic component that describes the random shocks. When expressed in a Cobb-Douglas format of the production function, $f(x_i; \beta)$ takes a log-linear form, and the stochastic frontier-production model can be written as:

$$\ln y_i = \beta_0 + \sum_{j=1}^{k} \beta_j ln(x_{ji}) + v_i - u_i. \tag{4}$$

The logarithmic production function can be further augmented by incorporating a human capital variable. The panel data production function for the empirical estimate is expressed as:

$$\ln Y_{it} = \alpha + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_H H_{it} + \sum_t \delta_t D_t + v_{it} - u_{it}, \tag{5}$$

where $i = 1, \ldots, N$ (provinces in China or economic sectors in Hong Kong), and $t = 1, \ldots, T$; $\ln Y_{it}$ is the log of real GDP for *i*th province/economic sectors in China/Hong Kong at time *t*. Where $\ln K_{it}$ is the log of physical capital stock; $\ln L_{it}$ is the log of total number of employed workers in China or the log of total number of labor-working hours in Hong Kong; H_{it} is the human capital variable; D_t is the time-dummy variable that captures technological progress; and the parameter δ_t can be used to measure technical level over time.

The random error, ν_{it}, is symmetric and normally distributed with $\nu_{it} \sim N(0, \sigma^2_v)$, and the technical inefficiency term, u_{it}, is assumed to be a non-negative truncated normal random error with the $u_{it} \sim N^+(\mu, \sigma^2_u)$, where μ is the mode of the normal distribution (Kumbhakar and Lovell 2000). Technical inefficiency can be either time variant (u_{it}) or time invariant (u_i). In the case of time variant, technical inefficiency, u_{it} can be expressed as a monotonic "decay" function as $u_{it} = \eta_t u_i$, where η_t

= exp[$-\eta(t - T)$], and η is an unknown scalar parameter for technical inefficiency. Then u_{it} can be increasing (if $\eta < 0$), decreasing (if $\eta > 0$), or constant (if $\eta = 0$) (Battese and Coelli 1992).

The maximum-likelihood method is used to estimate the parameters in a stochastic frontier production. The minimum-mean-square-error predictor of technical efficiency of the *i*th province/economic sector at time *t* is shown in the following equations (Battese and Coelli 1988, 1992, 1995; Battese and Corra 1977; Coelli 1996; Kumbhakar and Lovell 2000):

$$TE_{it} = E[\exp(-u_{it})|\varepsilon_{it}], \tag{6}$$

where

$$\varepsilon_{it} = v_{it} - u_{it}. \tag{7}$$

Equation (5) is applied to the provincial panel data of mainland China and the economic sectors panel data of Hong Kong to derive the measures of output growth, total-factor-productivity (TFP) growth, and their sources. The output elasticities for physical capital, labor, and human capital for mainland China and Hong Kong are denoted, respectively, as $e_{K_{it}} = \beta_K$, $e_{L_{it}} = \beta_L$, and $e_{H_{it}} = \beta_H H_{it}$. The returns to scale are measured as:

$$e_{it} = e_{K_{it}} + e_{L_{it}} + e_{H_{it}}. \tag{8}$$

Following Li and Liu (2011), the decomposition of output growth is shown as follows:

$$\dot{Y}_{it} = \frac{e_{K_{it}}}{e_{it}}\dot{K}_{it} + \frac{e_{L_{it}}}{e_{it}}\dot{L}_{it} + \frac{e_{H_{it}}}{e_{it}}\dot{H}_{it} + Scale_{it} + \Delta\delta_t + T\dot{E}_{it}, \tag{9}$$

where

$$Scale_{it} = (e_{it} - 1)\left(\frac{e_{K_{it}}}{e_{it}}\dot{K}_{it} + \frac{e_{L_{it}}}{e_{it}}\dot{L}_{it} + \frac{e_{H_{it}}}{e_{it}}\dot{H}_{it}\right). \tag{10}$$

Equation (10) gives a measure of the adjusted scale effect. Technical progress is measured by $\Delta\delta_t = \delta_t - \delta_{t-1}$, and δ_t can be estimated from Equation (5). The change in technical efficiency, $T\dot{E}_{it}$, can be estimated from Equation (6). Note that the ratio of output elasticity for each input to returns to scale is equivalent to the cost share of each input (for detailed discussion, see Li and Liu 2011). Define the growth of aggregate input as:

$$\dot{\Phi}_{it} = \frac{e_{K_{it}}}{e_{it}}\dot{K}_{it} + \frac{e_{L_{it}}}{e_{it}}\dot{L}_{it} + \frac{e_{H_{it}}}{e_{it}}\dot{H}_{it}, \tag{11}$$

then

$$\dot{Y}_{it} = \dot{\Phi}_{it} + Scale_{it} + \Delta\delta_t + T\dot{E}_{it}. \tag{12}$$

Define the *TFP* for a production function with multiple inputs at time *t* as

$$TFP_t = \frac{Y_t}{\Phi_t}. \tag{13}$$

Then the growth of *TFP* is

$$\dot{TFP}_{it} = Scale_{it} + \Delta\delta_t + \dot{TE}_{it}. \tag{14}$$

The decomposition of output growth and productivity growth, shown in Equations (12) and (14), will be applied to the empirical data for mainland China and Hong Kong. In particular, the components of decomposition, shown in Equations (8), (10), and (11), can be used to explain the change in growth over time.

Empirical Results

Table 3 presents the maximum-likelihood estimates of stochastic frontier production with panel data for two periods from mainland China's thirty provinces and Hong Kong's four sectors. The first period covers the first subsample through 1996. The second period is the whole sample period, which includes the transfer of sovereignty from Hong Kong to China in 1997 and the Asian financial crisis in 1997–98. For mainland China, the first subsample period covers 1985–1996 with 360 observations, and the whole sample period covers 1985–2006 with 660 observations. For Hong Kong, the first subsample covers 1983–1996 with 56 observations, and the whole sample period covers 1983–2005 with 92 observations. The purpose of selecting these two sample periods is to examine whether the two economies have encountered changes in production efficiency and frontier functions over time. Because of limited data in the second subsample period from 1997, the estimation cannot be applied to the second subsample period alone. However, the properties of the estimates for this period can be inferred by comparing the estimations from the first subsample period and the whole sample period.

The dependent variables of the models for both periods are the log real GDP. The independent variables, in addition to physical capital, labor, and human capital, include eleven and twenty-one time-dummy variables for the two periods for mainland China, and thirteen and twenty-two time dummy variables for the two periods in Hong Kong. The last row in Table 3 presents the four sets of model specification tests containing the likelihood-ratio tests for the joint effects of the time-dummy variables for the two sample periods. The significance level of the likelihood-ratio tests is set at 5 percent. The statistics for the two periods in mainland China and Hong Kong show that time-dummy variables are significant, implying that technology change over time is significant.[2]

In the pre-1997 period of mainland China, the effect of physical capital is clearly predominant in the production function. Nevertheless, the effect of labor remains close to physical capital over time, as indicated by a larger estimate of

Table 3

Maximum Likelihood Estimates of Stochastic Frontier-Production Function

	China		Hong Kong	
	Before 1997 1985–1996	Whole period 1985–2006	Before 1997 1983–1996	Whole period 1983–2005
	(1)	(2)	(3)	(4)
lnK	0.7750	0.4424	0.5393	0.4047
	(0.0381)	(0.0208)	(0.1139)	(0.0300)
lnL	0.1890	0.4320	0.4245	0.7087
	(0.0388)	(0.0239)	(0.0484)	(0.0313)
H	0.0133	0.0386	0.0712	0.0641
	(0.0109)	(0.0064)	(0.1811)	(0.0427)
μ	0.3825	0.8546	0.2750	0.4514
	(0.1838)	(0.1162)	(1.2704)	(0.2802)
η	–0.0361	–0.0223	0.0117	0.0073
	(0.0039)	(0.0017)	(0.0120)	(0.0049)
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.2031	0.1557	0.0775	0.0546
$\gamma = \sigma_u^2 / \sigma_s^2$	0.9880	0.9743	0.9713	0.9324
Log likelihood	474.4785	771.6274	79.0864	105.6346
Log likelihood ratio test:				
$\delta_t = 0$, for all t	160.76	454.45	37.93	64.92

Notes: Figures in parentheses stand for standard errors of estimates.

labor for the whole sample period of mainland China.[3] The estimated technical inefficiency parameters, η, are negative, meaning that the overall technical inefficiency is increasing over time for both periods. The measure of the variation in inefficiency is indicated by $\gamma = \frac{\sigma_u^2}{\sigma_s^2}$, where σ_s^2 refers to the sum of the variances of the combined error terms (i.e., the variance of the normal random error term, σ_v^2 and the variance of the technical inefficiency term, σ_u^2). The estimates for the two periods suggest that the inefficiency component showed a greater variation in the composite error term in the pre-1997 period (0.988) than in the whole sample period (0.9743).

In the case of Hong Kong, the effect of physical capital is mildly predominant in the production function in the pre-1997 period, but the effect of labor surpasses that of physical capital in the whole sample period. This implies that the effect of labor increased in the post-1997 period. The estimated technical-inefficiency parameters, η, are positive, suggesting that the overall technical inefficiency is decreasing over

Table 4

Output Elasticities and Cost Shares of Inputs

	Output elasticities				Cost shares (%)		
	e_K	e_L	e_H	e	$\frac{e_k}{e}$	$\frac{e_L}{e}$	$\frac{e_H}{e}$
Before 1997							
China	0.7750	0.1890	0.0650	1.0291	75.31	18.37	6.32
Hong Kong	0.5393	0.4245	0.8259	1.7897	30.15	23.74	46.11
Whole period							
China	0.4424	0.4320	0.2072	1.0817	40.29	39.97	19.11
Hong Kong	0.4047	0.7087	0.7801	1.8934	21.39	37.46	41.15

time. The estimates of the variation in inefficiency, γ, show that the inefficiency component has a higher variation in the pre-1997 period (0.9713) than in the whole sample period (0.9324). This implies a mild decrease in variation since 1997.

The estimates from Equation (5) are also used to derive the estimates for the sources of output growth ($\dot{Y}$) and total-factor-productivity growth ($\dot{TFP}$). The estimated terms are output elasticity with respect to factor input of capital (e_K), labor (e_L) and human capital (e_H); returns to scale (e); adjusted scale effect ($Scale$); rate of technical progress ($\Delta\delta_t$); and growth of technical efficiency ($\dot{TE}$).

Table 4 shows the overall means of output elasticity with respect to each input and the cost shares of inputs in mainland China and Hong Kong for the two periods. The results for the period before 1997 are considered first. For mainland China, physical capital has the largest output elasticity with an average value of 0.7750, followed by labor (0.1890) and human capital (0.0650). For Hong Kong, human capital has the largest output elasticity (0.8259), followed by physical capital (0.5393) and labor (0.4245). The differences in output elasticities between mainland China and Hong Kong result in the differences in returns to scale and cost shares of inputs. The returns to scale are much higher in Hong Kong (1.7896) than in mainland China (1.0291), such that returns to scale are an important factor for economic growth in Hong Kong. For cost shares in mainland China, the share for physical capital (75.31 percent) is highest, followed by labor (18.37 percent) and human capital (6.32 percent). For Hong Kong, the range of the three cost shares is smaller, with human capital the largest (46.11 percent), followed by physical capital (30.15 percent) and labor (23.74 percent). In terms of both output elasticity and cost share, physical capital was important for mainland China and human capital was important for Hong Kong before 1997.

In the whole sample period, as shown in Table 4, the output elasticities for physical capital and labor in mainland China (0.4424 and 0.4320, respectively) are similar and larger than the elasticity for human capital (0.2072). For Hong Kong, the output elasticities for labor and human capital (0.7087 and 0.7801, respectively) are similar and larger than the elasticity for physical capital (0.4047). In summary, the output elasticities for labor and human capital are larger in Hong Kong than in mainland China, while the elasticity for physical capital is similar for mainland China and Hong Kong.

By comparing the results from the pre-1997 period and the whole sample period, we can infer the change in output elasticities for the period since 1997. For mainland China, the output elasticity for physical capital in the whole sample period (0.4424) is much smaller than in the pre-1997 period (0.7750). This implies that output elasticity of physical capital has decreased since 1997 and should be smaller than 0.4424. As for labor and human capital, their output elasticities have increased since 1997 because these two elasticities are larger in the whole sample period than in the pre-1997 period. Therefore, physical capital became less important, while labor and human capital became more important since 1997 in mainland China. This may indicate the diminishing return after the intensive use of physical capital in the pre-1997 period. For Hong Kong, the output elasticity for labor is much higher in the whole sample period (0.7087) than in the pre-1997 period (0.4245). This implies that the output elasticity of labor became higher and labor became more important since 1997 in Hong Kong. However, the elasticities for both physical capital and human capital had a mild decrease since 1997. Overall, the output elasticities for all three inputs are higher in Hong Kong than in mainland China since 1997. The value of returns to scale is still much larger in Hong Kong (1.8934) than in mainland China (1.0817). Hong Kong consistently has larger returns to scale than mainland China in the whole sample period.

In the whole sample period, Table 4 shows that the pattern of cost share is similar to that of output elasticity. The cost shares for physical capital and labor in mainland China (40.29 percent and 39.97 percent, respectively) are close and larger than the share of human capital (19.11 percent). For Hong Kong, the cost shares of labor and human capital (37.46 percent and 41.15 percent, respectively) are larger than the cost share of physical capital (21.39 percent). Among the three inputs, mainland China has a larger share of physical capital than Hong Kong, while Hong Kong has a larger share of human capital than mainland China.

Cost shares since 1997 can be inferred by comparing the cost shares in the pre-1997 period and in the whole sample period. The cost share for physical capital in mainland China has declined and the shares for labor and human capital have increased during the whole sample period. The cost share for physical capital in mainland China has declined and the shares for labor and human capital have increased between the two sample periods. For Hong Kong, the cost share for labor has increased and both shares for physical capital and human capital have decreased between the two sample periods. One concludes that both cost shares for physical capital and labor are higher in mainland China than in Hong Kong and the cost share for human capital is higher in Hong Kong than in mainland China.

Table 5 shows the input growth for each input and adjusted scale effect. In the pre-1997 period, the weighted aggregate input growth in China is 7.79 percent, with physical capital accounting for 93.20 percent (7.26 of 7.79 percent), while labor and human capital account for 4.88 percent and 1.93 percent, respectively. This implies that physical capital is dominant in mainland China. The growth of aggregate weighted inputs in Hong Kong shows an average of 2.38 percent, with physical capital accounting for 63 percent (1.5 of 2.38 percent), while labor and human capital account for 9 percent and 27 percent, respectively. The input growth is lower in Hong Kong than in mainland China, mainly because of low growth in physical capital, although physical capital is still the main contributor to input growth in Hong Kong.

In the whole sample period, Table 5 shows that the growth of aggregate input in mainland China has an average of 5.10 percent and Hong Kong has an average of 1.14 percent. Both input growth rates are lower than their values in the pre-1997 period. The lower input growth in mainland China is mainly caused by a lower cost share of physical capital in the whole sample period than in the pre-1997 period. The low-input growth in Hong Kong is caused by low weighted-physical-capital growth and the negative labor growth (due probably to emigration, see Li 2006) during the post-1997 period. However, physical capital is still dominant in the weighted-input growth for both mainland China and Hong Kong in the whole sample period. Physical capital accounted for around 80 percent of mainland China's input growth (4.06 of 5.1 percent) and 70 percent of Hong Kong's input growth (0.83 of 1.14 percent).

Since each return to scale shown in Table 4 is greater than one, the adjusted scale effect is positive. In the pre-1997 period, Table 5 shows, the scale effect is lower in mainland China (0.24 percent) than in Hong Kong (1.89 percent). This difference is mainly caused by the higher returns to scale in Hong Kong than in mainland China (1.7897 and 1.0291, respectively, shown in Table 4). In the whole sample period, the scale effects in mainland China and Hong Kong are 0.42 percent and 0.97 percent, respectively. This gap between the two scale effects is smaller than the gap in the pre-1997 period. The higher scale effect in mainland China in the whole sample period is caused by the higher returns to scale in the whole sample period. The lower scale effect in Hong Kong is caused by the lower input growth in the whole sample period.

Finally, Table 6 shows the decomposition of output growth and TFP growth for both mainland China and Hong Kong for the two periods. The four sources of the output growth are growth in inputs (Φ), scale effect (Scale), rate of technical progress ($\Delta\delta_t$), and growth in technical efficiency ($\dot{TE}$). In the pre-1997 period, the average economic growth in mainland China was 9.6 percent. The major contributor to this high economic growth is input growth (7.79 percent) followed by technical progress (3.18 percent). The adjusted scale effect (0.24 percent) contributes only a small fraction to the economic growth. The contribution from technical efficiency is negative in all years, with an average of –1.54 percent. When the sources of TFP growth are considered, the factor of input growth is removed. The average TFP growth in mainland China is 1.88 percent. Technical progress (3.18 percent)

Table 5

Input Growth and Adjusted Scale Effect

	Input growth (%)				Scale effect (%)			
	$\frac{e_k}{e}\dot{K}$	$\frac{e_L}{e}\dot{L}$	$\frac{e_H}{e}\dot{H}$	Φ	$(e-1)(\frac{e_k}{e}\dot{K})$	$(e-1)(\frac{e_L}{e}\dot{L})$	$(e-1)(\frac{e_H}{e}\dot{H})$	Scale
Before 1997								
China	7.26	0.38	0.15	7.79	0.22	0.01	0.004	0.24
Hong Kong	1.50	0.22	0.65	2.38	1.20	0.16	0.52	1.88
Whole period								
China	4.06	0.67	0.36	5.10	0.34	0.05	0.03	0.42
Hong Kong	0.83	–0.17	0.47	1.14	0.74	–0.18	0.42	0.97

Table 6

Decomposition of Output Growth and TFP Growth (%)

	$\dot{Y}$	$\dot{\Phi}$	Scale	$\Delta\delta_{Tt}$	$\dot{TE}$	$\dot{TFP}$
Before 1997						
China	9.60	7.79	0.24	3.18	–1.54	1.88
Hong Kong	4.17	2.38	1.89	–0.50	0.41	1.79
Whole period						
China	9.90	5.10	0.42	5.89	–1.51	4.80
Hong Kong	2.39	1.14	0.97	–0.08	0.36	1.26

is the main factor for TFP growth. The negative contribution from technical efficiency change (–1.54 percent) significantly reduces the potential growth of TFP in mainland China.

In the case of Hong Kong, the mean of output growth in the pre-1997 period is 4.17 percent. As can be seen, the major contributors to its economic growth are input growth (2.38 percent) and scale effect (1.89 percent). The small positive of technical efficiency (0.41 percent) is offset by the negative of technology progress (–0.5 percent). Since the 1980s, political uncertainty generated by sovereignty reversion, coupled with de-industrialization as manufacturing plants moved to southern China, could explain the fall in Hong Kong's technical progress in the pre-1997 years. The average TFP growth in Hong Kong is 1.79 percent, which is close to the TFP growth in mainland China. However, the major factor for Hong Kong's TFP growth is scale effect (1.89 percent). A closer examination on the different performances of various TFP components in the pre-1997 period can be seen from the yearly figures (not included in Table 6). For example, technical progress has contributed much, 8.87 percent and 3.01 percent to TFP growth in 1987 and 1988, respectively, when the Sino-British Joint Declaration on the political future of Hong Kong was concluded, and economic stability was revived. However, it did not improve, but instead slackened to negative rates in later periods when the economy overheated in the years before 1997. As can be seen, TFP reached a peak of 4.96 percent in 1991 before it fell, largely due to the poor contribution of technical progress.

In the whole sample period, as Table 6 shows, average economic growth in mainland China was 9.9 percent, which is close to its value in the pre-1997 period. However, technical progress (5.89 percent) has taken up the role of input growth (5.1 percent) as major contributor to economic growth in the whole sample period. The scale effect (0.42 percent) is still a small positive, and the average contribution from technical efficiency remains negative (–1.51 percent). The TFP growth in the whole sample period is 4.8 percent, much higher than the value in the pre-1997 period (1.88 percent). This high TFP growth is largely responsible for technical progress. The economic growth in Hong Kong had an average of 2.39 percent in the whole sample period. The major contributors to its economic growth are still input growth (1.14 percent) and scale effect (0.97 percent). However, these values became about one-half of the values in the pre-1997 period and led to a lower growth rate in the whole sample period than in the pre-1997 period. The only small improvement is the rate of technical progress, with a smaller negative average value of –0.08 percent. The overall mean of TFP growth in the whole period is 1.26 percent. This value is lower than the value in the pre-1997 period and was mainly caused by the lower scale effect. As in the pre-1997 period, the most important factor for Hong Kong's TFP growth in the whole sample period is scale effect.

Comparing the economic growth of mainland China and Hong Kong over the whole sample period, Table 6 shows that mainland China had higher economic growth than Hong Kong, since input growth and technology progress are higher in mainland China. Technical progress also explains the higher TFP growth in mainland China than in Hong Kong. To infer the differences between mainland China and Hong Kong, we conclude that the input growth and technical progress have contributed to the higher economic growth and TFP growth in mainland China than in Hong Kong.

Conclusion

This article applies stochastic frontier models to analyze the economic performance of the two economies in two periods. Mainland China has experienced increases in output and productivity growth. Empirical results show that input growth was the main engine of economic growth before 1997, but its important role was replaced by technical progress after 1997. Technical progress was also the major contributor to TFP growth in the whole sample period and significantly contributed to the improvement of TFP growth after 1997. Technical inefficiencies remain and represent a significant drag on mainland China's productivity growth.

The growth pattern in Hong Kong is different from mainland China's in several ways. Although input growth was also the main engine for Hong Kong's economic growth before 1997, it remained important after 1997. Returns to scale in Hong Kong outperformed those in mainland China for all the years in the sample period. Hence, the adjusted scale effect induced by high returns to scale is the major contributor to the productivity growth in Hong Kong. Hong Kong has experienced decreases in output and productivity growth since 1997. The decreases are mainly caused by low-input growth. Unlike mainland China, Hong Kong has experienced negative technical progress. Hong Kong should adopt new technology and increase its research and development (R&D) expenditures to improve its technical progress. However, Hong Kong's positive technical efficiency changes contrast sharply with negative efficiency changes in mainland China. The production methods in mainland China should be improved in order to improve technical efficiencies, while more investment in technology innovation should be made in Hong Kong.

Factor accumulation is important in both mainland China and Hong Kong because input growth is an important factor for their economic growth. The empirical results show that human capital is a major constraint in mainland China. Continuous investment in education and training is needed. Statistical estimates on human capital in mainland China, measured in number of schooling years, show that human capital with only primary school education has increased at an average rate of 0.05 percent (with negative growth rates in recent years); the same average growth rates for junior middle school education, senior middle school education (including vocational secondary school and specialized secondary school) and higher education are 1.54 percent, 2.08 percent, and 4.64 percent, respectively, in the whole sample period. While tertiary education has received much attention since the economic reform in mainland China, the weakest segment of human capital is the middle range, as seen from the low average growth rates in human capital with junior middle school and senior middle school educations.

In the case of Hong Kong, the sample period reflected the changing situation in the era before and after the sovereignty reversion and Asian financial crisis in 1997. During the period since 1997, the decrease in physical capital growth and negative labor growth reduced input growth and resulting economic growth and productivity growth in Hong Kong. Political uncertainty before 1997 resulted in a lack of long-term investment, especially investments related to R&D or large-scale industrial plants. Investment contributing to technical progress has not been forthcoming since 1997 in Hong Kong. The Hong Kong economy needs to restore a more stable environment that can nurture investment and promote technical progress in the long term (Li 2006). However, Hong Kong's high level of technical efficiency will bring an added advantage when technical progress improves.

This empirical study adds to the debate on the economic integration of mainland China and Hong Kong. The production capacity of mainland China has expanded greatly, and improvement in technical progress is the driving force of productivity growth. The empirical findings have implications for the economic integration of mainland China and Hong Kong. Typically, the lack of technical progress in Hong Kong can be supplemented by stronger performance in technical progress in mainland China. Similarly, the poor technical efficiency performance of mainland China can be improved by learning from the experience of Hong Kong.

Notes

1. Information on various agreements and announcements can be found on the Hong Kong SAR Government's official Web site at www.info.gov.hk.
2. The maximum likelihood estimates of the coefficients of time dummies are not shown in the table, but are available from the corresponding author.
3. Since the human capital variable is not in logarithm form, its estimates are not comparable with the estimates of the other two inputs. The importance of human capital can be seen from its elasticity and cost share in the later tables.

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Appendix. Data Description

Due to differences in the collection and compilation of economic statistical data between mainland China and Hong Kong, the constructed economic variables may not be the same in the two economies, but they will provide a trend analysis for the two economies.

Hong Kong

The sources of data and the compilation of economic variables for the Hong Kong economy used in Li (2006, chap. 3) have been updated to 2005. The capital stock figures in Li (2006) were constructed from the accumulation of gross investment and the initial capital stock followed the assumption used in Kim and Lau (1994).

The human capital variable used in this article was constructed by using mean years of schooling. The mean years of schooling in the aggregate economy and different industries were estimated from the Hong Kong Population Census reports for the sample period from 1981 to 2006.[1] Estimation of mean years of schooling results from assigning years of schooling to different levels of educational attainment: levels 1 to 6 with 1–3, 4–9, 10–12, 13–14, 15–17, and 18–24 years of schooling for primary, lower secondary, upper secondary, polytechnic or technical institute, or nondegree courses at postsecondary institutions, and university or degree courses in universities, respectively. The mean years of schooling were estimated from the formula:

$$\sum_{i=6}^{6} x_i y_i \,/ \sum_{i=1}^{6} x_i,$$

where x = number of people in the working population, y = midpoint interval of the years of schooling, and i = level of educational attainment. The mean years of schooling for each industry were estimated for six years (1981, 1986, 1991, 1996, 2001, and 2006).[2] The exponential growth rates of human capital for the remaining years are calculated.

Mainland China

The methods for calculating the key macroeconomic variables used in the regression follow the studies by Li (2003), Liu and Li (2006), and Li et al. (2009). A similar method of constructing the physical capital stock is used in these studies, but the initial capital stock followed the estimation in Chow and Li (2002). For the human capital variable, there was a change of classification between 2003 and 2004 in the China data. The data series used in Liu and Li (2006) and Li et al. (2009), adjusted by migration and death, were recorded till 2003. Due to the lack of data on employment with a primary education, the difference in the number of students entering junior secondary education and graduates from primary education was used to calculate the number of primary education graduates that entered the workforce. The additional three years needed for junior secondary education explained why the human capital series in Liu and Li (2006) and Li et al. (2009) stopped in 2000. The new classification since 2004 only showed four levels of education, and that transformation is shown in Li and Liu (2011) and Li (2009). The data series for the human capital variable used in this article has been revised and updated. In order to remove the three-year constraint, the human capital variable was forecasted to 2010 by using the two average growth rates of 2004 to 2006 and assuming the same growth rates until 2010. Similar to Liu and Li (2006) and Li et al. (2009), the revised human capital variable has been adjusted by migration and death.

Notes

1. Reports of Hong Kong Population Census are updated and published every five years.
2. Estimation of mean years of schooling for years 1991 and 1996 cannot be calculated for the agriculture and fishing industry, the mining and quarrying industry, and the electricity, gas, and water industry. There are no data available in the Hong Kong Population Census reports for the years concerned.