Chapter

5

Capital Accumulation, Capital-Output Ratio and Total Factor Productivity in Singapore

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INTRODUCTION

Capital, together with labor, land and technology, are the key factors of production. Various growth theories relate the growth of capital to the growth of output. In Rostow's growth model, an increase of investment rate to 10% or more is necessary before growth can gather enough momentum to take-off. In the Harrod-Domar model, the growth rate of national output is equal to the growth rate of capital. In Lim's S-Curve hypothesis (1996, 2004), the rapid accumulation of physical capital is an important driver behind the superlative growth of the Newly Industrializing Economies (NIEs). De Long and Summers (1991, 1993) have also shown that investment in machinery and equipment has a strong association with growth.

However, statistical evidences on the importance of capital accumulation in causing GDP growth are mixed. Several studies on

the causality between capital accumulation and GDP growth have been conducted. While studies using panel data often produce results that disagree that it is capital growth that causes output growth (Blomstrom *et al*., 1996; Podrecca and Carmeci, 2001), studies on individual countries show that the causal relationship between investment and growth is country-specific and may run in either direction (Ghali and Al-Mutawa, 1999; Hatemi-J and Irandoust, 2002).

Singapore experienced very rapid increase in GDP between 1960s and 1990s on the back on sharp increases in factor inputs. However, Krugman (1994) and Young (1995) dismiss the spectacular rise of Singapore's GDP by emphasizing that Singapore's Total Factor Productivity (TFP) growth was negligible and that the high economic growth was only driven by resource accumulation. Krugman even predicts that Singapore could face a "Soviet-style" growth collapse. This Chapter disagrees with Krugman and Young, and takes the view that a sharp increase in capital accumulation during the development process of a developing country is necessary to fuel current and future economic growth.

This Chapter postulates that capital accumulation of an economy follows an S-Curve as the economy develops. The hypothesis suggests that a NIE would experience rapid accumulation of capital, and this rate of capital growth would slowly taper off as the economy develops. This sharp increase in capital accumulation is necessary to fuel further economic growth. It is further postulated that the growth rate of capital stock is likely to outpace that of GDP during the early phase of industrialization. As a result of this S-Curve of capital accumulation, the incremental capital-output ratio (ICOR) and the average capital-output ratio (ACOR) of the economy are likely to first increase, and then gradually decrease as the economy ascends the development ladder.

The outline of this Chapter is as follows: Section 1 puts forth the hypothesis of the S-Curve of capital accumulation and the probable patterns of capital-output ratios as an economy develops. Section 2 presents a case study of Singapore. Section 3 tests the long term causal relationship between Singapore's capital stock and GDP and

found it to be positive and bi-directional. Section 4 revisits the issue of TFP growth and capital growth in Singapore.

1. HYPOTHESIS OF THE S-CURVE OF CAPITAL ACCUMULATION AND ITS IMPLIED CAPITAL-OUTPUT RATIO

1.1. S-Curve of Capital Accumulation

According to Lim's S-Curve hypothesis (1996, 2004), the development of an economy can be divided into 3 stages: Stage 1 (underdevelopment with low-income and slow growth), Stage 2 (rapid development with middle income and rapid growth), and Stage 3 (highly developed with high-income and slow growth).

If capital accumulation is strongly associated with output growth, then a Stage 1 economy is likely to have a low-level of per capita capital stock and a low-rate of capital accumulation. Rate of capital accumulation would gain momentum as the economy enters Stage 2 of economic development, and the level of per capita capital stock, increases. A Stage 3 economy would enjoy a high-level of per capita capital stock but its rate of capital accumulation, although is still positive, would gradually decline.

An underdeveloped Stage 1 economy is likely to have a low-level of per capita capital stock. This is intuitive as capital investment needs to be financed out of savings from income which is lacking in the poor countries. In addition, foreign investment is likely to be scarce in the absence of investment-conducive policies. Growth rate of per capita capital stock is also expected to be low since governments of developing countries often have limited tax-collecting and revenue-generating capabilities.

On the other hand, a Stage 2 NIE with its improving business environment, better property rights protection and a comparatively cheaper cost structure would attract both foreign and domestic direct investment. The influx of foreign investment would provide increased business opportunities to domestic producers, thereby inducing further domestic investment. Moreover, as the fiscal position

of the government improves, the government would be able to invest more heavily in the development of physical infrastructure and human capital. It is further postulated that the growth rate of capital stock would outpace that of GDP during the early phase of industrialization.

A highly developed Stage 3 economy that has experienced continued capital accumulation over prolonged period would have a high-level of per capita capital stock. However, capital growth rate is likely to slow down due to diminishing returns of capital. In addition, the high-cost of production in the developed countries would lead to direct investment, especially those from the manufacturing sector, to flow to the cheaper developing countries.

The graphical representation of the time paths of capital stock and output level as an economy develops is shown in Fig. 1.

1.2. Time Path of Capital-Output Ratios

Due to a general lack of supply of capital and an excess supply of labor, an underdeveloped Stage 1 economy is likely to have low-levels of incremental capital-output ratio (ICOR = $\Delta K/\Delta Y$)

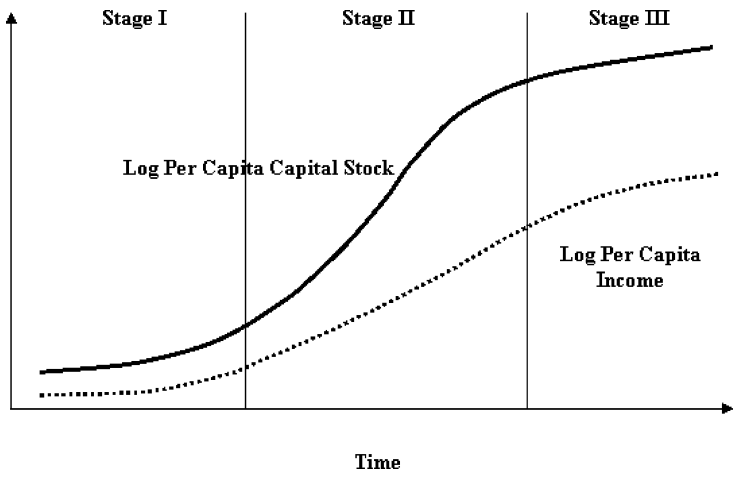


Figure 1: S-Curve of capital accumulation

and average capital-output ratio (ACOR = K/Y) (where K = capital stock, Y = GDP) as production processes are likely to be labor-intensive.

The NIE is likely to experience increasing ICOR and ACOR. Firstly, a rapidly developing economy is expected to undergo a period of rapid increase in capital investment. In the short to medium term, as the investment rate expands rapidly while the output growth lags behind, ICOR (= $(I/Y)/(\Delta Y/Y)$) will inevitably be pushed up. Secondly, as the excess labor in the economy is exhausted, production process has to become increasingly capital-intensive, and thus leading to higher ICOR. Thirdly, the government would be undertaking large-scale infrastructural projects which have higher levels of ICOR. As the NIE gradually matures into a developed economy, the rate of increase of ICOR will slow down, and the level of ICOR may even start to decline.

A highly-developed economy with its high-level of accumulated investment is likely to have a low investment rate. At the same time, the developed economy continues to reap the returns of earlier investment, especially those in infrastructure and buildings that have very long service lives. Thus, the ICOR of a developed economy is likely to be falling, albeit gradually, as the investment rate falls faster than the GDP growth rate. However, as the production processes adopted in a developed economy is of much higher capital intensity, the ICOR of the developed economy would be higher than that of an underdeveloped economy. As ICOR declines, ACOR would eventually stabilize or even decline.

The probable time paths of the ACOR and the ICOR over the development process of a country are given in Fig. 2.

2. SINGAPORE'S CAPITAL ACCUMULATION AND OUTPUT GROWTH

2.1. Estimation of Singapore's Capital Stock

Data on Singapore's capital stock are constructed from data on Gross Fixed Capital Formation (GFCF) at 2000 prices using the Perpetual

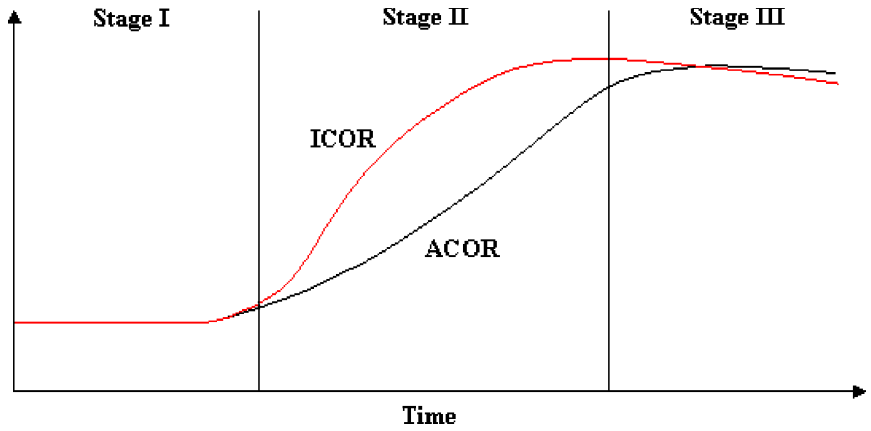


Figure 2: Probable time paths of capital-output ratios

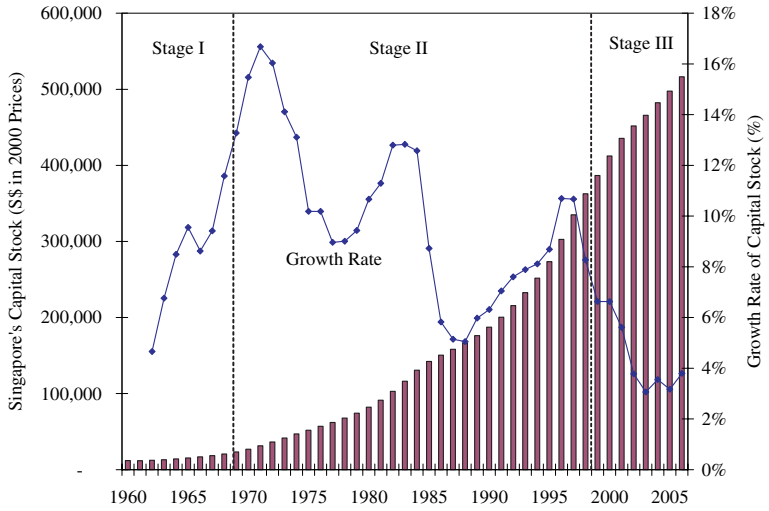
Inventory Method (PIM).[1] Straight-line depreciation is assumed and the assumptions on the longevity of various categories of capital stock, ranging from 15 to 80 years, follow those used by the Singapore's Department of Statistics (DOS) in their computation of the capital stock of Singapore (Department of Statistics, 1997; OECD, 2001).[2]

2.2. Singapore's Capital Stock

Figure 3 presents the estimated net capital stock of Singapore from 1960–2006. The time path of Singapore's accumulation of capital stock concurs with the hypothesis of S-Curve of capital accumulation. The accumulation of capital got on a slow start during the early phase of the Singapore's economic development (low-level and low-growth of capital). The building up of capital gained momentum in late 1960s, signaling Singapore's entrance into a new phase of rapid

[1] The PIM accumulates past purchases of each asset type, and removes from the capital stock fixed assets that are scrapped upon reaching the end of their respective service lives.

[2] Details on the construction of the data series of the capital stock of Singapore can be found in Sng (2007).



Source: Estimation using raw data from CEIC database.

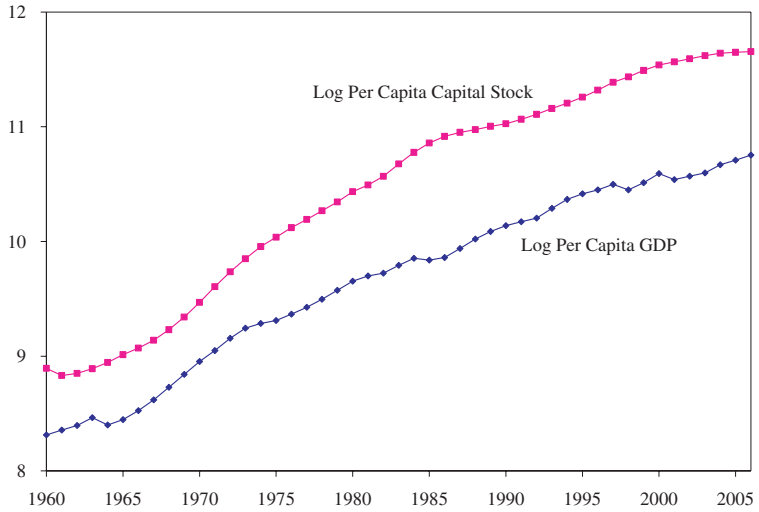
Figure 3: Singapore's net capital stock (S$ in 2000 Prices), 1960–2005

industrialization (medium-level and high-growth of capital). The growth of capital stock appears to slow down since 1998 (high-level and low-growth of capital).

2.3. Capital Accumulation and Economic Development of Singapore

Singapore's per capita GDP has grown in tandem with the increase in the per capita capital stock over the years (see Fig. 4). In 1960, Singapore's per capita GDP and per capita capital stock were both very low at only S$4,080 and S$7,290, respectively. Singapore began its metamorphosis into a NIE from mid-1960s. And since mid-1960s to late-1990s, Singapore's per capita capital stock grew rapidly, so did its per capita GDP. However, it can be seen from Fig. 4 that the growth of both the per capita GDP and the per capita capital stock appear to be slowing down since late 1990s.

Table 1 shows that since the 1970s, the growth rates of per capita capital stock were consistently higher than that of the GDP.



Source: Estimation using raw data from CEIC database.

Figure 4: Singapore's log per capita GDP and log per capita capital stock (S$ in 2000 Prices), 1960–2005

Table 1: Average annual growth rates of Singapore's per capita GDP and per capita capital stock (in 2000 Prices)

Year	Per Capita GDP (%)	Per Capita Capital Stock (%)
1960–1969	6.0	5.1
1970–1979	7.1	10.2
1980–1989	4.9	6.5
1990–1999	4.3	5.3
2000–2006	2.7	1.9
1960–2006	**5.4**	**6.2**

Source: Estimation using raw data from CEIC database.

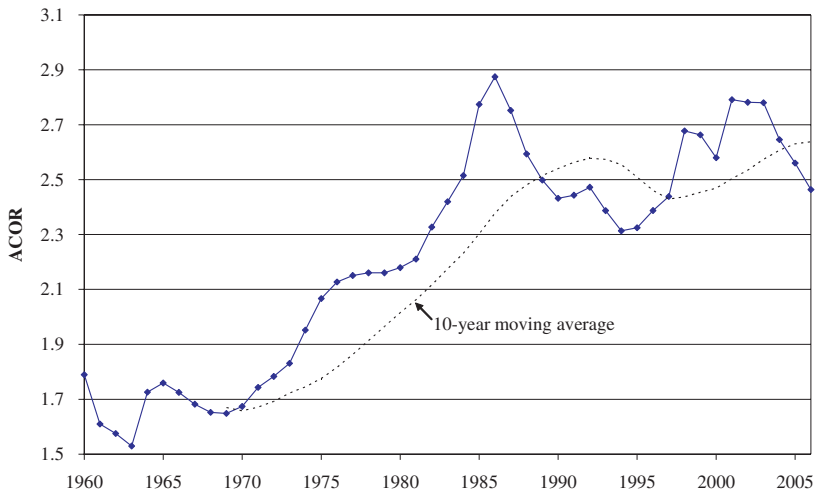
This is in line with our proposition that the per capita capital stock of a NIE would rise faster than its per capita GDP. Furthermore, the difference between the two sets of growth rates narrowed as the time went by. This supports the proposition that the increase in GDP will catch up with that of capital stock during the later phase of

development as the economy continues to reap benefits of earlier investments.

2.4. Singapore's Capital-Output Ratios

Figure 5 shows the variability of Singapore's ACOR over the period 1960–2006. Level of ACOR was rising steadily from less than 1.8 in early 1960s to about 2.8 in early 2000s. There were four prominent upsurges of the ACOR over the last 47 years, and they coincided with the recessionary years of Singapore: 1964, 1985, 1998 and 2001. During recession, output falls sharply while capital stock remains relatively stable resulting in an under-utilization of capital. This leads a sudden increase in ACOR, which is not representative.

It can be seen from Fig. 5 that Singapore's ACOR expanded rapidly in the first 20 years after Singapore attained independence in 1965. This is in line with the hypothesis of the S-Curve of capital accumulation: NIE would experience increasing ACOR (and ICOR) during the early stage of industrialization. The steady increase of the ACOR ran out



Source: Estimation using raw data from CEIC database.

Figure 5: Singapore's average capital-output ratio, 1960–2006

of steam in the late 1980s, and the ACOR was range-bound between 2.3 and 2.8 since 1988. The level of ACOR in 2006 was 2.5. Given Singapore's advanced stage of development, future level of ACOR is expected to hover around 2.6 and may even gradually decline.

3. GRANGER CAUSALITY BETWEEN SINGAPORE'S CAPITAL STOCK AND GDP

Granger Causality Bivariate Vector Error Correction Model (VECM) Test is used in this section to establish the causality between Singapore's capital stock (K) and GDP (Y). While the Augmented Dickey-Fuller (ADF) test shows that unit root exists in both the data series of K_t and Y_t, the first differences of K_t and Y_t are found to be stationary. The Johansen cointegration test shows that both K_t and Y_t are cointegrated, i.e., there exists a long-term equilibrium relationship between capital stock and GDP.

A Bivariate VECM is set up to establish the causality between capital stock and GDP:

$$\Delta Y_t = \mu + \theta(Y_{t-1} - \alpha - \beta K_{t-1}) + \sum \alpha_i \Delta K_{t-i} + \sum \beta_j \Delta Y_{t-j} + U_{yt}$$

$$\Delta K_t = \omega + \phi(Y_{t-1} - \alpha - \beta K_{t-1}) + \sum \gamma_i \Delta K_{t-i} + \sum \delta_j \Delta Y_{t-j} + U_{mt}$$

A lag of 1 period is found to minimize the value of the Akaike's Information Criteria (AIC). The VECM estimates are given as follows:

θ	−0.158*
ϕ	0.055**
$\sum\alpha_i$	−0.025
$\sum\delta_i$	0.341*

* denotes significance at 1 percent level

** at 5 percent level

The results of the VECM estimates show that there existed a positive and significant bi-directional long-term causal relationship

between Singapore's capital stock and its GDP. In the short-term, the granger causality ran from GDP growth to increases in capital stock. The granger causality from changes in capital stock to GDP growth is statistically insignificant.

4. CAPITAL GROWTH AND TOTAL FACTOR PRODUCTIVITY GROWTH IN SINGAPORE

Under the framework of growth accounting, economic growth is attributable to increases in factor inputs and improvements in total factor productivity (TFP). Factor inputs commonly included in growth accounting exercises are physical capital, labor force and human capital, while TFP is measured as the residual of the growth equation after accounting for the increases in factor inputs. TFP would include both technological progress and enhanced efficiency, although the contributions from these two factors are not distinguishable from the derived estimates.

In almost all studies on growth accounting, such as Hall and Jones (1999) and King and Levine (1994), TFP is found to account for the bulk of cross-country growth differences, while differences in physical capital accounts for little of the international differences in output growth. Thus, the long-term growth potential of an economy is often viewed to be determined by its ability to achieve and sustain a high level of TFP growth.

Singapore experienced very rapid increase in GDP between 1960s and 1990s on the back on sharp increases in factor inputs. Studies on decomposition of Singapore's economic growth, such as Tsao (1982), Young (1992, 1995), Rao and Lee (1995), Koh *et al*. (2002) and Hsieh (2002), have all pointed to the overwhelming importance of capital accumulation in propelling the growth of Singapore, and the smaller degree of contribution made by TFP growth. In addition, some of the earlier studies, such as those by Tsao (1982) and Young (1992, 1995), concluded that Singapore's TFP growth rates were negligible. The high-level of capital growth and the corresponding very low level of TFP growth have prompted Krugman (1994) and Young (1995) to cast doubt on the sustainability of

Singapore's economic growth; Krugman even predicted that Singapore could face a "Soviet-style" growth collapse.

There are two questions concerning the issue of TPF growth and capital growth. Firstly, was Singapore's TFP growth rates as low as those computed by Tsao (1982) and Young (1992, 1995). And secondly, is high capital growth the boon or the bane of sustainable economic growth?

The first question is a technical one that requires a technical answer. Young (1995) estimates that out of the 8.7% average GDP growth rate from 1966–1990, the growth in TFP averaged only 0.2%. The very low-level of TFP growth of Singapore obtained by Young, stems from his assumptions about the factors shares in the production function. Young estimates the output elasticity of capital of Singapore to be around 0.5, substantially higher than 0.35 in a typical economy (Eggertsson, 2004). Eggertsson cites the estimates of factor shares computed by Bosworth and Collins (2003) and Sarel (1997), and reasons that $\alpha = 0.35$ is more appropriate. Using the assumption of $\alpha = 0.35$, Eggertsson (2004) shows that Singapore's average TFP growth over the period 1960–2003 was at 1.4%. Eggertsson's decomposition of the economic growth of Singapore is reproduced in Table 2. In addition, Eggertsson also shows that Singapore's TFP growth rates are comparable to, if not higher than, those of the other advanced and emerging economies (see Table 3). Other studies on decomposition of growth of Singapore have also reported higher levels of TFP growth than those reported by Young. The reported TFP growth by

Table 2: Sources of growth in Singapore (1960–2003)

	1960–70	1970–80	1980–90	1990–03	1960–03
Output	9.4	8.6	7.2	6.2	7.7
Physical Capital	5.6 (60%)	4.8 (56%)	3.2 (44%)	2.6 (42%)	4.0 (52%)
Labor	1.9 (20%)	2.8 (33%)	2.2 (31%)	1.2 (19%)	2.0 (26%)
Education	0.5 (5%)	0.1 (1%)	0.3 (4%)	0.8 (13%)	0.5 (6%)
TFP	1.4 (15%)	0.9 (10%)	1.6 (22%)	1.6 (26%)	1.4 (18%)

Source: Eggertsson (2004) and author's own computation.
Note: Figures in parenthesis refer to percentage contribution to output.

Table 3: International comparison of sources of growth (1960–2000)

	Singapore	East Asia[3] (excluding China)	United States	Industrial Countries[4]
Output	7.7	6.7	3.4	3.5
Physical Capital	4.0 (52%)	3.3 (49%)	1.0 (29%)	1.4 (40%)
Labor	2.0 (26%)	1.8 (27%)	1.1 (32%)	0.8 (23%)
Education	0.5 (6%)	0.5 (7%)	0.3 (9%)	0.3 (9%)
TFP	1.4 (18%)	1.0 (15%)	0.9 (26%)	1.0 (29%)

Source: Eggertsson (2004) and writer's own computation.
Note 1: Data on Singapore is for the period 1960–2003.
Note 2: Figures in parenthesis refer to percentage contribution to output.

Wu and Thia (2002) for 1990–2000 is 1.6 percent. Hsieh (2002) estimates TFP growth for the East Asian economies using the dual approach and finds that Singapore's TFP growth to be around 1.6 to 1.9 percent between 1968 and 1990.

On the question of whether high capital growth is a boon or a bane of sustainable economic growth, the answer is less quantifiable but it is more intuitive. It can be seen from Table 2 that Singapore's growth since 1960 has been largely driven by capital accumulation; contribution from physical capital accounted for more than 50% of Singapore's output growth from 1960–2003. It is indisputable that the high rate of capital growth has contributed positively to the high economic growth rates and the rapid improvement in the living standards in Singapore. As pointed out by Ghesquiere (2006), "… notwithstanding the neo-classical concern about diminishing returns, high fixed capital formation can ensure high-growth and rising living standards from low initial levels. The transition to the "steady state" when these forces become impotent can take several decades".

[3] The 7 East Asian countries are Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand.

[4] The 22 industrial countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States.

Furthermore, the high rate of capital accumulation has built a strong physical foundation for Singapore that serves as a platform for future growth. It can be seen from Table 2 that the early strong contributions of physical capital and labor input have eased over time falling from 60% in 1960s to 42% during 1990–2003, while TPF growth and contribution of human capital have gradually increased.

CONCLUSION

The case study of Singapore shows that as Singapore underwent transformation from a developing economy to an industrializing economy, Singapore experienced rapid capital growth. Capital growth slows down as Singapore transforms into a developed economy. These results concur with the hypothesis of the S-Curve of capital accumulation. In addition, the rapid development of Singapore was accompanied by a rising ACOR. This rising ACOR is part and parcel of the development process and does not necessarily mean that Singapore is inefficient in utilizing its capital. Singapore's ACOR is expected to eventually stabilize or even decline.

Empirical exercise shows that the long-term causal relationship between Singapore's capital stock and GDP is found to be positive and bi-directional. In the short-term, GDP growth granger caused increases in capital stock. This chapter reasons that in the case of Singapore, strong growth in physical capital during the earlier stage of our development is necessary to fuel past, present and future economic growth. In addition, a high-level of capital stock is likely to serve as the foundation for future gains in TFP. Study has shown that as Singapore's economy matures, contribution from physical capital diminishes while contributions from TFP and human capital increase.

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