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Is Anything Left of the Debate about the Sources of Growth in East Asia Thirty Years Later?

by

Jesus Felipe
School of Economics, De La Salle University, Manila, Philippines

and

John McCombie
University of Cambridge

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To contact authors: Jesus Felipe (jesus.felipe@dlsu.edu.ph); John McCombie (jslm2@cam.ac.uk)

Levy Economics Institute
P.O. Box 5000
Annandale-on-Hudson, NY 12504-5000
http://www.levyinstitute.org

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ABSTRACT

The year 2023 commemorates the 30th anniversary of the publication of the influential, yet controversial, study *The East Asian Miracle* report by the World Bank (1993). An important part of the report's analysis was concerned with the sources of growth in East Asia. This was based on the neoclassical decomposition of growth into productivity and factor accumulation. At about the same time, the publication of Alwyn Young's (1992, 1995) and J. I. Kim and Lawrence Lau's (1994) studies, and Paul Krugman's (1994) popularization of the "zero total factor productivity growth" thesis, led to a very important debate within the profession, on the sources of growth in East Asia. The emerging literature on China's growth during the 1990s also used the neoclassical growth model to decompose overall growth into total factor productivity growth and factor accumulation. This survey reviews what the profession has learned during the last 30 years about East Asia's growth, using growth-accounting exercises and estimations of production functions. It demystifies this literature by pointing out the significant methodological problems inherent in the neoclassical growth-accounting approach. We conclude that the analysis of growth within the framework of the neoclassical model should be seriously questioned. Instead, we propose that researchers look at other approaches, for example, the balance-of-payments–constrained growth rate approach of Thirlwall (1979) or the product space of Hidalgo et al. (2007), together with the notion of complexity of Hidalgo and Hausmann (2009).

JEL CLASSIFICATIONS: O10, O47, O53

KEYWORDS: Accounting Identity, Biased Technological Progress, China, East Asia, Growth Accounting, Dual TFP, Primal TFP

In a sense, the total factor productivity debate is much ado about nothing.

Joseph Stiglitz (2001, 512)

Popular enthusiasm about Asia's boom deserves some cold water thrown on it. Rapid Asian growth is less of a model for the West than many writers claim and the future prospects for that growth are more limited than almost anyone now imagines.

Paul Krugman (1994, 64)

1. INTRODUCTION

This paper provides a critical survey of the literature on the debate about sources of growth in East Asia that took place mostly in the 1990s and early 2000s. It delves into the following two questions: (a) whether consensus was reached about East Asia's sources of growth; and (b) whether this literature ultimately had an impact on the development literature.

The year 2023 commemorates the 30th anniversary of the publication of the World Bank's (1993) *The East Asian Miracle*. This report provided an analysis of how a group of eight East Asian economies (Hong Kong, Indonesia, Japan, Korea, Malaysia, Singapore, Taiwan, and Thailand) managed to attain very fast growth rates during the previous 30 years, which translated into significant increases in living standards. By the mid-1990s, Hong Kong, Japan, Korea, Singapore, and Taiwan had attained (or were about to attain) high-income status, and Indonesia, Malaysia, and Thailand had attained middle income. The report proved to be a very controversial piece of work as a result of how it explained the miracle. Two related points made quite a few economists criticize the World Bank's work. One was the discussion on the role of government intervention, in particular the role of industrial policy (i.e., favoring some sectors through a set of distortionary policies). As a result of political pressure, the report ended up containing a mix of contradictory statements about the role of free markets and the relevance of "getting the prices right" and government intervention. Those critical of the report's analysis and who argued that industrial policy was key to explaining these countries' fast growth were left unhappy (e.g., Amsden 1994; Lall 1994).

The other discussion in the World Bank's Report was on the estimates of productivity growth, in particular total factor productivity (TFP) growth, used to apportion the sources of growth into capital, labor, and productivity, and to test the impact of industrial policies. Both the methodology used to estimate TFP and the estimates obtained (too low according to some, e.g., Kwon 1994) came to be a source of debate. This second debate (estimates of TFP growth) is the focus of this paper.

In fact, the debate about East Asia's growth emerged in the context of a rather controversial study published the previous year by Alwyn Young (1992) entitled *A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore*. Young performed a growth accounting exercise for these two small economies using data for 1965–90, the results of which, at the time, seemed to have very important implications for our understanding of Asia's development. He found that although multifactor or TFP growth in Hong Kong had been marginally positive during the period in question, it had been zero in Singapore, that is, all growth was due to factor accumulation, especially capital.

Krugman (1994) popularized this result in his much-discussed article, *The Myth of Asia's Miracle*. East Asia's spectacular growth between 1965 and 1990 was similar to that of the Soviet Union during the 1950s and 1960s for similar reasons. It would meet the same fate, namely stagnation.

Young (1995) extended his original work to include the Republic of Korea and Taiwan. The qualitative conclusion remained intact: most growth came from factor accumulation, especially capital. Young's paper, and a few others along similar lines, led to an intense debate in academia (many reputed economists had views on these results) and in policy circles.[1] The analysis of East Asia's growth in terms of multifactor productivity versus factor

[1] See Felipe (1999) for a survey.

accumulation was extended by Gregory Chow (1993) and other authors to the discussion of China's growth.

All this work appeared when the new growth theory (endogenous growth models) also became popular, and new, large data bases allowed the testing of key hypotheses (e.g., convergence, increasing returns to scale, and imperfect markets). Fogel (2009), in his analysis of the impact of Asia's miracle on growth theory, noted that:

> The early papers in the new wave of theoretical work, those which appeared between 1986 and 1990, were responding mainly to European and U.S. developments in the period between 1950 and 1980. When theorists shifted some of their focus to Asia during the first half of the 1990s, they concentrated mainly on the Four Little Dragons, sometimes adding such new contenders for the title of "miracle" as Indonesia, Malaysia, and Thailand. China and India did not move to center stage until the second half of the 1990s. (31–32)

It seemed obvious at the time that East Asia's phenomenal growth rates were forcing economists to rethink growth theory. Overall, this literature is seen by many in the profession to be important.

Many, if not all, empirical papers on East Asia's growth share one important commonality: they used the same model and empirical approach. They analyzed growth through the lens of the neoclassical model of Solow (1956), where growth is a supply-oriented process in the sense that demand never enters the picture (it is implicitly assumed that any production generates its own demand, that is, Say's Law holds), and is constrained by the availability of factors of production. Saving leads to investment, so that supply creates its own demand. Empirically, most of these authors performed growth accounting exercises with a view to apportion overall growth between that due to factor accumulation and that due to total factor productivity growth. In this, they followed the work of Solow (1957), Denison (1967), and Jorgenson and Griliches (1967).

The rest of the paper is structured as follows. Section 2 provides a summary and discussion of the debates on the sources of growth in East Asia, focusing on Hong Kong, Singapore, the Republic of Korea, and Taiwan (i.e., the so-called Newly Industrialized Economies or NIEs) through possibly the best-known papers on the topic. It also considers China, as a significant number of papers on China's growth were also based on the neoclassical model and divided overall growth into TFP growth and factor accumulation. This is somewhat surprising as some of these authors do acknowledge the restrictive assumptions that underlie TFP growth calculations. The discussion in Section 3 focuses on three important methodological issues about the calculations of TFP growth brought up during the 1990s and early 2000s: (i) how the assumption of technical progress affects the estimation of total factor productivity growth; (ii) the use of the dual of total factor productivity growth instead of the primal; and (iii) the accounting identity critique and the nature of the data used.

Although we do not claim that the profession did not learn anything from the debate, we think that a significant portion is smoke with seriously decreasing returns. Even today, what most economists remember are the original papers concluding that total factor productivity had been extremely low. To our disappointment, the criticisms on the original estimates had little impact.

We argue that the growth literature has to move beyond the framework of the neoclassical model. In this vein, Section 4 discusses the traditional notion of balance-of-payments–constrained growth rate, as well as the more recent work on capabilities, product space, and complexity to explain more meaningfully East Asia's growth. Section 5 offers some concluding remarks. Did the East Asian economies simply accumulate capital without generating any efficiency gains as one sector of the profession claimed? More generally, is the growth accounting framework useful to analyze growth? Is there anything to be learned from these exercises? Our answers are mostly negative. The paper questions the relevance of the growth-accounting exercises and estimation of production functions, and thus the discussion of growth performance in terms of factor accumulation versus TFP growth, to understand East Asia's growth.

2. THE DEBATES ABOUT TOTAL FACTOR PRODUCTIVITY GROWTH IN EAST ASIA AND CHINA: A REVIEW OF THE LITERATURE

The 1990s witnessed one of the most important debates in the history of growth and development.[2] This was the debate about the sources of growth in East Asia. The key aspect of this debate was that it was very empirical in nature, and it potentially had important policy implications, as policymakers and academics followed the debate and contributed to it at different levels. In the early 1990s, when the success of the East Asian countries was an open secret, it was of paramount importance for development economists and policymakers to understand how the East Asian countries had achieved such phenomenal growth rates since the mid-1960s, which led to large increases in the living standards of their populations.

As noted above, the debate started with the paper by Alwyn Young (1992) on Hong Kong and Singapore. Young compared the performance of these two economies in terms of a detailed growth accounting exercise covering the period 1965–90, when GDP growth was very high in both. Young found that, although TFP growth accounted for a sizeable share of overall growth in Hong Kong, it was negligible in the case of Singapore. Growth in the latter had been exclusively the result of capital accumulation. The reason, Young argued, was the negative effects of the significant industrial policies of the Singaporean government.

Young's very careful study was based on the single-sector neoclassical growth model. This exercise has its origins in the neoclassical model of growth, where output produced is assumed to be a function of the inputs used, labor and capital, and technology (Solow 1956).[3] The seminal paper on growth accounting is written by Solow (1957), who is credited with linking the decomposition of overall growth into the contributions of the factors of

[2] The literature on the sources of growth in East Asia is rather old. Even though it did not become a popular and debated subject until the 1990s, Chen (1979), for example, had already offered a quantitative treatment of these economies, and referred to them as hyper-miracle economies.

[3] The model is based on three key assumptions: (a) employment grows at an exogenous rate; (b) all saving are invested and there is no independent investment function; and (c) output is a function of capital and labor through an aggregate production function with constant returns to scale and with diminishing returns to the individual factors of production. This last assumption means that increasing the amount of one factor of production (e.g., capital) indefinitely, relative to another one (e.g., labor), cannot increase production indefinitely. When one increases, say, machines relative to workers, the return to each additional machine will steadily decrease.

production (which was done since the 1940s through index numbers but without a solid theoretical basis) with the neoclassical aggregate production function. The latter is what gave this work a theoretical basis. During the next decade, Denison (1967) and Jorgenson and Griliches (1967) refined and extended this methodology.

The growth accounting methodology based on Solow (1957) is well known. He assumed an aggregate production function $Y_t = A_t F(L_t, K_t)$, where Y is the volume of physical output (in reality, deflated monetary values), K is the stock of physical capital (also deflated monetary values), L is employment, and A is the level of technology (or total factor productivity), assumed to be Hicks-neutral (i.e., technical progress that leaves the ratio of the marginal products unchanged), the level of TFP is obtained as $A_t = Y_t / F(L_t, K_t)$. By totally differentiating the production function with respect to time, the growth rate of output is $y_t = TFPG_t + \varepsilon_t^L \ell_t + \varepsilon_t^K k_t$, where y_t is the growth rate of output, ℓ_t is the growth rate of labor, k_t is the growth rate of the capital stock, ε_t^L and ε_t^K denote the elasticities of output with respect to labor and capital, respectively, and $TFPG_t$ denotes the rate of technological progress (i.e., the growth rate of A_t), which is referred to as *total factor productivity growth*, a residual category that captures all output growth not due to increases in factor inputs. The objective of growth accounting is to obtain an estimate of $TFPG_t$ as $TFPG_t = y_t - \varepsilon_t^L \ell_t - \varepsilon_t^K k_t$. The problem, however, is that there are very few reliable estimates (in the sense of being statistically unbiased) of the elasticities. To solve this dilemma, growth accounting exercises assume that: (a) production is subject to constant returns to scale; (b) the objective function of the firms in the economy is to maximize profits; and that (c) labor and capital markets are perfectly competitive (the first-order conditions). Under these circumstances, the factor elasticities equal the shares of labor and capital in total output, that is, $\varepsilon_t^L = s_t^L$ and $\varepsilon_t^K = s_t^K$, where s_t^L and s_t^K denote the shares of labor and capital in total output, respectively. Then output growth can be written as:

$$y_t = TFPG_t + s_t^L \ell_t + s_t^K k_t \qquad (1)$$

and the growth rate of TFP becomes:

$$TFPG_t = y_t - s_t^L \ell_t - s_t^K k_t \qquad (2)$$

Given that data for all the right-hand-side variables are now readily available, it can be *easily* calculated. The residually measured TFP growth in equation (2), known as the "primal" measure of TFP growth, is taken to provide an estimate of that part of output growth, not explained by the growth of labor and the growth of capital.

Other research programs have been shadowed by this one.[4] This concept is crucial to understanding modern discussions of growth, both theoretical models and empirical exercises, as a result of the fact that a segment of the profession believes that the key to explaining differentials in growth rates across countries rests on differences in this variable. There is a whole body of literature that tries to explain this (Felipe and McCombie 2007).

Note that equations (1)–(2) are truisms, in the sense that the estimate of *TFPG* is definitionally true. However, it is based on an underlying behavioral model in that the output elasticities are assumed to be equal to the relevant factor shares. There is nothing in neoclassical production function theory that says that this has to be the case; that is, one could potentially test it empirically and refute it. The importance of the assumptions above, which allow researchers to substitute the shares of labor and capital in output for the elasticities of labor and capital, respectively, should not be underestimated. This substitution is done by using the first-order conditions of profit maximization, that is, that marginal products equal the factor prices. The problem is that this assumption is hardly ever directly tested. This could be done by positing and estimating a particular form of equation (1), for example, a Cobb-Douglas, $y_t = \lambda + \gamma_1 \ell_t + \gamma_2 k_t + u_t$, where λ measures the constant rate of total factor productivity growth and where the coefficients γ_1 and γ_2 are unrestricted. Then one can test the null-joint-null hypotheses that $\gamma_1 = s^L$ and $\gamma_2 = s^K$. Obviously, these coefficients need

[4] This is not for lack of alternative theories, and models of growth. We think it is worth revisiting the classical works of Kaldor, Robinson or Pasinetti (see Sen 1970). For a survey of alternative theories of economic growth, see Setterfield (2010).

not be constant, so one can use any form (such as the CES or translog production functions) and a statistical procedure that allows time-varying coefficients.

Using this methodology, Young (1992) obtained the surprising result that, while for Hong Kong $TFPG_t$ was sizeable—namely, around a third of output growth—it was zero for Singapore.[5] How did Young justify his findings? He argued that the freedom of markets in Hong Kong was at the back of the result. Singapore, on the other hand, had been a victim of its industrial policies and state intervention, which led it to move into the production of sophisticated goods and services industries before it had acquired the necessary capabilities.

Young (1995) extended his growth accounting analysis to include Korea and Taiwan. Overall, he concluded that there was nothing miraculous about these economies' performances. Again, *TFPG* for Singapore was zero. For Hong Kong, Korea, and Taiwan, it had been positive but not spectacular when put in an international context. Capital accumulation had been the essence of their growth strategy. Table 1 summarizes Young's results.

Table 1: Growth Accounting for the East Asian NIEs

	Output growth (%)	**Contribution of capital growth (%)**	**Contribution of labor growth (%)**	**Contribution of TFP growth (%)**
Korea (1966–90)	10.3	4.1	4.5	1.7
Taiwan (1963–90)	9.4	3.2	3.6	2.6
Singapore (1966–90)	8.7	5.6	2.9	0.2
Hong Kong (1966–91)	7.3	3.0	2.0	2.3

Source: Young (1995, Tables V, VI, VII, VIII)
Note: the contributions of weighted (translog indices of factor input growth, with labor services measured by hours of work) labor and capital are the products of each factor growth rate times the respective shares.

Less cited is the work of Kim and Lau (1994), who also provided TFP growth estimates by using a different methodology, namely, the econometric estimation of the aggregate

[5] More precisely, Young (1992) used a translog production function, where the shares used are the average of the initial and final periods.

production function by pooling data for the four East Asian NIEs and for the G-5 countries into the analysis.[6] Kim and Lau's results were even more provocative than those of Young (1992, 1995) because these authors concluded that productivity growth had been zero not only in Singapore but also in the other three successful East Asian economies, namely, Hong Kong, Korea, and Taiwan. These authors also calculated the level of technology of the East Asian Tigers with respect to that of the United States and concluded that in 1960 it was only around one-fifth. Kim and Lau also calculated the relative level of technical progress of these economies vis-à-vis that of the United States in 1990 and concluded that it was still only around a quarter.

These papers became widely known in academic circles, and Young's (1992) paper was even featured in *The Economist*. It was in 1994 when the debate became a popular controversy. Krugman (1994) popularized this literature when he explained in layman's terms what the discussion was about. As the region's initial rapid growth was predominantly due to capital accumulation, the argument asserted stagnation would eventually occur because of diminishing returns, in much the same way it had occurred in the Soviet Union (which had collapsed just a few years earlier). Few papers in the fields of (policy) growth and development have been as controversial as that of Paul Krugman. He argued that the East Asian Tigers' success during the previous three decades was no miracle, that it had been more the result of *perspiration* (capital accumulation) than of *inspiration* (efficiency or productivity gains).[7,8] The neoclassical growth framework is still used as the starting point of growth analyses, and, as a consequence, most discussions about growth are still today framed in terms of factor accumulation versus TFP growth, interpreted as measuring the rate of technical progress.

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6 Their methodology avoided the problem of imposing the seemingly restrictive assumptions of growth accounting. In fact, Kim and Lau (1994) tested those assumptions and rejected them.

7 The East Asian financial crisis only a few years later seemed to prove him right, although Krugman explained that his arguments were unrelated to the factors that led to the crisis.

8 It is worth noting that Krugman, in discussing Young's paper in 1992, questioned the latter's results on the basis of measurement issues: "Singapore in particular has an import share well over 100 percent, thanks to intermediate inputs. This means that measures of real output are essentially measures of real value added. Such measures are notoriously fickle, easily biased by problems of quality adjustment—and especially when there is rapid structural change. So, one possible rationalization of the results is that, in fact, Singapore grew more rapidly than the numbers suggest" (Krugman 1992, 55).

Krugman's paper set off a "cyclone of protest" in academic journals (see Felipe's [1999] survey of this work). Singapore's government even announced that it set up the goal of achieving a 2 percent annual increase in TFP growth.

The problem with the low-TFP growth results was that the conventional wisdom during the period of high growth of the East Asian economies was that much of their success had been due to technological catch-up and productivity gains. What was the role, otherwise, of all the influx of, for example, foreign direct investment? How was it that the accompanying foreign technology had not translated into productivity gains? But if productivity growth was not there, what was there to be learned from the successes of these countries?

After the publication of these papers, there was a lively debate for a number of years on the accuracy of the estimates and on the validity of the inferences and implications for policy and development. These issues were summarized and discussed by Felipe (1999), who offered an extensive review and discussion and warned researchers of what he termed the *Solowresidualization of the East Asian economies* in order to understand how they had grown and appealed to the profession to abandon that research program unless one had something truly novel to say. The recalculation of TFP growth rates was an exercise that, in general, would not produce new insights.[9]

On the issue of the accuracy of the estimates, the problem with this literature was that, in trying to prove Young and Kim and Lau wrong, journals and books were flooded with alternative estimates of TFPG using different data series and slightly different periods to the point that the discussion became of limited value. One positive aspect of this controversy was, nevertheless, the questioning of some of the assumptions made by Young, such as the existence of competitive markets in the region in the face of overwhelming evidence to the

[9] Felipe (1999) provided a comprehensive survey of many of the estimates of TFP growth for the East Asian countries since 1992. Authors used different databases on output and inputs, introduced human capital into the production function, applied different factor shares from those Young had used (and set them constant across time on the assumption of a Cobb-Douglas production function, and equal across countries). However, the rationale provided for doing this was more than questionable. See Fischer (1993), Collins and Bosworth (1997) and Klenow and Rodriguez-Clare (1997) for examples of fixing the shares for a large sample of countries.

contrary. Governments intervened, for example, in wage settings, as in Singapore. Thus, Stiglitz (2001), for example, argued as follows:

> Alwyn Young's (1992) often-cited study arguing that the freedom of markets in Hong Kong, China can explain the relatively rapid increase in its total factor productivity illustrates how the Solow technique can yield erroneous results. Not only is it the case that the measurement of total factor productivity increases can be unreliable […] but the interpretation of the residual, what is left over after measuring inputs is highly ambiguous. Assume that one could feel confident that Hong Kong's residual was greater than that of Singapore. Is it because of better economic policies? Or is it because Hong Kong was the entrepôt for the mainland of China, and as the mainland's economy grew, so did the demand for Hong Kong's services? In this interpretation, Young's explanation of Hong Kong's higher TFP relative to Singapore is turned on its head: Hong Kong's success actually was a result of the growth of perhaps the least free-market regime of the region. (512)

On the question of the inferences and implications of these results, and the lessons for other developing countries, those who argued that the role of TFPG was small did not deny that the East Asian countries had reduced the technology gap with the developed world (contrary to the results of Kim and Lau). What they argued was, first, that the technology gains of these countries were obtained from abroad and that this was not miraculous; and second, that if all the East Asian countries did for 30 years was accumulate capital, like the Soviet Union, there was not much to learn from them (the so-called *fundamentalist* view derived from the Young and Kim and Lau results). On the other side of the debate, many other voices, especially in East Asia, argued, and continue arguing today, that the key to understanding the East Asian miracle resides in an understanding of how the countries in the region *assimilated* and incorporated foreign technology, and that the methodologies used by Young and Kim and Lau cannot shed any light on this. For example, Rashid (2000) argued:

> If the Koreans do not have the TFP of the USA in the fifties despite having copied them, what can we say about this method? If Japan shows significant

TFP during the fifties and Korea is the country that most closely followed the Japanese path to development, how is it that Korea does not show the same TFP? Since Singapore grew through heavy direct foreign investment, does the low TFP indicate a failure of foreign firms to use modern technology? (152)

The Work on China

Parallel to the discussion of East Asia's NIEs, there also emerged a discussion about China's sources of growth. The problem with analyzing China was that, for a long time, it was a centrally planned economy and did not have National Income and Product Accounts (NIPA) data constructed following internationally accepted criteria. In the 1990s, several authors compiled complete data sets that led to a mushrooming of empirical work. This work used the same methods and assumptions (e.g., competitive factor markets) applied to East Asia as discussed above, and its objective was also the apportioning of output growth between TFP growth and factor accumulation.

Gregory Chow (1993) was among the first authors to provide a complete data set on output, employment, and capital stock that allowed the econometric estimation of sectoral (services, construction, industry, transportation, and commerce) Cobb-Douglas production functions such as $Y_t = A_0 \exp(\lambda t) L_t^{\alpha} K_t^{\beta} \exp(u)$ for 1952–80, where t is a time trend that captures the rate of technical progress, and λ consequently measures the constant annual rate of TFP growth.[10]

Chow was ultimately interested in estimating the rate of technical progress, that is, the size and statistical significance of λ. Instead of estimating the production function using all data available, he excluded the period 1958–69. The argument was that these years were abnormal as they were affected by the Great Leap Forward and the Cultural Revolution. In his words: "To exclude the years from 1958 to 1969 in estimating an aggregate production function is a reasonable and rewarding procedure" (Chow 1993, 821). This is tantamount to saying that during those years, China had not been on its production function. Hence, observations from

[10] More recently, Chow (2006) used the same method.

that period should not be taken as reflecting the same production function as observations from other periods.[11]

Borensztein and Ostry (1996) justified Chow's approach by arguing:

> One approach is to see which combinations of output, labor, and capital, are consistent with the hypothesis of a *stable* aggregate production function. On this basis, Gregory C. Chow (1993) excluded the period from 1958 (when the Great Leap Forward began) to 1969 (the first year of positive growth following the end of the Cultural Revolution), finding that for the remaining years, combinations of (logs of) output and capital per worker are fairly close to a straight line." (225; italics added)

From the statistical point of view, however, this can be seen as an exercise in data mining. Even though these excluded years saw a collapse in total output (the value in 1962 was only 64 percent of the value in 1959) followed by rapid recovery (1966 was 177 percent of the 1962 value), this should not affect the parameters of the production function, if indeed the data were estimating the latter. The fall in the flow of the services of inputs should lead to a decline in output that should be closely predicted by the production function.

All of Chow's sectoral regressions found that the rate of technical progress was zero. Chow argued that it is easy to explain why there was no technical change in China before the reforms started:

> There is no reason to assume that technical progress occurred during the period up to 1980. Economic cooperation with the Soviet Union ended in the 1960s. Without incentive from private enterprises, where could technological progress have come? I have found no theory to support the assertion that central planning will produce technological progress. (Chow 1993, 841)

[11] Note that this method is not new. Cobb and Douglas (1928) did the same thing in their seminal study. They estimated their production function for 1899–1922. However, they noted that 1920–21 saw a fall in output of just under 30 percent, and 1921–22 saw a recovery of a similar magnitude. See Felipe and Adams (2005) for a discussion.

We shall see below why we disagree with Chow's procedure and reasoning for eliminating certain years from the regressions.

Hu and Khan's (1997) justification for applying growth accounting to China was also unconvincing from a methodological point of view. After stating that "[t]he estimates of productivity growth for China may be biased in either direction if there are deviations from the assumptions imposed by the adopted methodology." They continued as follows:

> However, since this methodology is widely used in studying sources of economic growth for members of the Organization for Economic Cooperation and Development, the newly industrialized economies of East Asia, and many developing countries with divergent income levels and economic structures, it is of interest certainly as a first step, to apply the same analysis to the Chinese economy to obtain what could be viewed as a "benchmark" estimate. (Hu and Khan 1997, 108)

Finally, other times, authors seemed to need to justify *perverse findings*. For example, Blanchard and Giavazzi (2005, Table 4), in summarizing various estimates of TFP growth for China, indicated that these estimates are about 3 percent per year since reforms started but that TFP growth appears to have slowed significantly in recent years. The authors, however, explained that the finding of low TFP growth is compatible with very high GDP growth:

> The implication of this computation should not be however that there is no technological progress in China. The assumption underlying the computation is that *factors are paid their marginal products*. If, in fact, capital has been misallocated, then contrary to this assumption, the marginal productivity of capital in those sectors where there has been excessive investment could be negative. Therefore, the right way to interpret the computation is that, while technological progress is surely present, it is partly offset by capital misallocation. (Blanchard and Giavazzi 2005, 11; italics added).

The World Bank's East Asian Miracle

We close this review with a reference to the World Bank's (1993) report. The World Bank estimated TFP growth to study whether or not industrial policies (i.e., selective sectoral interventions) had increased productivity. The Report's hypothesis was that if the rates of productivity change in government-promoted sectors were lower than those in unpromoted sectors, then this could be taken as evidence that industrial policy did not achieve one of its key objectives. The report reached two conclusions: (a) rates of productivity growth were high by international standards, and (b) productivity growth in promoted sectors was higher only in Japan.

3. WHAT SHOULD WE MAKE OF EAST ASIA'S GROWTH ACCOUNTING EXERCISES AND AGGREGATE PRODUCTION FUNCTION ESTIMATIONS?

There are three options in evaluating the discussions of the main results and conclusions of the empirical literature on the sources of growth. The first is to accept the results summarized in the previous section and argue that, indeed, there was nothing miraculous in the way East Asia had succeeded. The second is, as indicated above, to come up with a different set of estimates to justify the opposite view. This was done on countless occasions, but the truth is that any discussion about growth in the region still today starts from the old Young (1992) and Kim and Lau (1994) results. Finally, a third option is to question not the numbers per se but the methodology used. We considered the last option the most useful way to understand the discussion with a view toward moving forward. In fact, during the late 1990s, some authors shifted gears and began emphasizing that the analysis of the sources of growth embedded in the neoclassical growth model had serious methodological shortcomings.

It is important to recall that the derivation of the growth accounting equation requires the assumption that factor markets are perfectly competitive and that the production function is subject to constant returns to scale. This matters because many of the papers in this discussion were published at the peak of the new endogenous growth theory, which postulated increasing returns to scale and imperfect markets. In any case, most authors who undertook work on Asia did not even discuss these assumptions, much less test them (e.g., Soludo and Kim 2003). They simply assumed and imposed them. These authors admitted that "what you get in terms of the contributions of TFP depends largely on the 'choice' of the size of alpha (share of physical capital in the production function). Often growth-accounting exercises simply 'impose' the alpha across all developing countries due mainly to data problems. Attempts […] to directly estimate the alpha from national data is a bold beginning" (67). The fact that many countries do not have data on factor shares does not mean that one can simply impose a number. We shall see below why estimating econometrically the factor shares is problematic.

Second, the neoclassical framework implies that growth is the result of two sources, factor accumulation and technological progress (broadly defined). The problem is that one has to accept that growth can be *algebraically split* and apportioned this way. In the words of Pritchett: "This is something that we 'know it ain't so'" (Pritchett 2003, 221). To see what the algebraic splitting of growth means, consider what growth accounting does according to Nelson (1981). Suppose one bakes a cake. One combines flour, yeast, water, sugar, and so forth. Then after the cake is baked, one makes the following claim: 30 percent of the size (or of the taste) is due to flour; another 5 percent is due to the water….and a residual 10 percent is due to the baker's cooking skills. This may seem silly. However, this is what growth accounting does. One thing is to ask: what would happen to the cake (economy) if one added a given amount of extra flour (capital)? Or one may speculate about what would have happened to the cake (economy) if it had been baked (managed) by a more competent baker (Chairman of the Central Bank). But this is different from apportioning the overall result to the individual components. Growth cannot be apportioned the way it is done in growth accounting exercises because it does not make sense (Kaldor 1957; Pasinetti 1959; Scott 1989).

Growth is the result of the interaction of a myriad of factors. Moreover, one has to be careful in interpreting these decompositions, as factor accumulation and productivity growth are both endogenous. This means that factor accumulation accounting for 75 percent of growth, for example, does not imply that growth would have been 75 percent as high in the absence of technical change. Indeed, in the absence of productivity change, the incentive to accumulate would have been much lower, and the resulting capital accumulation would have also been significantly lower. Or, stated in different terms: how is it possible to split the contributions of physical capital, labor, and technology in the case of IT services? Are not capital and technical progress the two sides of the coin? What is the meaning of separating this from the contribution of labor? Who runs the computer?

The power of Nelson's (1981) critique of standard growth accounting exercises is more formidable if one considers production functions that include human capital (e.g., Mankiw et al. 1992), that is, $Y_t = A_t F(L_t, K_t, H_t)$, where H denotes the stock of human capital, measured in terms of, for example, number of years of education in the labor force, or through some similar proxy. The role of human capital in this framework is to recognize that labor in different economies, or at different points in time in the same economy, may possess different levels of education and different skills. However, the inexplicable aspect of this production function is that labor (L) and human capital (H) appear as separate factors of production. Indeed, it is very difficult to understand and comprehend what labor and human capital are and mean as separate entities.

Our view is that one can list the possible sources of growth of an economy the way, for example, Olson (1996) did, that is, as an organizational device or as a tool to think about growth in a systematic way. However, another quite different thing is to try to quantitatively apportion these sources to account for overall growth the way growth accounting exercises do.

In the rest of this section, we discuss what we consider was the most interesting work published after the original papers by Young (1992, 1995) and Kim and Lau (1994) (as the most representative of this literature) and how it addressed the issue of the low TFP growth rates estimated. First, we discuss what happens if technical progress is not neutral but biased. Second, we discuss whether undertaking growth accounting from the dual yields different results. Third, we question the meaning of growth accounting exercises (and econometric estimations of aggregate production functions) on the grounds that the same data used in these exercises are related through an accounting identity.

3.1 Biased Technological Progress and Growth Accounting: Nelson and Pack (1999) and Felipe and McCombie (2001)

Nelson and Pack (1999) were the first authors to provide a coherent attack—on methodological grounds—on the fundamentalist view of growth in East Asia. First, Nelson and Pack proposed an *assimilationist* view of growth in East Asia, along the lines of, for example, Hobday (1995). Nelson and Pack (1999) emphasized the role of entrepreneurship, innovation, and learning, all of which were encouraged by the policy regimes of the East Asian countries. These authors suggested that investment in human and physical capital was necessary but that it was only part of the assimilation process that propelled rapid East Asian growth. What distinguished the East Asian economies was their capacity to successfully assimilate new capital. These economies borrowed much of their technology from more advanced economies and put enormous efforts into absorbing it productively, thus continuously catching up to international best practices during their economic development.

How did Nelson and Pack (1999) resolve the low TFPG paradox? The conventional growth accounting approach uses the Divisia index, where weights are continuously rebased, hence $TFPG_t = y_t - \ell_t - s_t^K (k_t - \ell_t)$. In practice and with discrete data, researchers use $TFPG_t = y_t - \ell_t - \bar{s}^K (k_t - \ell_t)$, with $\bar{s}^K = (s_0^K + s_T^K)/2$, that is, the so-called Tornqvist approximation where s_0^K and s_T^K are the initial and final period capital shares, respectively. The critique of Nelson and Pack (1999) arose from the observation that, according to the National Income and Product Accounts (NIPA), the observed factor shares of the East Asian economies had remained rather constant during the miracle period, despite a substantial increase in the capital–labor ratio (i.e., the capital share had not declined). How could this be explained? In the neoclassical model, this can be seen in two cases (Ferguson 1968): (a) if the underlying elasticity of substitution of the aggregate technology is unity, and with a Cobb-Douglas production function, technical change is Hicks- (and Harrod-) neutral; or (b) if the elasticity of substitution differed from unity and technical progress was biased to the extent that, in spite of a rapidly growing capital–labor ratio, factor shares remained constant.

Nelson (1973) had already argued that the purpose of growth accounting is to separate the contribution of technological progress from that of factor accumulation. In doing this, the factor shares that multiply the growth rates of capital and labor in equation (2), that is, s_t^L and

s_t^K , should be those that would have occurred if there had been no technical change. However, the factor shares actually used in these exercises are the observed ones, taken from the NIPA, which incorporate the effect of technical progress. If the latter is labor saving, purging this effect would reduce the capital share. A lower capital share, which multiplies the growth of capital—the fast-growing factor in these economies—would subtract less from output, thus leading to a higher TFPG. Hence, the puzzle is solved. In other words, if the observed stability of the factor shares was due to an elasticity of substitution that is less than unity and labor-saving technical change, the Nelson and Pack argument makes a substantial difference to the estimates of TFP growth. Nelson and Pack argued that it was difficult to assume that technical progress in East Asia had been Hicks-neutral, implying that equally proportionate amounts of the two factors were saved, thus leaving the ratio of marginal products constant. Rather, they argued, technical progress had been biased, and likely labor saving (i.e., technical progress saved proportionately more labor). The issue is not an innocuous point, as Steedman (1985) had proved that Hicks-neutrality is an impossibility, an internally inconsistent concept at the economy level, in the presence of produced inputs.[12] He was very explicit when it came to explaining the implications of his work for growth accounting exercises:

> It would be too strong to conclude that Hicks neutrality is never legitimately assumed, but it might not be unreasonable to suggest that those who do assume it –for example in estimating the separate contributions of technical progress and input growth – are obliged to show explicitly that that assumption is compatible with their other assumptions. (Steedman 1985, 758)

Under these circumstances (i.e., biased technical progress), the problem is that once an allowance is made in the values of the factor shares for the effect of biased technical progress, the growth-accounting estimates become indeterminate in the absence of

[12] Steedman (1985) provided several alternative sufficient conditions under which Hicks-neutral technical progress is impossible. His analysis used the real wage–price frontier. This is derived from the relationship $Y = wL + rK$, written as $w = y[1-(r/\rho)]$, where y is labor productivity and ρ is capital productivity. The last expression shows that there is a trade-off between wage and profit rates. The sufficiency conditions are stated in terms of the wage–price frontier, e.g., "at least one kind of primary input is paid in advance," or "differential profit rates."

information about the elasticity of substitution. What does this imply for the estimation of total factor productivity growth? In the neoclassical model with the production function $Y = F(A_L L, A_K K)$, where A_L and A_K represent factor-augmenting technical change (not Hicks-neutral as in Young's formulation), the growth of the share of capital is given by (Ferguson 1968):

$$\hat{s}_t^K = [(1-\bar{s}^K)(1-\sigma)/\sigma)][(\lambda_L + \ell) - (\lambda_K + k)] \qquad (3)$$

where $\bar{s}^K = (\bar{s}_0^K + \bar{s}_T^K)/2$ is the average share of the initial (s_0^K) and final (s_T^K) periods, λ_L and λ_K are the corresponding growth rates of factor augmenting technical change, and σ is the elasticity of substitution. The degree of bias is given by $B = [(1-\sigma)/\sigma](\lambda_{\mathrm{L}} - \lambda_K)$.

We noted above that the factor shares did not change very much in East Asia between the mid-1960s and the mid-1990s. As seen from equation (3) for the growth rate of the capital share, this may be due to an elasticity of substitution equal to unity and a Cobb-Douglas production function. Alternatively, it could have occurred because the degree of bias of technical change was such that $\lambda_L - \lambda_K = k - \ell$. Suppose that there is rapid growth in the capital–labor ratio, as did occur in these economies. In the absence of technical change, the capital's observed share would have fallen. In the present case, however, the rate of biased technical change was such that it kept the factor shares constant.

The conventional growth accounting approach is, therefore, subject to error unless technical progress is Hicks-neutral due to its use of current factor shares (as reflected in the NIPA) as weights in the terminal period. The value of the capital share in the terminal period (s_T^K) is high only because of the impact of biased technical change. If capital's observed share in the terminal period is used to calculate $\bar{s}^K$, it will incorporate the effect of biased technical change to the extent that the latter has prevented the observed share from falling. This, in turn, will erroneously cause the contributions of factor input growth to output growth to be overstated, with the result that the true contribution of total-factor-productivity growth is underestimated.

To obviate this problem, Nelson and Pack (1999) argued that the preferable procedure for constructing $\bar{s}^K$ was to use the value of the capital's share in the terminal period that would have occurred in the absence of technical change. Thus, one should calculate *unobserved constant-technology factor shares*. Once this is done, capital's share in the terminal period will be lower, and, as may be seen from equation (3) for $\hat{s}^K$, the growth of total factor productivity will be higher, the lower the elasticity of substitution, and the faster the rate of growth of the capital–labor ratio.

Felipe and McCombie (2001) elaborated upon the Nelson-Pack thesis and devised an iterative procedure to construct the unobserved constant-technology factor shares by eliminating from the observed factor shares the effect of technical progress.[13,14] The left-hand side of Table 2 shows the final shares, and the righthand side shows the average shares (the latter denoted by $\bar{s}$) for different values of the elasticity of substitution (σ). To differentiate them from the actual shares in the NIPA, they are denoted with the superscript *. Results show that, as time passes (subscript 1, 10, 20, 30 years) and the elasticity of substitution increases, the capital share declines.

Table 2: Unobserved Constant-Technology Factors Shares: Singapore, Hong Kong, Republic of Korea, and Taiwan

SINGAPORE								
σ	s_1^{*K}	s_{10}^{*K}	s_{20}^{*K}	s_{30}^{*K}	$\bar{s}_1^{*K}$	$\bar{s}_{10}^{*K}$	$\bar{s}_{20}^{*K}$	$\bar{s}_{30}^{*K}$
0.2	0.439	0.083	0.008	0.000	0.467	0.232	0.119	0.077
0.6	0.487	0.401	0.312	0.233	0.492	0.447	0.397	0.348
0.8	0.493	0.460	0.425	0.389	0.495	0.478	0.460	0.441
1.0	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497
1.2	0.499	0.521	0.545	0.569	0.498	0.509	0.520	0.532
HONG KONG								
σ	s_1^{*K}	s_{10}^{*K}	s_{20}^{*K}	s_{30}^{*K}	$\bar{s}_1^{*K}$	$\bar{s}_{10}^{*K}$	$\bar{s}_{20}^{*K}$	$\bar{s}_{30}^{*K}$

[13] The iterative procedure is described in Felipe and McCombie (2001).

[14] See also Rodrik (1997) and Young (1998a), who discussed similar issues.

0.2	0.298	0.069	0.010	0.001	0.318	0.170	0.094	0.062
0.6	0.332	0.272	0.213	0.164	0.336	0.304	0.271	0.241
0.8	0.337	0.313	0.288	0.264	0.338	0.326	0.313	0.300
1.0	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340
1.2	0.341	0.358	0.376	0.395	0.341	0.349	0.358	0.367
KOREA								
σ	s_1^{*K}	s_{10}^{*K}	s_{20}^{*K}	s_{30}^{*K}	$\overline{s}_1^{*K}$	$\overline{s}_{10}^{*K}$	$\overline{s}_{20}^{*K}$	$\overline{s}_{30}^{*K}$
0.2	0.251	0.023	0.001	0.000	0.279	0.110	0.056	0.036
0.6	0.299	0.216	0.144	0.093	0.305	0.260	0.217	0.181
0.8	0.306	0.272	0.237	0.206	0.308	0.291	0.272	0.254
1.0	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310
1.2	0.312	0.336	0.364	0.393	0.311	0.323	0.323	0.350
TAIWAN								
σ	s_1^{*K}	s_{10}^{*K}	s_{20}^{*K}	s_{30}^{*K}	$\overline{s}_1^{*K}$	$\overline{s}_{10}^{*K}$	$\overline{s}_{20}^{*K}$	$\overline{s}_{30}^{*K}$
0.2	0.208	0.017	0.000	0.000	0.233	0.090	0.046	0.030
0.6	0.251	0.177	0.116	0.074	0.256	0.216	0.179	0.148
0.8	0.257	0.227	0.196	0.168	0.259	0.243	0.227	0.211
1.0	0.261	0.261	0.261	0.261	0.261	0.261	0.261	0.261
1.2	0.263	0.285	0.311	0.338	0.262	0.273	0.285	0.298

Note: s_T^{*K} for T=1, 10, 20, 30 are the constant-technology capital shares in the final period; while $\overline{s}_T^{*K}$ for T=1, 10, 20, 30 are the average (of initial and final periods) capital shares.
Source: Felipe and McCombie (2001, Table 1)

Felipe and McCombie (2001) used these shares to recalculate the growth rate of TFP. They reached the conclusion that, with these new shares and for low values of the elasticity of substitution, it is true that the procedure makes a significant difference, and TFP growth accounts for a larger share of output growth. Table 3 summarizes Felipe and McCombie's results for Hong Kong, Korea, Singapore, and Taiwan (the recalculated total factor productivity is denoted with the superscript *). The upper part of each section in the table shows the growth rates of output, labor, and capital, as well as the initial capital share, according to Young (1995). This part of the table also shows the standard growth rate of TFP, denoted TFPG.

The rest of the table shows the TFP growth rates for different elasticities of substitution (σ) and for periods that range from 1 year to 30 years. They are denoted $TFPG_t^*$, where t=1, 10, 20, and 30. The results indicate that, indeed, TFP growth increases as the elasticity of substitution decreases. When σ=0.2 (and with a longer time horizon), the Nelson and Pack (1999) argument makes a difference.[15, 16]

Table 3: Growth Accounting Simulations for Singapore, Hong Kong, Korea, and Taiwan, 1966–90

Singapore: y = 0.087; ℓ = 0.057; k = 0.115; s_0^K = 0.497; s_T^K = 0.494; $TFPG$ = 0.0012

Hong Kong: y = 0.073; ℓ= 0.032; k = 0.080; s_0^K = 0.34; s_T^K = 0.391; $TFPG$ = 0.0234

	SINGAPORE				HONG KONG			
σ	$TFPG_1^*$	$TFPG_{10}^*$	$TFPG_{20}^*$	$TFPG_{30}^*$	$TFPG_1^*$	$TFPG_{10}^*$	$TFPG_{20}^*$	$TFPG_{30}^*$
0.2	0.0028	0.0165	0.0230	0.0255	0.0257	0.0328	0.0364	0.0380
0.6	0.0014	0.0040	0.0069	0.0097	0.0248	0.0263	0.0280	0.0294
0.8	0.0012	0.0022	0.0033	0.0044	0.0247	0.0253	0.0259	0.0265
1.0	0.0011	0.0011	0.0011	0.0011	0.0246	0.0246	0.0246	0.0246
1.2	0.0011	0.0004	-0.0002	-0.0008	0.0242	0.0242	0.0238	0.0233

Rep. Korea: y = 0.103; ℓ = 0.064; k = 0.137; s_0^K = 0.31; s_T^K = 0.261; $TFPG$ = 0.0181

Taiwan: y = 0.094; ℓ= 0.049; k = 0.123; s_0^K = 0.261; s_T^K = 0.251; $TFPG$ = 0.0260

	REP. KOREA				TAIWAN			
σ	$TFPG_1^*$	$TFPG_{10}^*$	$TFPG_{20}^*$	$TFPG_{30}^*$	$TFPG_1^*$	$TFPG_{10}^*$	$TFPG_{20}^*$	$TFPG_{30}^*$

[15] However, this did not entirely solve East Asia's problem of low TFPG rates. Indeed, when Felipe and McCombie (2001) applied the procedure to a group of advanced countries, TFPG also increased for this group, thus leaving things, in relative terms, unchanged.

[16] Two additional important implications of this work exist. First, if the share of capital was about constant, then the growth rate of capital augmentation has to be $\lambda_K = \hat{r} = q - k$. But the data used (from Young 1995), implies that $\lambda_K < 0$. This is puzzling, especially if technical progress is exogenous. How can this be possible? Maybe Young (1992) was right and the rate of capital accumulation and the movement into high-tech industries were so rapid that there was no time for productivity gains to accrue in the form of learning-by-doing. With little managerial and organizational capabilities, maybe capital productivity growth was negative. If these countries "leapfrogged," there was never learning. Of course, why this policy of jumping fast led to a fall in capital-augmenting, and not labor-augmenting, technical change is a mystery. Second, the constant-technology rate of TFP growth will tend to the growth of labor productivity as the period under consideration increases.

0.2	0.0185	0.0309	0.0349	0.0363	0.0277	0.0383	0.0416	0.0427
0.6	0.0167	0.0199	0.0231	0.0258	0.0260	0.0289	0.0317	0.0340
0.8	0.0165	0.0177	0.0191	0.0204	0.0258	0.0270	0.0282	0.0293
1.0	0.0163	0.0163	0.0163	0.0163	0.0256	0.0256	0.0256	0.0256
1.2	0.0162	0.0154	0.0144	0.0134	0.0256	0.0248	0.0238	0.0230

Notes: (i) y = Annual growth rate of output (1966–90; Hong Kong, 1966–91); ℓ = Annual growth rate of employment (1966–90; Hong Kong, 1966–91); k = Annual growth rate of stock of capital (1966-1990; Hong Kong, 1966–91); s_0^K = Average share of capital initial subperiod (1966–70; Hong Kong, 1966–71); and s_T^K = Average share of capital final subperiod (Singapore, Taiwan 1980–90; Hong Kong, 1986–91; Republic of Korea 1985–90); (ii): σ is the elasticity of substitution; (iii): $TFPG_t = (y_t - \ell_t) - [1/2(s_0^K + s_T^K)(k_t - \ell_t)]$; (iv): $TFPG_t^* = (y_t - \ell_t) - \bar{s}_T^{*K}(k_t - \ell_t)$ is the annual rate of *TFPG* over a period of *T* years under the assumption of constant technology, where $\bar{s}_T^{*K}$ is the value of the calculated constant-technology capital share.
Source: Felipe and McCombie (2001, Table 2)

3.2 The Use of Dual TFP Growth: Hsieh (1999, 2002)

Hsieh (1999, 2002) argued that Young's (1992, 1995) calculations were problematic because the latter had used the primal measure of TFP growth (equation [2]), which requires information on capital stocks (difficult to construct). Hsieh's point, in particular for Singapore, was that, with a more or less constant share of capital in GDP and an increasing capital–output ratio, the implied rate of return should have fallen dramatically. However, different measures of the marginal product of capital showed no decline. Hsieh then concluded that Singapore's national accounts overstated the amount of investment spending, the data used to construct the capital stock.[17]

To solve this problem, Hsieh (1999, 2002) proposed to calculate the dual measure of TFPG. Theoretically, this is derived from the cost function, that is, the relationship between total cost, output, and factor prices, $C = f(Y, w, \rho, t)$. In this case, technical progress is equated to the rate of cost diminution, and the idea is that technical progress lowers the cost of obtaining a given output. The dual is simply calculated by equating the rate of change in product prices with the rate of change in unit costs. It is equal to

$$TFPG^D \equiv s_{ct}^L \hat{w}_t + s_{ct}^K \hat{\rho}_t \tag{4}$$

[17] Young (1992) had made a similar point. Young's capital stock data implied that the rate of return had declined from 37 percent in the mid-1960s to 13 percent in the mid-1980s. This was very counterintuitive.

where s_c^L and s_c^K are the employment and capital shares in total cost, not in revenue, and ρ is the rental price of capital. The dual is then a weighted average of the growth rates of the wage and of the rental price of capital, the latter estimated following Hall and Jorgenson (1967) as $\rho = (i+\delta)P_K - \dot{P}_K$, where i is the real return on capital, δ is the depreciation rate, P_K is the deflator for business-fixed investment, and $\dot{P}_K$ is the capital goods appreciation.

However, Hsieh (1999, 2002) did not derive the dual from the cost function. Instead, he derived it by expressing the national income accounting identity $Y_t = w_t L_t + \rho_t K_t$ (where Y is aggregate output, w is the average wage rate, L denotes employment, ρ is the rental rate of capital, and K is the capital stock), in growth rates, that is, $y_t = s_t^L \hat{w}_t + s_t^K \hat{\rho}_t + s_t^L \ell_t + s_t^K k_t$, or $y_t - s_t^L \ell_t - s_t^K k_t = s_t^L \hat{w}_t + s_t^K \hat{\rho}_t = TFPG_t^D$. This is the same as equation (4), assuming there are no monopolistic profits, hence revenue and cost shares coincide (i.e., $s_t^L = s_{ct}^L; s_t^K = s_{ct}^K$). We shall return to this derivation of the dual in the next section.

Because the estimate of the rental price of capital calculated by Hsieh did not show a marked decline, he found higher TFP growth rates using the dual than using the primal (Table 4).[18]

[18] Young (1998b), commenting on an early version of Hsieh's work, argued that it was erroneous because it contained many methodological and computational errors. Young claimed, for example, that Hsieh's formula for the rental price of capital did not include the impact of changes in the tax code. The correct formula Hsieh should have used according to Young is: $\rho = (i+\delta-\hat{P}_K)P_K \dfrac{(1-\tau D - C)}{(1-\tau)} + t * P_B$, where D is the present discounted value of tax deductions for depreciation; τ is the corporate income tax rate; C is the effective tax rate of investment tax credit; t is the property tax rate; P_B is the real property tax basis. Young also claimed that Hsieh's method generated negative rentals in levels. Once these alleged errors were corrected, Young showed that dual and primal produced the same result, a very low TFP growth rate for Singapore. Hsieh disagreed by pointing out that he did not have enough information on tax policies in these countries to calculate tax-adjusted rental prices (Hsieh 2002, footnote 14). He nevertheless used some aggregate data on Singapore to check this (Hsieh 2002, section IV) but concluded that the inclusion or not of taxes in the estimation of the rental price of capital does not explain the large discrepancy between primal and dual estimates of TFP growth.

Table 4: Growth Accounting for Singapore, Hong Kong, Rep. Korea, and Taiwan: Dual and Primal Estimates

	Real interest rate used	Annual growth of Dual TFP (%)	Annual growth of Primal TFP (%)
Korea	Curbed market rate (1966–90)	1.91	1.70
	Deposit rate (1966–90)	2.07	1.70
	Discount rate (1966–90)	1.62	1.70
Singapore	Return on equity (1971–90)	1.52	-0.69
	Average lending rate (1968–90)	2.16	-0.22
	E-P ratio (1973–90)	1.61	-0.66
Hong Kong	Prime lending rate (1966–91)	2.12	2.30
	Call money rate (1966–91)	1.98	2.30
	E-P ratio (1973–1991)	2.92	2.18
Taiwan	Curb loan rate (1966–90)	3.79	2.60
	One-year deposit rate (1966–90)	3.87	2.60
	Secured loan rate (1966–90)	3.36	2.60
	Three-month treasury bill rate (1975–90)	3.79	2.70

Source: Hsieh (2002, Table 1)

3.3 The Aggregate Production Function and the Accounting Identity: Felipe and McCombie (2003)

> Despite all this work, there is still no general agreement on what the computed productivity measures actually measure, how they are to be interpreted and what are the major sources of their fluctuations and growth. (Griliches 1988, 363)

> The question then to be answered is whether the residual effect of "technical progress" corresponds to anything interesting. I rather doubt it. There is no reason to suppose, for example, that technical progress, so defined, measures

> the effect of research and development expenditures. Indeed, I cannot think what it measures, except (tautologically) the difference between an actual increase in output and a purely hypothetical increase, which is based on a set of definitions that I can see no reasons for using. (Scott 1989, 88)

Sections 3.1 and 3.2 offered two possible solutions to East Asia's low TFP growth dilemma. They showed that the original TFP growth estimates were too low because of the assumption made about the type of technical progress or because, due to problems estimating capital stocks correctly, the dual measure is more reliable. Both arguments are within the realm of the neoclassical growth model.

Felipe and McCombie (2003) provided a different type of assessment and critique of the conventional literature on the Asian miracle.[19] Their view of the TFPG discussion was rather *nihilistic* and provided a sound rationale for Stiglitz's (2001) assessment of the debate quoted at the beginning of this paper. Felipe and McCombie (2003) argued two main points. The first was that standard growth accounting analyses assume that an aggregate production function exists. Indeed, the assumption is so critical that Nelson and Pack (1999, 424), being aware of its importance, explicitly mentioned that they assumed an aggregate production function existed. However, simply assuming this is no more than wishful thinking. This assumption is of crucial importance, for it is the sine qua non of the growth accounting exercises, and yet it was never questioned in the debate on sources of growth in East Asia. Though, it is easy to understand why this is the case. Although the hypothesis of competitive markets, for example, can be relaxed without too much difficulty (it leads to a slightly different growth accounting equation), if the aggregate production function does not exist, the whole growth accounting exercise or the econometric estimation of the aggregate production function would become impossible.

The truth, however, is that aggregate production functions almost certainly do not exist, as explained below. This result has been known since the 1940s (Felipe and Fisher 2003) and, very clearly, since late 1960, as a result of the work of Franklin Fisher and others.[20,21] It is

[19] The overall argument has been further developed and extended in Felipe and McCombie (2013).

puzzling that such a well-established finding was ignored in all this debate, and authors preferred to spend time "refining" total factor productivity growth calculations. Felipe and Fisher (2003) reviewed and discussed the well-established literature on aggregation in production functions and reminded the profession that the conditions under which an aggregate production function with neoclassical properties exists—in the sense that it can be generated from micro-production functions—are so stringent that they are not met by actual economies.[22] Wilson (2009) has provided evidence that this is indeed the case. It is very difficult to understand the modern literature on TFP growth when, as far back as 1970, Nadiri, in a survey on the topic, already claimed that the aggregation problem matters because "without proper aggregation we cannot interpret the properties of an aggregate production function, which rules the behaviour of total factor productivity" (Nadiri 1970, 1144).[23, 24]

[20] Solow (1957) was aware of these results to the point that, in his famous growth accounting exercise for the US, he wrote: "…it takes something more than the usual "willing suspension of disbelief" to talk seriously of the aggregate production function. But the aggregate production function is only a little less legitimate a concept than, say, the aggregate consumption function…" (Solow 1957, 312). As Felipe and Fisher (2003) argued, the conditions to aggregate micro-production functions into an aggregate production function are much more stringent than those for consumption.

[21] Parallel to the development of the aggregation literature, an important debate in the profession took place under the name of the Cambridge capital theory controversies. An important aspect of the controversies was also about the legitimacy of the neoclassical aggregate production function to depict an economy. See Cohen and Harcourt (2003) and Felipe and Fisher (2003).

[22] This is not the place to go in detail on the aggregation conditions. Suffice it to say that Fisher approached the issue for the first time in the 1960s by asking how to aggregate the production functions of individual firms when markets allocate factors of production so that the aggregate production is efficient. When can this be represented by an aggregate production function? The efficiency condition is very important, for without it, the literature had already shown that aggregation was virtually impossible. Fisher showed that even under this condition, aggregation was virtually impossible. It can be done in some very restrictive circumstances, such as when relative prices remain constant, relative quantities remain constant, every firm has the same constant-returns-to-scale production function, or there is only one kind of capital, one kind of labor, and one kind of output to begin with—and all are allocated to firms to achieve efficiency. Even under constant returns, the conditions for aggregation are so very stringent as to make the existence of aggregate production functions in real economies a non-event. See Felipe and Fisher (2003).

[23] It is worth quoting Nadiri on this:

> The conclusion to be drawn from this brief discussion is that aggregation is a serious problem affecting the magnitude, the stability, and the dynamic changes of total factor productivity. We need to be cautious in interpreting the results that depend on the existence and specification of the aggregate production function…That the use of the aggregate production function gives reasonably good estimates of factor productivity is due mainly to the narrow range of movement of aggregate data, rather than the solid foundation of the function. In fact, the aggregate production function does not have a conceptual reality of its own. (Nadiri 1970, 1145–46)

If one has doubts about the legitimacy of an aggregate production function, it probably does not make much sense to talk about technical progress in aggregate terms at the economy-wide level. Actual technical change occurs at the level of the individual production process, and the various industries are linked by their use of inputs produced by all of them. What types of changes at the process level can give rise to the standard kind of technical change at the aggregate level?

Felipe and McCombie's (2003) second argument was empirical. It is based on an old argument used by Herbert Simon (1979) and Paul Samuelson (1979), among others (but neglected by the neoclassical growth literature), to question production function estimations. These authors asked if there is any possible interpretation of the estimates of production functions that is compatible with the non-existence of an aggregate production function. Implicit in their argument is the puzzling fact that in econometric analyses, some authors have shown that simple functions (e.g., the Cobb-Douglas form) of aggregate capital and labor can explain a large fraction of the variation in GDP. This is difficult to square because actual production relationships are very complex (e.g., think of an oil refinery), as any modern economy has thousands of firms, each with its own production function.

Felipe and McCombie (2003) showed that growth-accounting exercises and the derivation of *TFPG* could be identically carried out from the accounting identity that relates output to the sum of the wage bill plus overall profits in the NIPA without making any assumption. This has serious implications that have been ignored by most researchers, including Hsieh (1999, 2002) and Barro (1999), when they claimed that the growth accounting equation could be derived from the national income accounts because the claims of Felipe and McCombie (2003) and Hsieh and Barro (1999) are not the same, and the differences must be made clear.

The NIPA identity is:

$$Y_t \equiv W_t + \Pi_t \equiv w_t L_t + r_t K_t \qquad (5)$$

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[24] Fisher (1993, xiii) recalled that at the 1970 Econometric Society Meetings, where he was a discussant in a session that featured Robert Solow and Joan Robinson, he (Fisher) made it clear that he called "into question the use of aggregate production functions in macroeconomic applications such as Solow's famous 1957 paper."

where r_t is the profit rate, different conceptually from the user cost of capital ρ_t (used by Hsieh). We stress that the symbol $\equiv$ indicates that equation (5) is an accounting identity and that no assumption is needed to write it. It holds always, and average wage and profit rates may or may not equal the corresponding average marginal productivities. Likewise, equation (5) is not derived from Euler's theorem, the validity of which depends on the existence of the aggregate production function. Now write equation (5) in growth rates as:

$$y_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t + s_t^L \ell_t + s_t^K k_t \qquad (6)$$

Compare now equations (1) and (2) with equation (6). Because the latter is an identity, it must be true that $y_t - s_t^L \ell_t - s_t^K k_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t$. The important point to note is that $y_t - s_t^L \ell_t - s_t^K k_t$ is exactly what equation (2) calculates as total factor productivity growth ($TFPG_t$). However, this poses a very serious problem for the interpretation of $TFPG_t$, calculated either as $y_t - s_t^L \ell_t - s_t^K k_t$ or as $s_t^L \hat{w}_t + s_t^K \hat{r}_t$ (which are obviously identical), as a measure of productivity growth, given that equation (6) is just an accounting identity (always true) and not a model that can be tested and potentially refuted. Because equation (2) was derived from a model, but is the same as equation (6), equation (2) must also always be true. Moreover, if there is no aggregate production function, wage and profit rates cannot be equated to their respective marginal products. The bottom line is that it is incorrect to state that total factor productivity calculations do not rely on the production function because they can be derived from national accounts. We shall get back to this point below in the discussion of Hsieh (1999, 2002).

Quite often, economists refer to $y_t - s_t^L \ell_t - s_t^K k_t$ (derived from the production function as shown above, equation [2]) as a "black box" or a "measure of our ignorance," the part of output growth that is not explained by factor accumulation. Our view is that they do this because they focus on the idea that there remains something else after subtracting the contributions of labor and capital ($-s_t^L \ell_t - s_t^K k_t$) from output growth ($q_t$). Surely there is something else: the identity tells us that this is $s_t^L \hat{w}_t + s_t^K \hat{r}_t$, that is, the weighted average of the growth rates of the wage and profit rates, which can be interpreted as a measure of distributional changes. This is not a measure of our ignorance. The expression $s_t^L \hat{w}_t + s_t^K \hat{r}_t$ might or might not be of economic interest, but certainly it is not a black box. What are black boxes (even black holes) are the regressions that many economists run with $y_t - s_t^L \ell_t - s_t^K k_t$ on the left-hand side, considering it is a measure of productivity growth, and then data-mine for statistically significant regressors, for example, education, FDI, R&D, openness, or some variables in levels and some others in growth rates. Once one realizes that what they are trying to model is $s_t^L \hat{w}_t + s_t^K \hat{r}_t$, the role of these regressors becomes somewhat dubious. Moreover, because factor shares (s_t^L and s_t^K) only change slowly over time and the growth rate of the wage ($\hat{w}_t$) rate is mildly pro-cyclical (wages are sticky), most of the fluctuations in $s_t^L \hat{w}_t + s_t^K \hat{r}_t$ (and, consequently, in $y_t - s_t^L \ell_t - s_t^K k_t$) result from fluctuations in the growth rate of the profit rate ($\hat{r}_t$). Although efforts at modeling $\hat{r}_t$ may be worthwhile in some contexts, one should probably reconsider the righthand side variables in these regressions.

This deceptively simple argument is very damaging for all applied work using the neoclassical production function.[25] It now becomes straightforward to correctly interpret Young's (1992, 1995) work. The question is not whether or not Young made a computational mistake. It is much more serious. First, in light of the aggregation problem, the growth accounting exercise is theoretically very dubious. Second, the accounting identity argument shows that all these exercises do is manipulate an accounting identity.

To be more precise, equation (6), $y_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t + s_t^L \ell_t + s_t^K k_t$, can certainly be used as an organizational device. After all, it is true, as a matter of algebra, that growth is the result of increases (growth) in the wage bill and in total profits (appropriately weighted). What neoclassical economics does, and this is the heart of the problem, is to link this identity to the

[25] Robert Solow tried to refute this argument twice. Felipe and McCombie (2013, chapter 5) provide a detailed discussion of his arguments and showed why he was wrong the two times. Herbert Simon (1978) was also aware of the argument and exchanged letters with Solow about it. Moreover, Simon thought the argument was so important that he touched upon it in his Nobel lecture (see Felipe and McCombie 2013). Paul Samuelson (1979) also knew the relationship between the identity and the aggregate production functions. He used it in his paper to discuss Paul Douglas's work. Based on this, Samuelson questioned the meaning of Cobb and Douglas's estimates (see Felipe and Adams 2005). And finally, econometricians like Cramer (1969, 234–37), Intriligator (1978, 270), and Wallis (1979, 62–63) also showed the algebra of the argument, although, paradoxically, none took it to its ultimate logical conclusion, i.e., that estimation of the aggregate production function is a meaningless exercise. They seemed to be more concerned with technical econometric issues (see Felipe and McCombie 2013).

notion of a neoclassical aggregate production function and then argue that what underlies the accounting identity is the production function (via Euler's theorem and the usual neoclassical assumptions). We dispute this claim. What we have argued is that the notion of an aggregate production function is very problematic theoretically. Secondly, we have shown that the accounting identity given by equation (5) in levels, and by equation (6) in growth rates already encapsulates the same idea as neoclassical economics, with the aggregate production function.

To put the argument in even starker terms, we review several examples of the work discussed earlier through the prism of the accounting identity critique:

Example 1: It should be clear by now that if Young's (1992, 1995) growth accounting exercises can be interpreted as simply transformations of the accounting identity, the explanation of the "residual" as a measure of aggregate productivity growth (technical progress) raises questions. To emphasize our arguments, we review here Young's (1994) work, a "growth-accounting exercise" estimating a growth regression instead of the accounting exercise.

To understand Young's method, note that one can write equation (6) as

$$y_t \equiv \lambda_t + s_t^L \ell_t + s_t^K k_t \qquad (7)$$

where $\lambda_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t$. Now compare equations (1) and (7). The former is supposed to be a model that could be estimated as $y_t \equiv \lambda_t + \alpha_t \ell_t + \beta_t k_t + u_t$. But what does the identity equation (7) tell us? It should be obvious that the only possible result is $\alpha_t \equiv s_t^L$, $\beta_t \equiv s_t^K$ and $TFPG_t \equiv \lambda_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t$, with a perfect fit, unless one decides to incorrectly assume, for example, that α_t, β_t and λ_t are constant. Under these circumstances, the fact that the statistical fit is not perfect could lead to the misapprehension that a behavioral model is being estimated. But this simply misunderstands the underlying logic. Note also that there are no estimation problems as discussed in the literature, for example, regressors' endogeneity that calls for IV estimation. Any estimation method that picks up the variation in factor shares and in λ_t should show that what is being estimated is the identity.

The discussion above has an important corollary. The hypothetical finding that $\alpha_t \equiv s_t^L$ and $\beta_t \equiv s_t^K$ would seem to imply constant returns to scale and perfectly competitive factor markets.[26] These results do not mean, however, that the world is one of constant returns to scale and perfectly competitive markets. Rather, all they mean is that if researchers estimated the equation correctly, for example $y_t \equiv TFPG_t + \alpha_t \ell_t + \beta_t k_t + u_t$, using a time-varying parameter methodology, they would always need to find that factor elasticities equal the factor shares, as a matter of logic. It is the result of the accounting identity. Naturally, this approach is very problematic for the literature on endogenous growth and imperfect markets. These might exist, but this method will always reject these hypotheses (once again, if the regression is estimated correctly).[27]

We now return to Young (1994). He estimated a cross-country production function using data from 118 countries between 1970–85. This was the growth-accounting regression, $y_t = \varphi + \gamma_1 \ell_t + \gamma_2 k_t + u_t$, or $(y_t - \ell)_t = \varphi + \gamma_2 (k_t - \ell_t) + u_t$, under the assumption that $\gamma_1 + \gamma_2 = 1$. As argued above, this is thought to be a model in the sense that it can be tested and potentially refuted. Each country residual, $\hat{u}_i$, measures the growth of country *i's* total factor productivity less the world average. That is, the per country TFP growth rate equals $\hat{\varphi} + \hat{u}_i$, where the circumflex denotes a statistical estimate. Young obtained the following result:

$$(y_i - \ell_i) = -0.21 + 0.45(k_i - \ell_i) + u_i \qquad (8)$$

[26] Fisher (1971) showed using simulation analysis that if factor shares are constant, it is not because the economy's technology is Cobb-Douglas. Rather, it is the other way around, that is, the Cobb-Douglas form works empirically (when it does) because factor shares happen to be constant (if they are). The latter could be simply due to the fact that firms use a constant mark-up on unit labor costs to set prices.

[27] See Hall (1988) on imperfect markets and the replies by Felipe (2001) and Felipe and McCombie (2002, 2008). See also Mankiw, Romer, and Weil's (1992) estimation of Solow's model and the discussion by Felipe and McCombie (2005).

He noted that the residuals for the East Asian countries ($\hat{\varphi} + \hat{u}_i$) were very close in value to his much more detailed analysis using the growth accounting methodology.

The question is, what does this regression tell us? We know from the accounting identity that $y_i \equiv s_i^L \hat{w}_i + s_i^K \hat{r}_i + s_i^L \ell_i + s_i^K k_i$, or $(y_i - \ell_i) \equiv s_i^L \hat{w}_i + s_i^K \hat{r}_i + s_i^K (k_i - \ell_i)$, where the subscript *i* denotes the *i*th country. It will be recalled that, as argued earlier, this is not a model. This means that if one estimates econometrically $(y_i - \ell_i) \equiv \mu_1[s_i^L \hat{w}_i + s_i^K \hat{r}_i] + \mu_2[s_i^K (k_i - \ell_i)] + u_i$, it should be obvious that the result must be $\mu_1 = \mu_2 = 1$ and $R^2 = 1$, as there is no error term ($u_i = 0$) for all the observations. Consequently, if one estimates:

$$(y_i - \ell_i) \equiv c + b(k_i - \ell_i) + u_i \tag{9}$$

as Young did, it should be apparent that the estimate of *b* will approximate the average value of the share of capital in the sample ($\bar{s}_i^K$). The sum of the error plus the constant will, by definition, provide an estimate of φ_i, the weighted average of the growth rates of the wage and profit rates. Of course, the estimates may be subject to some bias if φ_i is not orthogonal to $(k_i - \ell_i)$. Note that now equation (9) contains the error term u_i. This is not zero as in the accounting identity because equation (9) proxies $s_i^L \hat{w}_i + s_i^K \hat{r}_i$ by the constant term c, and s_i^K by the coefficient b (also constant). To the extent that these two variables are not constant, the left and righthand sides in equation (9) will not be identical. It should be clear, nevertheless, that the nature of this error term is not the same as that in a true economic model, that is, random error that results from other factors not considered. Young's estimates of the TFPG of the East Asian countries from the regression exercise must be virtually identical to those from the accounting identity; the latter shows that it cannot be otherwise.

Example 2: What about Hsieh's (1999, 2002) dual? Recall that Hsieh's rationale for questioning Young's (1992) results was that the national income accounts overstated the investment, and thus the estimated stock of capital (and its growth rate) was too high. The dual solved the problem because it uses price data. However, before we get to whether this is true or not, we can explain what Young's data implied from the dual's point of view and the accounting identity. If the primal was zero in Young's calculations (i.e.,

$TFPG_t \equiv s_t^L \ell_t + s_t^K k_t \equiv 0$), the identity implies that $TFPG_t^D \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t \equiv 0$. With a capital share more or less constant and taking a value of approximately 0.5, this implies that $\hat{w}_t = -\hat{r}_t$ for Singapore. In other words, the wage rate grew at a rate that was matched by the decline in the growth rate of the profit rate. This is the point Hsieh disagreed with, as he argued that it was caused by the very high and possibly incorrect estimates of the capital stock.

As we noted above, Hsieh (1999, 2002) claimed that the dual could be derived directly from the national income accounts. This is methodologically questionable because, although it is true that similar expressions can be derived from the cost function and the identity, the interpretation of the latter as a measure of productivity growth (technical progress) is unwarranted. A careful reading of Hsieh's paper, however, suggests that underlying his argument *must be* the aggregate neoclassical production and cost functions upon which the theory of total factor productivity growth is based to interpret his derivation.

To see the problem that the identity poses for the dual of TFP, let us write the NIPA identity as $Y_t \equiv w_t L_t + \rho_t K_t + \Sigma_t$, with $\rho = (i + \delta) P_K - \dot{P}_K$, and define $TC_t = w_t L_t + \rho_t K_t$ as total costs where Σ_t denotes monopolistic profits. It must be self-evident that $Y_t \equiv w_t L_t + \rho_t K_t + \Sigma_t$ is identical to $Y_t \equiv w_t L_t + r_t K_t$, with $\rho_t K_t + \Sigma_t = r_t K_t$. Using instead the identity $Y_t \equiv w_t L_t + \rho_t K_t + \Sigma_t$ does not change our arguments as the accounting identity is preserved, and one can write $Y_t \equiv w_t L_t + \rho_t K_t + \Sigma_t$ in growth rates too. The difference is that now we would have to split the share of capital into two parts: (a) $s_{ct}^K = (\rho_t K_t / Y_t)$, and (b) Σ_t / Y_t. Naturally, if one writes the identity as Hsieh did, then $w_t L_t + \rho_t K_t$ need not be equal to $Y_t \equiv w_t L_t + r_t K_t$, unless $\Sigma_t = 0$, which would also mean that $\rho_t = r_t$. Moreover, we insist that underlying Hsieh's arguments are the aggregate neoclassical production and cost functions upon which the theory of TFP growth is based. In other words, he used the identity to derive the expression but interpreted it as if derived from the neoclassical production or cost functions.

Example 3: Wong and Gang (1994) tested the equality of primal and dual with data for Singapore. They estimated the regression, $TFPG_t = c + d\ TFPG_t^D + u_t$, for 27 manufacturing industries and tested whether $d = 1$ (Wong and Gang 1994, Table 5). To calculate the dual $TFPG_t^D$, they estimated the rental price of capital, ρ. They considered four types of capital assets, each with its own rental price. Except in one case, Wong and Gang found that the estimates of d were equal to 1 and quite tightly estimated (with extremely high t-values) and almost perfect matches ($R^2 > 0.99$ in most cases). In light of our discussion, it seems they did not appreciate, a priori, that the two sides of their regressions had to be virtually identical to get these results. Instead, they concluded that their findings suggested that the movements in TFP growth reflect true changes in productivity. Furthermore, they added an additional explanatory variable to the same regression, a measure of industry demand, to test the Keynesian theory that movements in demand drive TFP growth: $TFPG_t = c + d\ TFPG_t^D + \phi X_t + u_t$ (Wong and Gang 1994, Table 6). Given the previous result, it should have been apparent that $d = 1$ and $\phi = 0$ must be the values of the estimates (since X is an "irrelevant" variable in the identity), as proved to be the case. Wong and Gang, however, interpreted the finding $\phi = 0$, as a refutation of the Keynesian theory.

The important question is why, systematically and across most of the 27 industries, the estimated slopes of the regressions of TFP growth primal on TFP growth dual were equal to unity (with, as we have noted, extremely high t-values and an almost perfect fit). The answer, in terms of our arguments, is straightforward: $TFPG_t$ and $TFPG_t^D$ had to be the same. Why was this case? There is only one reason: the rental price of capital that Wong and Gang estimated had to be virtually identical to the profit rate consistent with the accounting identity. Indeed, this was the case if one looks at how they proceeded to calculate the rental price of capital (see the Appendix in their paper, in particular, equation [13]). To calculate the rental price, they used the formula $\rho K \equiv \Pi$, where Π denotes "total payments to capital derived as a residual of output after all other inputs have been paid," that is, all profits in the accounting identity. Hence $\rho \equiv K / \Pi$, which is identical to $r \equiv K / \Pi$.[28]

[28] One final point is that Wong and Gang (1994, Table 3) found higher TFP growth rates than Young (1992, Table VI) for manufacturing. This is interesting because, as we argue in the text, the rental price of capital that they calculated should be the same as the profit rate. The reason for their higher TFP growth rates is that they worked with gross output (i.e., including energy and materials) rather than with value added. This means that their equation for the dual of TFP growth (equation [10] in their paper) contains four terms, the growth rates of the wage and profit rates and also the growth rates of the price of energy and the growth rate of the price of materials. These four terms add up to a higher TFP growth rate than with only the first two terms.

Example 4: Kim and Lau (1994) also participated in the debate on the sources of growth in East Asia. Their main methodological contribution was the estimation of a translog meta-production function where they used panel data for nine economies—the four East Asian NIEs and the G5. The econometric estimation of the supposed production function allowed them to test the key assumptions of growth accounting, namely, linear homogeneity of the production function and perfect competition. These are assumptions that most authors working in the field have not even discussed but rather simply imposed. Kim and Lau's work rejected both assumptions, although this important result seems to have passed unnoticed by the profession. They also concluded that technical progress was capital-augmenting and that exogenous TFP growth, which they interpreted as the rate of technical progress, in Asia's NIEs had been zero.

In light of the accounting identity, however, we can also show that Kim and Lau's (1994) exercise was an approximation of the identity. This example will also allow us to show how the argument equally applies to the case when factor shares are not constant. Kim and Lau hypothesized a production function with inputs expressed in efficiency units:

$$\ln Y_t = \ln A_0 + \alpha \ln A_{Lt} L_t + \beta \ln A_{Kt} K_t + \gamma (\ln A_{Lt} L_t \ln A_{Kt} K_t) + \delta (\ln A_{Lt} L_t)^2 + \phi (\ln A_{Kt} K_t)^2 \qquad (11)$$

where A_{Lt} and A_{Kt} are the levels of factor-augmenting technology (allowed to differ across countries) and λ_L and λ_K are the rates of labor- and capital-augmenting technical change. Substituting $\ln A_{Lt} = \ln A_{L0} + \lambda_L t$ and $\ln A_{Kt} = \ln A_{K0} + \lambda_K t$ (where A_{L0} and A_{K0} are the initial levels) into the production function leads to an expression that can compressed into:

$$\ln Y_t = c + b_1 \ln L_t + b_2 \ln K_t + b_3 (\ln K_t)^2 + b_4 (\ln L_t)^2 + b_5 (\ln L_t \ln K_t) + b_6 (t \ln K_t) + \\ + b_7 (t \ln L_t) + b_8 t + b_9 t^2 \qquad (12)$$

where c and $b_1 ... b_8$ are functions of the coefficients in the production function, equation (11). Equation (12) was estimated by Kim and Lau in first differences together with the corresponding first-order condition for labor, that is, a system of two equations. The first-order condition for labor is obtained by differentiating the production function with respect to labor, that is,

$$\partial \ln Y / \partial \ln L = (\alpha + \gamma \ln A_{K0} + 2\delta \ln A_{L0}) + (2\delta\lambda_L + \gamma\lambda_K)t + 2\delta \ln L_t + \gamma \ln K_t \qquad (13)$$

This follows from the argument that estimation of the production function alone is inappropriate as it treats labor and capital as exogenous variables. Consequently, as A_{L0} and A_{K0} differ across countries, the coefficients c, b_1, b_2, and b_8 are country-specific constants. If profit maximization and perfect competition hold, this will be equal to the share of labor in GDP, that is, $\partial \ln Q / \partial \ln L = s^L$. Therefore, the test of the assumption of a competitive labor market is whether the output elasticities equal the factor shares.

However, in light of our earlier comments, this method is invalidated by the accounting identity. To see this, differentiate equation (12) with respect to time to express it in growth rates. This yields:

$$y_t = \alpha_t^{'}\lambda_L + \beta_t^{'}\lambda_K + \alpha_t^{'}\ell_t + \beta_t^{'}k_t \qquad (14)$$

with

$$\alpha_t^{'} = (\alpha + \gamma \ln A_{K0} + 2\delta \ln A_{L0}) + (2\delta\lambda_L + \gamma\lambda_K)t + 2\delta \ln L_t + \gamma \ln K_t \qquad (15)$$

and

$$\beta_t^{'} = (\beta + \gamma \ln A_{L0} + 2\phi \ln A_{K0}) + (2\phi\lambda_K + \gamma\lambda_L)t + 2\phi \ln K_t + \gamma \ln L_t \qquad (16)$$

where $\alpha_t^{'}$ and $\beta_t^{'}$ are the respective output elasticities. It thus follows from the above (the first-order condition and equations [15] and [16]) that if the labor market is perfectly competitive, the following must be true:

$$y_t = s_t^L\lambda_L + s_t^K\lambda_K + s_t^L\ell_t + s_t^K k_t = \lambda_t + s_t^L\ell_t + s_t^K k_t \qquad (17)$$

Now, compare equation (17) with the identity equations (6) or (7), that is, $y_t \equiv s_t^L \hat{w}_t + s_t^K \hat{r}_t + s_t^L \ell_t + s_t^K k_t \equiv \lambda_t + s_t^L \ell_t + s_t^K k_t$. It should be obvious that equation (17) will always hold (in the sense that it is the correct functional form) by virtue of equation (6). It is, therefore, not possible to test and potentially refute the hypothesis that the elasticity of output with respect to labor equals the share of labor, that is, that the labor market is perfectly competitive. This also shows that the Kim and Lau (1994) procedure must indicate that there are constant returns to scale.

Given the above, how did Kim and Lau (1994) claim to refute the growth, accounting underlying assumptions? Suppose factor shares do not follow the close paths in equations (15) and (16), and recall that Kim and Lau pooled data for nine countries, then it is obvious that their translog-production function will seem to imply that they reject the null hypothesis. However, as we explained earlier, this is simply a matter of finding the correct path. We will always return to the identity.

Example 5: Let's see finally what lies behind Chow's (1993) method of eliminating certain years from his regressions, as discussed above. The problem Chow faced is very simple and can be checked by running the regressions as he provided the data. The regression results, including all periods, give implausible results, for example, a negative coefficient for the stock of capital. The regression for the construction sector, including the complete data set for 1952–85 without eliminating a single year, is $\ln Y = 1.873 + 0.045 * t + 0.489 lnL - 0.010 lnK$ with coefficients statistically significant except that of the capital stock.

To improve the results, Chow estimated the construction regression by eliminating certain years that he considered anomalous, namely 1961, 1962, and 1968, and then estimated it for 1954–80. His result was (Chow 1993, Table XII): $\ln Y = 2.672 - 0.002 * t + 0.362 lnL + 0.545 lnK$ with all coefficients statistically significant except that of the time trend. This procedure yielded the desired results: the estimates of elasticities of labor and capital that could be more or less interpreted as factor shares (adding up to unity) and a statistically insignificant coefficient of the time trend, that is, zero TFP growth. This led him to the desired conclusion that China had not experienced any technical progress during the Great Leap Forward and the

Cultural Revolution years. This might well be true, but as we shall see below, Chow's method is more than questionable.

Our interpretation of Chow's (1993) exercise is as follows. The time trend that Chow added to his regressions to capture technical progress is likely a bad proxy for $\lambda_t = s_t^L \hat{w}_t + s_t^K \hat{r}_t$. Could this be Chow's problem? Felipe and McCombie (2011, Table 1) showed that, indeed, this is the case. Instead of the linear time trend, they added to the Cobb-Douglas regression the function $t^* = \sin(t^2) + \sin(t^3) + \sin(t^4) + \cos(t) - \cos(t^2) - \cos(t^3) + \cos(t^5) + \log(t^2)$. This regression, unlike that of Chow, yielded statistically significant coefficients of the factor elasticities and of t^*. The estimated regression for 1952–85 was: $lnQ = 0.967 + 0.034t^* + 0.412lnL + 0.412lnK$. It should be clear that this result is driven entirely by the accounting identity.

This analysis leads us to question Chow's (1993) overall conclusions about the lack of technical progress in China. Even under the very unlikely assumption that China's aggregate production function exists, we have shown that one does not need to eliminate certain years from the regression to obtain "good" or plausible results, including a statistically significant estimate of the proxy for the rate of technical progress. Secondly, under the premise that the aggregate production function does not exist, Chow's exercise can be viewed as simply one for the search for a good approximation to the income accounting identity. It may well be that technical progress in China between the 1950s and 1980s was zero. Our point is simply that the methodology used by Chow is not suited to answer this question.[29]

What Lies Under the Accounting Identity Critique?

The answer is straightforward: it is the nature of the data used, namely, constant-price value (dollars, euros, pounds, etc.), as opposed to physical quantities. This is because, at any level of aggregation (e.g., sector, national economy), the data has to be aggregated and presented in value terms, that is, there is no aggregate physical quantity for the output of the (aggregate) manufacturing sector (which produces automobiles, plastics, pharmaceuticals, machines,

[29] Certainly, Chow's (1993) work is not the only one on China. We simply chose it as representative of this literature. See also, for example, Wan's (1995) attempt to construct a measure of technical progress that is assumption-free; and Felipe and McCombie's (1999) comment: it is the accounting identity in disguise.

etc.), much less of the overall economy. Note that, theoretically, neoclassical production theory is stated in physical terms, that is, a production function is a technical relationship among physical quantities. The question concerning the nature of the data used poses an insurmountable problem for estimations of production functions and TFP growth calculations. In value terms, the data are linked through the identity, and the latter determines the results. This renders the analysis and results in value terms misleading if one thinks they are supported by the neoclassical theory.[30]

The accounting would not happen if the researcher had true physical data (Q, L, J, Z) because these series are not linked through an accounting identity like the one with value (monetary) data. Q is physical output, as opposed to revenue or value added (monetary terms) and, therefore, the production function has to include the quantities of materials (intermediate inputs), Z. The stock of physical capital (e.g., number of machines) is now J. Indeed, with physical quantities, it would be possible to estimate the production function and obtain the true elasticities, which may differ from the factor shares.

Suppose there exists a production process that converts L (the number of workers), J (number of identical machines), and a single intermediate input, Z (kilowatts of electricity) into Q (widgets). Assume that this production process is given by $Q = AL^{\alpha} J^{\beta} Z^{(1-\alpha-\beta)} e^{\varepsilon}$. This specific form is not essential to the argument. As this is an "engineering" or physical production function; the output must be determined by the correctly measured flow of services from labor and capital and the rate of utilization of materials.

Now, a researcher estimates $\ln Q = c + b_1 \ln L + b_2 \ln J + b_3 \ln Z + \varepsilon$. What would the estimates of b_1, b_2, and b_3 pick up? We argue that they would obtain the true technological relationship, that is, α, β, and ($1-\alpha-\beta$). In this case, the series (Q, L, J, Z) are not definitionally related through actual accounting identities. Notice, though, that one could construct an infinite number of accounting identities with arbitrarily chosen weights (b, c) that would determine

[30] Note that the recent literature distinguishes between "revenue TFP" and "quantity TFP," somewhat acknowledging our arguments, although not entirely so. Our argument is that the only meaningful notion of TFP is if estimated using physical quantities. Besides, we wonder how anybody would calculate "quantity TFP" at any level of aggregation.

the distribution of factor rewards in physical terms, for example, $v = b(Q/L)$, $x = c(Q/J)$, and $p = (1-b-c)(Q/Z)$, with $0 < b < 1$ and $0 < c < 1$, and then construct $Q \equiv vL + xJ + pZ$, that is, the identity in physical terms. As above, this expression could then be transformed into one that resembles the production function. The important point now is that there is no actual identity relating the series (Q, L, J, Z). It is for this reason that the regression will pick up the true elasticities and not the factor shares—an infinite number, depending on the values of (b, c).

However, with value data, the series of revenue (Y), inputs (L, K, Z^*), where Z^* is the monetary value of intermediate inputs, the factor shares $a^* = wL/Y$, $b^* = rK/Y$, and $(1-a^*-b^*) = Z^*/Y$, are related through only one identity. This is the identity that the monetary data regression will undoubtedly pick up.

Finally, it must be noted that with physical quantities, researchers face two problems. First, is that one would need to know which functional form to estimate. The second problem is that, in practice, estimating a production function for manufacturing (or services) with physical quantities is next to impossible. This is due to the data requirements needed (e.g., individual capital stocks for an oil refinery). If these two issues were addressed, then the endogeneity of the regressors would be a correct concern because there is no identity directly linking the series (Q, L, J, Z), and the regression would contain a true econometric error.

4. IF NOT TFP GROWTH VERSUS FACTOR ACCUMULATION, HOW CAN WE EXPLAIN EAST ASIA'S FAST GROWTH?

Given the above discussion, that is, the problems of the neoclassical growth model in explaining satisfactorily (in our view) Asia's growth (and growth in general), the natural question is how can East Asia's growth be understood? The resilience of the neoclassical growth model has been due to the fact that growth accounting exercises appear to be very easy to undertake and the attractiveness of the result, for example, 30 percent of GDP growth is due to the accumulation of labor, 40 percent to the accumulation of capital, and another 30 percent to how efficiently inputs are used, or TFP growth. To some this seems to give quantitative insights into the economic growth process, however questionable. Yet, there usually isn't the slightest attempt at questioning any of the more than dubious assumptions upon which the exercise is based—no mention of aggregation problems or the accounting identity.

Our view is that it is impossible to understand the episode of the phenomenal growth of the East Asian countries between the mid-1960s and the financial crisis of 1997–98 without bringing the massive structural transformation of these economies into the picture, namely the transfer of workers out of agriculture, industrialization (manufacturing growth), and the diversification and upgrading of their export baskets. These were not simply the result of expenditure on R&D, but of behind-the-frontier improvements. For example, Hobday (1995) described in detail how East Asian firms climbed the ladder by slowly learning by doing:

> East Asian latecomers did not leapfrog from one vintage of technology to another. On the contrary, the evidence shows that firms engaged in a painstaking and cumulative process of technological learning: a hard slog rather than a leapfrog. The route to advanced electronics and information technology was through a long difficult learning process, driven by the manufacture of goods for export. (1188)

Kim (1997) described Hyundai's efforts to produce a car after it had purchased the foreign equipment, hired expatriate consultants, and signed licensing agreements with foreign firms as follows:

> Despite the training and consulting services of experts, Hyundai engineers repeated trials and errors for fourteen months before creating the first prototype. But the engine block broke into pieces at its first test. New prototype engines appeared almost every week, only to break in testing. No one on the team could figure out why the prototypes kept breaking down, casting serious doubts even among Hyundai management, on its capability to develop a competitive engine. The team had to scrap eleven more broken

> prototypes before one survived the test. There were 2,888 engine design changes… Ninety-seven test engines were made before Hyundai refined its natural aspiration and turbocharger engines… In addition, more than 200 transmissions and 150 test vehicles were created before Hyundai perfected them in 1992. (129)

What these and other authors (e.g., Lee 2012) are referring to is the capabilities that these countries accumulated via learning. This is the essence of their growth. Empirically, this can be understood through the concept of a balance-of-payments–constrained growth rate introduced by Thirlwall (1979). A second strand of the literature that helps explain East Asia's growth is the work encapsulated in the *product space* idea (Hidalgo et al. 2007) and the concept of *complexity* (Hidalgo and Hausmann 2009). We review both below.

4.1 The Importance of the Income Elasticities: The Balance-of-Payments–Constrained Growth Rate

A second strand of the literature that is extremely useful in understanding East Asia's growth is based on Thirlwall's (1979) notion of the balance-of-payments–constrained (BOPC) growth rate. This is the growth rate consistent with (dynamic) equilibrium in the current account. It is based on the idea that, before achieving its potential growth rate, an economy's actual growth performance can be curtailed by macro constraints. For emerging economies, the external constraint associated with the current account balance is particularly significant, given these countries' dependence on the availability of foreign exchange to finance their imports. Current account deficits can be sustainable and, indeed, necessary in the short run—especially when they allow for faster capital accumulation. But countries cannot finance ever-growing current account deficits in the long run, as there is a limit beyond which the deficit becomes unsustainable (or is perceived as such by financial markets), and a balance-of-payments crisis ensues. Thus, countries that find themselves in balance-of-payments (BOP) problems may be forced to constrain growth while the economy still has the surplus capacity and surplus labor—that is, while the actual growth rate is still below the potential growth rate.

The simplest version of this model is that the BOPC growth (y_B) rate is $y_B = \left(\frac{\varepsilon}{\pi}\right) z$, where ε and π are, respectively, the income elasticities of demand for exports and imports, and z is the growth rate of the country's trading partners. This expression means that, to grow, a developing country has to increase its y_B so as to avoid a BOP (current account) crisis. This rate will increase as a result of, first a higher growth rate by its trading partners, and second—and more important from a policy point of view—a higher $\left(\frac{\varepsilon}{\pi}\right)$. These two elasticities are summaries of the non-price characteristics of exports and imports (quality, variety, reliability, speed of delivery, or distribution network). The model indicates that this is what matters for long-run growth. As a country imports products with a higher income elasticity, it will have to export products with a higher income elasticity. Under this view, the East Asian economies transformed, and this showed up in a higher $\left(\frac{\varepsilon}{\pi}\right)$. This is consistent with the notion of complexity explained above. This allowed these economies to grow faster and, at the same time, avoid balance-of-payments crises. Felipe et al. (2019) used this model to discuss Indonesia's growth, and Felipe and Lanzafame (2020) discussed China's.

4.2 The Product Space and Complexity

Hidalgo and Hausmann and their associates have effectively revived the literature pioneered by Lewis (1955), Rostow (1959), Kuznets (1966), Kaldor (1957), and Chenery and Taylor (1968), among others, during the 1950s and 1960s. These authors viewed development and growth as a process of structural transformation, whereby resources are transferred from activities of lower productivity into activities of higher productivity. As a consequence, this literature also acknowledged that different activities play different roles in the economy because they were subject to different degrees of returns to scale, their outputs had different income elasticities of demand, and their market structures were different. For a long time, however, this body of work was dormant.

The originality of the work by Hausmann and Hidalgo lies, first, in that it explains economic development as a process of learning how to produce (and export) more complex products. Secondly, it provides metrics that summarize differences across countries. Using network theory methods, they have shown that the development path of a country is determined by its capacity to accumulate the capabilities required to produce a more varied and sophisticated basket of goods. Therefore, the overall complexity of a country's productive structure is the key variable in explaining growth and development; countries' different abilities to accumulate capabilities explain differences in their performance. There is now well-established literature that highlights the importance of capabilities in various contexts. For example, Acemoglu and Zillibotti (1999) advanced a theoretical explanation for the wide variation in the stock of knowledge across countries. They argued that societies accumulate knowledge by repeating certain tasks and that scarcity of capital restricts the repetition of various activities. Kremer (1993) referred to the crucial role of capabilities in the context of growth and development. Lall (1992) and Bell and Pavitt (1995) referred to the importance of capabilities from an innovation and development point of view,[31] and Sutton (2001, 2005) from a firm-level perspective.

In Hidalgo and Hausmann's (2009) theory of capabilities, economic development is not only a process of continuously improving upon the production of the same set of goods but, more importantly, a process that requires acquiring more complex sets of capabilities to move toward new activities associated with higher levels of productivity. Specifically, capabilities refer to (a) the set of human and physical capital, the legal system, and institutions, among others, that are needed to produce a product (hence, they are product-specific, not just a set of amorphous factor inputs); (b) at the firm level, the "know-how" or working practices held collectively by the group of individuals comprising the firm; and (c) the organizational abilities that provide the capacity to form, manage, and operate activities that involve large numbers of people. According to Sutton (2001, 2005), capabilities manifest themselves in quality-productivity combinations. A given capability is embodied in the tacit knowledge of the individuals who comprise the firm's workforce. The quality-productivity combinations are not a continuum from zero; rather, there is a window with a "minimum threshold" below

[31] Lall (1992) and Bell and Pavit (1995) also provide a framework to analyze the industrial "technological capabilities" required for innovation. Among the capabilities at the advanced level are those necessary to: (a) develop new production systems and components; (b) process basic design and related R&D; (c) process innovation and related R&D; (d) do radical innovation in organization; (e) do product innovation and related R&D; (f) do collaboration in technology development; and (g) do R&D for specifications and designs of new plant and machinery. These capabilities are distributed across different functions: (a) and (b) are related to investment activities; (c) to (e) are related to production activities; and (f) and (g) are related to the development of linkages to the economy and capital goods supply.

which the firm would be excluded from the market. Therefore, capabilities are largely non-tradable inputs.

The complexity of a product is a function of the capabilities it requires, whereas the complexity of a country is given by the number of locally available capabilities. These capabilities are not defined a priori. However, what one can say is that countries that have revealed comparative advantage in the same products share those same capabilities. The "method of reflections" explained below uses an iterative procedure to tease out which products require a greater variety and more complex capabilities, as well as which countries have a greater array of more complex capabilities. As discussed above, these capabilities can range from organizational abilities to legal systems. Hausmann and Hidalgo (2010) noted that, depending on the disaggregation level of the data used, the total number of capabilities worldwide varies from 23 to 80. For a product to be exported with comparative advantage, more than one of those capabilities has to be present. Akin to the O-ring theory of development (Kremer 1993), the lack of one capability may result in the product not being exported with a comparative advantage.

This literature, in effect, implies that development is slow for countries with productive structures geared toward low-productivity and low-wage activities, producing mostly low-valued commodities or agricultural products. Development is fast, on the other hand, for countries with productive structures geared toward high-productivity and high-wage activities.

The newly developed product space of Hidalgo et al. (2007) encapsulates these ideas. The product space is a representation of all products exported in the world, where products are linked based on the similarity of their required capabilities—for example, the link between shirts and pants is stronger than that between shirts and iPods. One implication of the product space is that the lack of connectedness between the products in the periphery (low-productivity products) and in the core (high-productivity products) explains the difficulties poor countries face converging to the income level of the rich countries.

Hausmann et al. (2007) suggested two simple empirical measures of product and economic complexity (or sophistication). The complexity of a product, PRODY, is represented by the income level associated with that product, and it is calculated as a weighted average of the income per capita of the countries that export said product. The weight is the index of revealed comparative advantage.[32] Economic (or country) complexity (EXPY) represents the productivity level associated with a country's export basket, and is calculated as a weighted average (where the weight is the share of the product in the country's export basket) of the complexity of the products exported by the country.[33] Hausmann, Hwang, and Rodrik (2007) showed that not all products have the same consequences for economic development. There are products whose capabilities can be easily redeployed into the production and export of other products (which facilitates development), but there are other products that embody capabilities that can hardly be used for the production of other goods. They also showed that rich countries export rich-country products and that the measure of EXPY is a good predictor of future growth. PRODY and EXPY include information on income (income per capita of the countries that export the product), as well as information about the network structure of countries and the products they export (the weights). Felipe et al. (2012a) provide an analysis of China's progress using these metrics.

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[32] The weight is the ratio of the share of the product in a country's export basket to the sum of all shares across all countries exporting that product. Algebraically:

$$PRODY_i = \sum_c \left[\frac{xval_{ci} / \sum_i xval_{ci}}{\sum_c \left(xval_{ci} / \sum_i xval_{ci} \right)} \right] \times GDPpc_c$$

where $xval_{ci}$ is the value of country *c*'s export of commodity *i* and $GDPpc_c$ is country *c*'s per capita GDP. PRODY is measured in 2005 PPP$. PRODY provides a measure of the income content of a product and is not therefore an engineering notion.

[33] Algebraically:

$$EXPY_c = \sum_i \left(\frac{xval_{ci}}{\sum_i xval_{ci}} \times PRODY_i \right)$$

EXPY is measured in 2005 PPP$.

Hidalgo and Hausmann (2009) improved upon these two measures by separating the information on income from the information on the network structures of countries and the products they export. In doing so, they addressed the criticism that using income information in the computation of the measures makes the conclusion "rich countries export rich-country products" circular (Hidalgo 2009). To provide an intuition of how complexity is measured in the new method, Hidalgo and Hausmann (2009) used the Lego models as an analogy. Suppose we have a Lego bucket (representing a country) with various kinds of Lego pieces (representing the capabilities available in the country). The different Lego models we can build (i.e., different products) depend on the kind, diversity, and exclusiveness of the Lego pieces that we have in a bucket. We can build more complex Lego models if we have the necessary Lego pieces, that is, the Lego model we can build is limited by the Lego pieces we have. A Lego bucket that contains pieces that can only build a bicycle, most likely does not contain the pieces to create an airplane model. However, a Lego bucket that contains pieces that can build an airplane model may also have the necessary pieces needed to build a bicycle model. Moreover, two Lego buckets may be capable of building the same number of models, but the models that the first bucket can build may be entirely different from those that the second bucket can build. Hence, determining the complexity of an economy by looking at the products it produces amounts to determining the "diversity and exclusivity" of the pieces in a Lego bucket by simply looking at the Lego models it can build.

To calculate measures of product and country complexity, Hidalgo and Hausmann (2009) devised the *method of reflections*. This method looks at trade data as a network connecting two mutually exclusive sets—the set of countries and the set of products that they export with revealed comparative advantage (RCA). To make their method operational, Hidalgo and Hausmann (2009) defined diversification as the number of products a country exports with RCA (in the Lego analogy, this is represented by the number of models a Lego bucket can create) and ubiquity as the number of countries that export the product with RCA (and this is represented by the exclusivity of the Lego pieces in the bucket). Diversification and ubiquity are the simplest measures of the complexity of a country and a product, respectively. A country that exports more goods with RCA (i.e., is more diversified) is more complex than a country that exports fewer goods with RCA (i.e., is less diversified); a product that is exported by fewer countries with RCA (i.e., is less ubiquitous) is more complex than a product that is exported with RCA by more countries (i.e., is more ubiquitous). The intuition behind this is that a country can export a particular product with RCA if it possesses the necessary and specific capabilities (labor skills, institutions, machinery, public inputs, tradable inputs, etc.). Thus, a more diversified country has more capabilities. Similarly, a product that is less ubiquitous requires more exclusive capabilities. Complexity, therefore, is associated with the set of capabilities required by a product (product complexity) or with the set of capabilities that are available to an economy (economic complexity).[34]

The progress in economic complexity of the East Asian countries is well documented in, for example, the Harvard Atlas of Economic Complexity.[35] This metric, as well as other quantitative information provided, shows the progress of many East Asian economies.

Using also the method of reflections and data for over 120 countries but for over 5,000 products and averaging data for 2001–07, Felipe et al. (2012b) showed the distribution of the product of complexity across different product categories. Figure 2 shows that the most complex products are chemicals and machinery, where the least complex are textiles and footwear. The analysis by Felipe et al. (2012b) corroborates that some Asian countries (but not all) have made significant inroads into complex products.

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[34] Diversification and ubiquity are computed as follows:

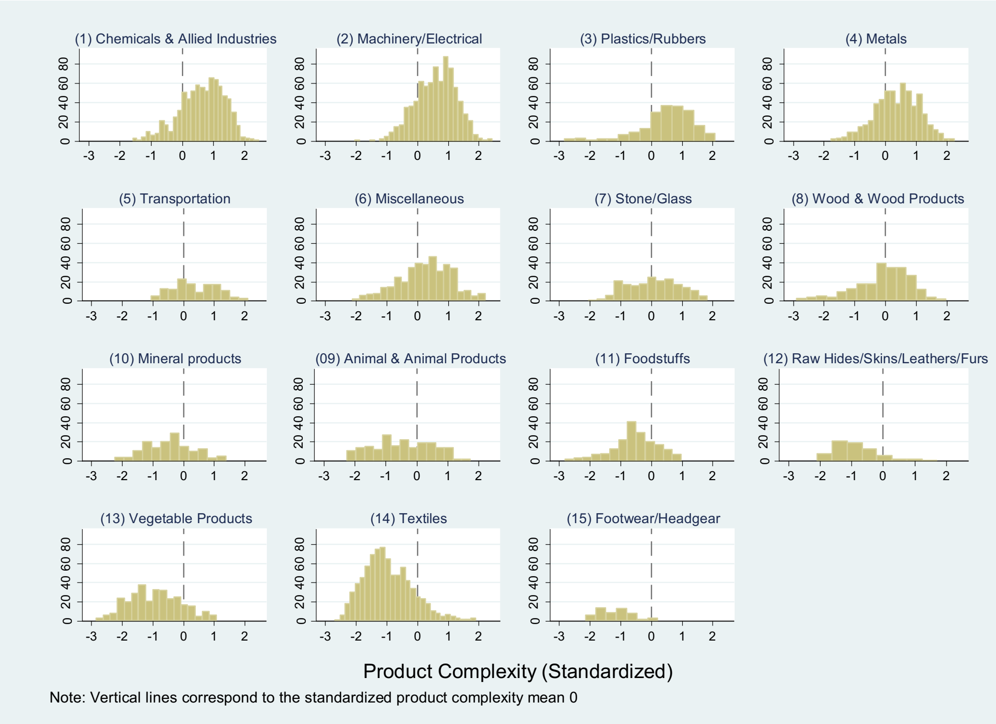
$$k_{c,0} = \sum_{p=1}^{N_p} M_{cp} \quad \text{(Diversification)} \qquad \text{(a)}$$

$$k_{p,0} = \sum_{c=1}^{N_c} M_{cp} \quad \text{(Ubiquity)} \qquad \text{(b)}$$

where c denotes the country, p the product, and M_{cp}=1 if country c exports product p with revealed comparative advantage and M_{cp}=0, otherwise. As can be seen, these measures only include information about the network structure of countries and products. The method of reflections consists in calculating jointly and iteratively the average value of the measure computed in the preceding iteration, starting with a measure of a country's *diversification* (equation [a]) and a product's *ubiquity* (equation [b]). The succeeding iterations of the method of reflections refine the measures of complexity by taking into account the information from the previous iterations.

[35] The Atlas of Economic Complexity (harvard.edu)

Figure 2: Distribution of Product Complexity by Groups



Source: Felipe et al. (2012b, Figure 1)
Note: The figure shows the normalized (i.e., mean 0 and standard deviation 1) distribution of product complexity (overall 5,107 products).

5. CONCLUSIONS: WHAT DID WE LEARN FROM (AND WHAT IS LEFT OF) THE DEBATES ABOUT THE SOURCES OF GROWTH IN EAST ASIA?

This paper has surveyed the literature that originated in the early 1990s on the sources of growth in East Asia and China, based on estimating the contributions of factor accumulation and total factor productivity growth, or “perspiration” versus “inspiration,” as Krugman (1994) put it. Some conclusions that emerge from the analysis in the paper are as follows:

First, no matter how common it is in the literature, it is difficult to conceptually understand what growth accounting exercises try to do, namely dividing the contributions of factor inputs and of so-called technical progress in total output growth. Capital accumulation and technical progress are the two sides of a coin. Moreover, the mathematical derivation of this decomposition requires assumptions such as perfectly competitive factor markets, which are implausible. It is hardly ever tested.

Second, the basic tool from which growth accounting exercises are derived—the aggregate production function—was also shown long ago to have very weak theoretical foundations. Aggregate production functions cannot be derived from micro-production functions except under extremely stringent conditions that are not found in the real world. The "grandfather" of this literature, Fisher (2007), put it vividly in the title of a recent paper, "Is growth theory a real subject?", referring to the neoclassical model. The reader should not have problems guessing what the answer is.

Third, technical progress occurs at the individual production process level. It is very difficult to understand how changes at this level can give rise to the type of technical change discussed and often assumed (Hicks-neutral) at the aggregate level. Moreover, the concept of technical progress implicit in most calculations of total factor productivity, Hicks-neutral, was shown long ago to be theoretically impossible. If anything, technical progress is probably biased, which has implications for how TFP growth should be calculated (assuming one decides to proceed with the decomposition of growth and also disregard the aggregation problems).[36] This means that even in case the aggregate production function existed and growth accounting was a meaningful exercise, the way TFP growth is calculated is most likely wrong because it assumes a type of technical progress that is difficult to justify.

Fourth, aggregate growth accounting exercises are problematic because, by default, they have to use value data as opposed to physical quantities, that is, a production function is a technological relationship among physical quantities. The problem is that an underlying accounting identity that relates definitionally to the same variables that appear in the production function (in constant-price value terms) makes the theoretical interpretation of growth accounting exercises (i.e., as derived from neoclassical production theory) very problematic.[37] Returning to the World Bank's (1993) exercise, the problem is that the

[36] Using the real wage–profit frontier and with aggregate data, Marquetti (2003) concluded that technical progress across the world is, in general, a combination of labor saving (i.e., increase in labor productivity) and capital using (i.e., decline in capital productivity).

[37] Given this, we consider that working with the identity (mentioned earlier) that decomposes overall labor productivity growth into the sum of intra-sectoral labor productivity growth rates and the sum of inter-sectoral transfers of labor, would be much more enlightening.

measure of productivity used was TFP growth, thus incurred all the problems discussed above. Given this, our view is that actual results are irrelevant. The conclusions reached by the report (summarized above) rely entirely upon TFP growth estimates and the particular way these were computed. We have no doubt that, using a different methodology or variant of growth accounting, results would change. These would be subject to the same concerns we have expressed.

Finally, as a consequence of the above, Krugman's (1994) discussion of the East Asian Miracle was far from compelling. These somewhat nihilistic conclusions do not mean that nothing was learned about growth in East Asia during the last 30 years, even from the literature that we have criticized. The papers we surveyed (and many others) contained very interesting case-study accounts of the analyzed countries. Asia's growth caught the full attention of economists, although it is more difficult to know if this literature ultimately had a lasting impact on growth theory. What we question is the relevance of the growth accounting exercises per se and the discussion of these countries' growth performance in terms of factor accumulation versus TFP growth. As a result of the focus on the latter, it was more a transitory shock than a permanent effect.[38]Moreover, although policymakers across Asia were very much concerned with these results in the 1990s, today, they are seen as no more than an academic footnote with little relevance. This was partly the result of the fact that policymakers in East Asia did not see much value in the policy recommendations of this research program ("increase TFP"); and partly the result of the shift in emphasis away from the NIEs when growth rates declined significantly after the Asian Financial Crisis of 1997–98. The latter severely affected Indonesia, Korea, Malaysia, and Thailand. Korea was already a high-income economy and recovered quickly, but the other three economies have since experienced much lower growth rates. The growth accounting focus then shifted to China (and to a lesser extent India), now in the context of being the largest driver of world growth during the last 15 years (e.g., Bosworth and Collins 2007; Rodrik and Subramanian 2004; Perkins 2015; Lin and Zhang 2015).[39] Methodologically, these papers did not do anything

[38] It is true though that these results made it to development and growth textbooks. See Felipe (1999).

[39] There is also the new literature on misallocation that has focused on China and India. Examples are Hsieh and Klenow (2009) and Bollard et al. (2013). The first one contains a derivation of a measure of misallocation from

new, however. China's growth rate also started declining after 2008–09, partly as a result of the Great Financial Crisis and partly as a result of its own internal dynamics (Asian Development Bank 2016). This has led Pritchett and Summers (2013) to speak of an *Asiaphoria*, predicting that the region's growth rates would have to decline because the evidence suggests that growth rates show little statistical persistence; that is, there is regression to the mean, and Asia's growth rates have, for a long time, been more than two standard deviations of the historical growth mean. This cannot last.[40]

Consequently, we have argued that the growth literature has to move beyond the framework of the neoclassical model and the TFP research program, and that there are signs this is underway, for example, in the work discussed earlier on complexity by Rodrik et al. (2017) using productivity decompositions. Some may find it difficult to understand that we question one of the jewels of modern economics—the neoclassical research program on growth and its empirical counterparts, growth accounting, and the estimation of TFP. Our view on this is clear: trying to explain growth with this model is akin to, and reminds us of, the long process it took mankind to understand the motions of the planets through the perpetuation of the geocentric model of planetary movement. As Felipe and McCombie (2013) showed, the hypotheses that this model generates are "not even wrong" because they cannot be tested. East Asia grew (and continues growing) as a result of the accumulation of capabilities. This was a slow and painstaking process that happened in the context of the export-led growth model and the industrialization drive of the region from the 1960s through the 1990s, which underpinned its fast structural change. Finally, we have argued that the newly developed product space and the concept of complexity, as well as the older literature on the balance-of-payments–constrained growth rate, are much more useful tools for understanding the region's progress.

a Cobb-Douglas production function, where the notion of TFP is central. The second one uses directly the accounting identity.

[40] Note that Pritchett and Summers's (2013) arguments are very different from those of Krugman (1994).

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