7-2024

Can Structural Transformation Happen Without Technical Change? The Case of Singapore

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AKI
Angelo King Institute
for Economic and Business Studies

DLSU-AKI Working Paper Series
2024-10-093

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This paper was awarded the second prize in the 2023-2024 essay-writing competition organized by the Angelo King Institute among the students of the Carlos L. Tiu School of Economics, on "The Economics of Professor Robert Solow."

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July 2024

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"Since Singapore grew through heavy direct foreign investment, does the low TFP indicate a failure of foreign firms to use modern technology?"

Salim Rashid (2000, p. 152).

I. INTRODUCTION

Alwyn Young's (1992) landmark study, titled *A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore*, spawned a wave of literature covering the 'miraculous' growth of Asian economies. His study employs growth accounting exercises for Hong Kong and Singapore using 1965-1990 data in order to decompose the countries' sources of growth into factor accumulation and total factor productivity (TFP). He finds that Hong Kong's TFP growth during the period was fairly positive, while it was zero for Singapore.

His work was then followed by other studies conducting similar growth accounting exercises for other Asian countries experiencing significant rates of growth at the time, most notably Kim & Lau's (1994) study. Their work finds that TFP growth had been zero, not only for Singapore, but also for Korea, Taiwan, and Hong Kong. Krugman (1994) further popularized these findings when he compared the growth of these Asian economies to the Soviet Union, which had recently collapsed, and said that they would suffer a similar fate to the communist country, stagnation.

Looking at international trade data from The Growth Lab at Harvard University (2019), we can see that Singapore was able to move from primarily exporting crude materials in 1965 to developing more complex manufactured products in 1975 and to growing its high-skill service

export from 1980 and onwards. With this, I argue that the significant developments in Singapore's export basket from 1965-1990 may provide evidence against the findings of zero TFP growth in the country. Much of the debate on understanding the rapid growth of Asian economies in the 1990s centers around the role of industrial policy and government intervention and on the estimates of TFP growth. This paper will cover the latter discussion.

The rest of the essay will proceed as follows. Section 2 will provide an overview of the popular literature on the sources of growth in Asia. Much of the better-known work on the topic employs the neoclassical growth framework pioneered by Solow (1957). Section 3 briefly tackles the theoretical and empirical issues of using the neoclassical growth framework, particularly on the issue of aggregation and estimates of productivity. Section 4 examines the case of Singapore, specifically in terms of policy and the development of its economic complexity and export basket. Section 5 concludes.

II. THE SOURCES OF ASIA'S GROWTH

Alwyn Young's (1992) study sparked an important debate concerning long-run economic growth in Asian economies. In his 1992 paper, he compares the growth of two economies, Hong Kong and Singapore using 1965-1990 data. He finds that total factor productivity (TFP) growth in Hong Kong had been mostly positive for the period, while it was zero for the latter. Table 1 summarizes Young's (1992) findings.

Table 1.

Growth Accounting for Hong Kong and Singapore

	Output Growth	**Percentage contribution of labor growth**	**Percentage contribution of capital growth**	**Percentage contribution of TFP growth**
Hong Kong (1971-1990)	1.472	0.23	0.42	0.35
Singapore (1970-1990)	1.545	0.23	0.83	-0.08

Source: Young (1992, Table V)

Young's (1992) study is an application of the neoclassical growth model introduced by Solow (1956), where an economy's output is a function of labor, capital, and technology. Solow (1957) is credited as the seminal paper for growth accounting exercises, decomposing growth into the contributions of the inputs, labor and capital, and technology. The framework assumes an aggregate production function,

$Y = A\,F(K, L)$, where Y is output, A is the level of technology, K is the capital stock, and L is the employment of labor. It is well-known that Solow's (1956) growth model posits that the long-run growth of an economy (and subsequently, the differentials in growth rates across economies) would be determined by total factor productivity growth (TFPG) or the rate at which the level of technology grows. Understanding this model is crucial as it serves as the primary theoretical backdrop for much of the popular literature on Asia's sources of growth.

Young's (1992) findings had very important implications for Singapore, as the country's growth in the past decades has not been due to developments in technology and productivity. Rather, it had been a result of the accumulation of the factors, labor, and capital. Going back to Solow's (1956) growth model, growth through factor accumulation would be unsustainable in the long run as the economy would eventually reach a 'steady state,' where capital accumulates at the same rate it deteriorates. This means that should Singapore continue to grow through how it has been doing for the past decades, it would eventually come to a screeching halt. This is precisely what Krugman's (1994) summary of the debate was saying: that the growth of the four Asian 'Tigers' was that of 'perspiration' (accumulation of factors) rather than 'inspiration' (productivity growth). He even likened the growth of these economies to that of the Soviet Union, which had only recently collapsed in 1991. Krugman (1994) also recognizes Singapore as the "most extreme" as the country has been able to dramatically increase its labor and capital as shares of output in a span of a few decades, calling the growth of the city-state the "economic twin of the growth of Stalin's Soviet Union". Another important study he cites on the sources of Asia's growth is that of Kim & Lau (1994), which estimated the aggregate production functions for the Asian 'Tigers' and G-5 countries. Their findings show that TFP growth had actually been zero for the four Asian economies, Hong Kong, Korea, Taiwan, and Singapore.

Young (1992) argues that the differences between the productivity growth of Hong Kong and Singapore came from the fact that the latter was suffering from the effects of excessive government intervention in its markets and that the former had freer markets. The aggressive industrial and "factor-accumulating" policies imposed by Singapore had been well-documented in these decades (see Lee Kuan Yew School of Public Policy, 2016), where they provided

sizeable tax incentives to capital-intensive firms, the large importation of foreign workers, and wage hikes across the board to force less productive firms to close out. Young's (1992) findings suggest that Singapore had been "leapfrogging" into sophisticated goods and services as opposed to gradually attaining the capabilities to make them.

III. THE PROBLEM(S) WITH THE NEOCLASSICAL GROWTH FRAMEWORK

A significant faction of the debate on the sources of Asia's growth in the 1990s is the critique of the methodology being used by the popular literature at the time, specifically, the neoclassical growth theory pioneered by Solow (1956). In this section, we cover two important critiques of this framework. The first is on the theoretical basis for the empirical work being conducted by the likes of Young (1992) and Kim & Lau (1994). As we have discussed, their works have, for a theoretical backdrop, the Solow (1956) growth model, which assumes an aggregate production function. We argue that the idea of a production function at an aggregate level is particularly dubious. Secondly, we present the 'accounting identity critique' brought forward by Felipe & McCombie (2003), which helps us argue that at an empirical level, the idea of an aggregate production function and the growth accounting exercises themselves are obscure.

A. THE AGGREGATION PROBLEM

Central to the neoclassical growth framework and, subsequently, to the growth accounting exercises is the existence of an aggregate production function. Growth accounting studies are required to assume that an aggregate production function exists, and it is usually the starting point for much of the empirical work on the sources of Asia's growth. There is a large body of literature

on the ‘aggregation problem’ as it has been a very controversial topic in the profession, however, in this paper, we only try to scratch its surface.

There is no doubt that a production function can exist at the micro level. Take, for example, a business that manufactures furniture, it can be possible for us to estimate a production function for that firm given the data exists. However, if we look at a commercial bank, how would we measure its output? Would it be the number of accounts opened? Perhaps it could be interest income? Maybe the amount of withdrawals? Given the heterogeneity of firms, output, and inputs in an economy, it then becomes difficult to say that we can simply add them together and arrive at a single aggregate measure for everything.

Felipe & McCombie (2024) recount that Solow (1957) was already aware of the aggregation problem, to which he [Solow] writes that “... the aggregate production function is only a little less legitimate concept than, say, the aggregate consumption function…” (Solow, 1957). Felipe & Fisher (2003) counter this, showing that the conditions required to assume the possibility of aggregating firm-level production functions are much more rigid than those of aggregating consumption functions. They argue that an aggregate consumption function is plausible when the marginal propensities to consume at an individual level are roughly constant and equal or that income distribution is fairly fixed (Felipe & Fisher, 2003). In comparison, Felipe & McCombie (2024) summarize Franklin Fisher’s work on the matter, where the conditions for aggregating production functions are as follows: (1) aggregate production functions only exist if and only if firm-level production functions are identical (with the exception of the capital efficiency coefficient), (2) that the existence of a labor aggregate requires that there be no specialization in

employment, and (3) that the existence of an output aggregate requires that there be no specialization in production (Felipe & McCombie, 2024). In other words, aggregate production functions can only exist if labor, capital, and output are homogeneous across firms in an economy. Clearly, the conditions for the existence of an aggregate production function are far more outlandish than those of the consumption function. The aggregation problem exists in many areas of economics apart from production functions, much more so for capital, which spurred the Cambridge Capital Theory Controversies in the 1950s (see Coven & Harcourt, 2003).

B. THE ACCOUNTING IDENTITY CRITIQUE

The Accounting Identity Critique is what Felipe & McCombie (2024) calls the "final blow to the concept of the aggregate production function" as it is an empirical argument. This argument not only deals with the issues of assuming an aggregate production function but also with the estimation of total factor productivity (TFP) (see Felipe & McCombie, 2020).

Taking the National Income and Product Accounts (NIPA) identity:

$$Y_t \equiv W_t + P_t \qquad (1)$$

where Y is the real output (GDP), W is the total wages paid, and P is the total profits. It is important to note that equation (1) is an identity as it holds true for all levels of aggregation and that it is theory-free as no assumptions are made to construct it (Felipe & McCombie, 2020). We can rewrite equation (1) as:

$$Y_t \equiv w_t L_t + r_t K_t \qquad (1a)$$

where w refers to the average wage rate, L refers to the total number of workers, r is the average profit rate, and K is the capital stock. We then can take the total differential of equation (1a) with respect to time and write it in terms of growth rates:

$$\hat{Y}_t \equiv \alpha\, \hat{w}_t + \alpha\, \hat{L}_t + \beta\, \hat{r}_t + \beta\, \hat{K}_t \qquad (2)$$

where $\widehat{Y_t}$ is the growth rate of output (GDP), α is the share of total wages given by $\frac{W_t}{Y_t}$, β is the share of total profits given by $(1-\alpha) = \frac{P_t}{Y_t}$, where a circumflex hat denotes a growth rate. Here, we begin to see some resemblance to what Solow (1956) posits is total factor productivity (TFP). We will get back to this shortly. Felipe & McCombie (2020) take the integral of equation (2) to arrive at:

$$Y_t \equiv A_0 {w_t}^{\alpha}\, {r_t}^{1-\alpha}\, {L_t}^{\alpha}\, {K_t}^{1-\alpha} \qquad (3)$$

where A_0 is the coefficient of integration. We can see that equation (3) resembles a Cobb-Douglas production function, except that it includes ${w_t}^{\alpha}\, {r_t}^{1-\alpha}$. From that alone, we can see that there is already a definitive relationship between the inputs and the outputs without the need for an aggregate production function. Through the identity, we are able to arrive at a relationship the aggregate production function assumes to establish, without the need to assume perfectly competitive markets, or the degree of returns to scale (Felipe & McCombie, 2020).

Going back to the Solow's (1956) growth model, he asserts that:

$$\hat{Y}_t = \widehat{TFP_t} + \alpha\, \hat{L}_t + \beta\, \hat{K}_t \qquad (4)$$

where $\widehat{TFP}$ is the growth rate of technology. However, as was established in equation (2), $\widehat{TFP}$ is, by construction, defined by:

$$\widehat{TFP_t} \equiv \hat{Y}_t - \alpha\, \hat{L}_t - \beta\, \hat{K}_t \equiv \alpha\, \hat{w}_t + \beta\, \hat{r}_t \qquad (5)$$

From this simple proof, we learn that what Solow (1956) calls a measure of technical change is the weighted average of the growth rates of wage rates and profit rates. This means that if we estimate an "aggregate production function" correctly (as in equation (3)), we may end up with an R^2 of unity (Felipe & McCombie, 2020). However, when the likes of Alwyn Young (1992) and Kim & Lau (1994) estimate these, they don't end up with a good fit. Why is that? Felipe & McCombie (2004) elaborate that the problem is with how $A_0 {w_t}^{\alpha} {r_t}^{1-\alpha}$ is proxied. Since these are not usually included in a regression, they are then proxied by a linear time trend, when in fact, the log-transformed weighted wage and profit rates do not really follow a linear trend. This has been interpreted by the neoclassical framework as a measurement of the rate of exogenous technical change. In an interview with McCombie, Hein & Lavoie (2015) note that once we include a "flexible, non-linear time trend", then we effectively approximate the identity, equation (3).

Additional arguments could also be made specifically against the growth accounting methodology. Given data constraints, growth accounting exercises tend to have the following assumptions (1) the aggregate production function exhibits constant returns to scale, (2) profit maximization, (3) factor markets are perfectly competitive. These conditions allow the researcher to substitute the shares of the factors in total output in place of their elasticities (Felipe, 2023). However, the accounting identity critique and the derivations already tell us that these assumptions are unnecessary. Felipe (2023) documents that by estimating the equation correctly, that is, using a time-varying parameter methodology, then the factor shares should always equal their elasticities. Moreover, while it is important to note that the above assumptions are hardly ever tested in the literature, Kim & Lau's (1994) study did. They tested both the linear

homogeneity of production, which is a condition that implies constant returns to scale, and perfectly competitive markets, both of which have been rejected.

The relationship that has been established through the manipulation of identity points (1) against the existence of an aggregate production function and (2) obscure the idea of technical change (TFP) in the neoclassical framework. Given that the neoclassical framework's estimation procedures are already preceded by the accounting identity, then that would mean that any attempt at estimating an 'aggregate production function' would only lead to a biased approximation of the identity. We have also found that the manipulation of the identity tells us that TFP is, tautologically, the weighted share of wages and profits, and unless it is proven that an aggregate production function exists, which at this point would be difficult, then it would be impossible to say that TFP is a measure of the rate of technical change. Until then, the 'Solow residual' can be interpreted as a measure of distributional changes (Felipe & McCombie, 2024).

These arguments can be detrimental to studies that follow the neoclassical growth framework, particularly of Alwyn Young (1992). In light of these, what then becomes of Alwyn Young's (1992) justification of his zero TFP findings for Singapore? What about the policies that Singapore pursued in hopes of raising TFP growth?

IV. THE CASE OF SINGAPORE

Singapore has had an unarguably successful run in its early years, capturing the attention of economists worldwide with its large periods of growth in terms of total output and per capita income. Hidalgo (2009) recounts that in a span of four decades beginning in 1963, Singapore,

along with countries such as South Korea and China, had shown impressive developments in its export basket complexity. These developments become even more so apparent when we look at disaggregated export data from The Growth Lab at Harvard University (2019), where we can see the immense difference between Singapore's 1965 and 1990 export baskets, where the country primarily produced and exported crude materials in 1965 to predominantly exporting fuels and manufactured goods in 1975 and to scale the country's services and manufacturing exports in 1985.

Then, Young's (1992) findings suggest that Singapore has been able to go through impressive stages of structural transformation and export basket complexity developments without experiencing any form of technological progress. Knowing how much the Singaporean economy grew over the period makes Young's (1992) findings all the more provocative and arguably, at the same time, questionable. However, given the cases that we have made against the neoclassical growth framework when Young (1992) says that the deleterious effects of industrial policy caused Singapore's zero TFP growth, it begins to sound quite dubious.

Another way to argue against Young's (1992) findings, and subsequently against the neoclassical growth framework, is to consider Singapore's path to growth, that is, through acquiring massive amounts of foreign direct investment (FDI) inflows through large tax incentives. Rashid (2000) does so in a quotable fashion:

> "Since Singapore grew through heavy direct foreign investment, does the low TFP indicate a failure of foreign firms to use modern technology?" (p. 152).

Rashid (2000) also draws other parallels in criticizing the TFP methodology. A notable instance is in his example of Korea. How could they, a country that so closely followed the "Japanese path" of development, be so that TFP estimates for Korea are significantly lower?

So, why exactly did Young (1992) find that TFP growth was zero in Singapore? Referring back to our earlier derivation of TFP from the accounting identity, equation (5), there is an explanation. Felipe (2023) recounts that the derivation from the accounting identity and Young's (1992) findings imply that $\widehat{TFP}_t \equiv \alpha\,\hat{w}_t + \beta\,\hat{r}_t \equiv 0$, given the differences and changes in α and β are negligible, then $\hat{w}_t = -\hat{r}_t$. That is, wages have been growing at the same rate profits were declining. In fact, substantial wage increases have been well-documented in Singapore during the period (see Lee Kuan Yew School of Public Policy, 2016).

In light of these, it becomes quite risible how much influence Krugman (1994), Kim & Lau (1994), and Young (1992) had on policy circles in Singapore, so much so that the Lee Kuan Yew School of Public Policy (2016) would dub their findings as the KKLY hypothesis, and that the country would set a target of 2% annual TFP growth. The country then decided to set development targets: (1) raise its gross expenditure on research and development (GERD) at 3% by 2010 and 3.5% in 2015, (2) running firm-level labor productivity and efficiency drives, and generally (3) shifting the country's economy to become more innovation-driven and, therefore, less factor-driven (Lee Kuan Yew School of Public Policy, 2016). However, as we have established, TFP, as measured in the neoclassical framework, could not possibly have any definitive link to things like R&D.

Today, Singapore stands as one of the most developed economies in the world, being one of the only two ASEAN economies to be classified by the World Bank as "high-income," the country prides itself as a knowledge-based and innovation-driven economy. Still, the country maintains its efforts through technological advancement by making the country more friendly towards technological startups through incentives and its advanced ICT infrastructure (Asian Development Bank, 2022).

So, were Young (1992) and the others wrong? Did Singapore make a mistake in pursuing technology-oriented policies when we have shown that the notion of TFP couldn't be regarded as a measure of technical change? Recent growth accounting estimates for Singapore from Nomura & Kimura (2022) do not show much to be beholden.

Table 2

Growth Accounting Estimates for Singapore

	Output Growth (%)	**Labor Growth (%)**	**Capital Growth (%)**	**TFP Growth (%)**
1995-2000	6.2	2.1	3.7	0.5
2000-2005	4.9	1.5	2.0	1.3
2005-2010	7.2	2.8	2.5	2.0
2010-2015	4.7	1.6	2.7	0.3
2015-2020	2.3	0.3	1.8	0.2
1970-2020	6.5	2.6	3.5	0.7

Source: Nomura & Kimura (2022, Table 21)

Technical progress happens at a micro level, as Felipe (2023) suggests. The idea of technical change becomes difficult to understand and to prove to be measurable at an aggregate level, both theoretical and empirical, as was proven. This may mean that Singapore may have been misguided by the controversial zero TFP findings; however, this is not to remove any merit from the policies inspired thereafter. Moving past the 1990s and looking forward, we see a highly advanced Singapore, technologically and economically. Such is undoubtedly a feat to behold.

V. CONCLUSIONS

This essay has briefly covered a rather small scope in the discussion of economic growth. It is quite dubious to claim that Singapore had developed its economic complexity and undergone stages of structural transformation without experiencing any form of efficiency gains. To back this, we have discussed the underlying problems of the neoclassical growth framework, primarily used in the discussion on the sources of growth in Asia, particularly in Singapore. First, we questioned the existence of an aggregate production function and found that the conditions required to assume it exists are stringent and are very unlikely to hold in the real world. We then brought forth the accounting identity critique, which shows that at an empirical level, an aggregate production would be impossible to estimate even if it exists and that TFP could not reliably capture the effects of technical change. At the end of it all, Singapore had outgrown many other countries that, along with it, were heralded as ‘miracles’. Whether that proves either side of the debate right or wrong could be left to speculation.

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