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RESEARCH

Is anything left of the debate about the sources of growth in East Asia 30 years later? A critical survey

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Abstract
We assess the debate about the sources of growth of Hong Kong, Korea, Singapore, and Taiwan that took place during the 1990s and early 2000s. The debate focused on the significance of total factor productivity growth relative to factor accumulation in explaining these economies' high growth rates between the mid-1960s and the early 1990s. The initial growth accounting exercises found that the contribution of productivity growth was nil, a result that was questioned but that became accepted wisdom. This survey reviews three criticisms that questioned that result: (i) that technical progress was probably biased and not Hicks-neutral; (ii) that the dual of total factor productivity growth provided a better estimate than the primal; and (iii) that the estimates of total factor productivity growth captured a distributional accounting identity, rather than anything about productivity. Thirty years later, we conclude that the analysis of growth within the framework of the neoclassical model contributed much less to our understanding of East Asia's growth than was initially thought. Instead, we argue that the literature on structural transformation, evolutionary theory of firm upgrading, and industrial policy, together with the balance-of-payments–constrained growth rate model, provide a much richer understanding of East Asia's high growth rates.

Keywords Accounting identity · Biased technological progress · East Asia · Growth accounting · Total factor productivity

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1 Introduction

The 1990s and early 2000s witnessed one of the most interesting debates in economics in decades. This was the debate about the sources of (high) growth in East Asia between the mid-1960s and the early 1990s. It focused on the four Asian Tigers: Hong Kong, Korea, Singapore, and Taiwan. The debate was mostly empirical and involved some of the most respected economists at the time, and the questions debated were very important.

During significant parts of this 30-year period, these economies registered growth rates of 7–10% per annum. Understanding how these economies achieved these growth rates became a subject of intense debate in the 1990s. Did the profession have models that could explain such unique experiences? Could other countries follow in their footsteps? These questions stimulated one of the most important debates in the profession in decades.

This paper argues that to make sense of this debate, one must first understand properly the type of analysis that it involved. Following the neoclassical model, authors decomposed output growth into the contributions of factor accumulation and technical progress, the latter measured by Solow's residual, or total factor productivity (*TFP*) growth. The first paper to do so was Alwyn Young's (1992) *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 1965–1990, the results of which seemed, at the time, to have very important implications for our understanding of East Asia's development. He found that although *TFP* growth had been marginally positive in Hong Kong during the period in question, it had been zero in Singapore; that is, all growth was due to factor accumulation, especially capital accumulation. Young (1995) extended his original work to include Korea and Taiwan. The qualitative conclusion remained intact: most growth came from capital accumulation.

The World Bank's (1993) well-known study, *The East Asian Miracle*, also provided modest estimates of *TFP* growth. Both the methodology used to calculate *TFP* growth and the estimates obtained also came to be a source of debate, e.g., see Kwon (1994).

Kim and Lau (1994) also apportioned output growth between factor accumulation and *TFP* growth, and also concluded that the Solow residual or *TFP* growth was very small.

Krugman (1994) popularized the low *TFP* growth result in his much-discussed article, *The Myth of Asia's Miracle*, where he argued that East Asia's spectacular growth between 1965 and 1990 was similar to that of the Soviet Union during the 1950s and 1960s, an episode of capital accumulation without technological progress. It would therefore meet the same fate, namely stagnation.

This view of East Asia's growth led to an intense debate in academic and policy circles. The results, very low, even zero *TFP* growth, defied logic and reality. In the early 1960s, the export baskets of the Asian Tigers were very unsophisticated. Hong

Kong exported mostly textiles, garments, and simple manufactures. Korea exported food products and raw materials. Singapore exported natural rubber and oil. Taiwan exported food products and a variety of simple manufactures. By 1990, their export structures had changed dramatically: with differences, they had become exporters of relatively complex manufactures, especially in the electronics cluster. Korea had already entered the automobile and shipping clusters.[1]

The phenomenal transformation of these economies during this period clashed with the thesis that it did not involve some combination of technical progress, productivity growth, and significant accumulation of technical and organizational capabilities. If the transformation in the product mix had occurred without technical progress, how would it have happened? Also, what did technical progress in the *TFP* sense capture? A myriad of other estimates therefore followed the original ones attempting to show that *TFP* growth had been higher (Felipe 1999).

All this work appeared just as the new growth theory (endogenous growth models) became popular, and new, larger databases began to allow the testing of key hypotheses (e.g., convergence, increasing returns to scale, and imperfect markets). It seemed obvious at the time that East Asia's phenomenal growth rates were forcing economists to rethink growth theory: "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." (Fogel 2009, pp. 31–32).

This paper surveys the literature on the debate about sources of growth in East Asia. Our analysis focuses exclusively on Hong Kong, Korea, Singapore, and Taiwan, during the period of high growth, from the mid-1960s to the early 1990s.[2] It addresses the following questions: (a) was consensus reached about East Asia's sources of growth?; (b) did this literature ultimately have an impact on the development literature?; and (c) is the decomposition of growth into the contributions of factor accumulation and *TFP* growth useful?

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 the four economies that were at the center of the discussion, namely Hong Kong, Singapore, Korea, and Taiwan.

Section 3 discusses three important methodological issues raised during the 1990s and early 2000s on the estimation of *TFP* growth rates, and which questioned

[1] Source: Hong Kong, Singapore and Korea: The Observatory of Economic Complexity: https://www.media.mit.edu/projects/oec-new/overview/. Taiwan: The Atlas of Economic Complexity: https://atlas.cid.harvard.edu/. Both accessed March 20, 2024.

[2] Although Japan was part of the Asian miracle, it was not considered in this debate, which focused on the four Asian Tigers. China was not part of the Asian Miracle as discussed in the early 1990s. Hence, we do not discuss these two cases. Felipe and McCombie (2011) analyze China based on arguments similar to those in Sect. 3.3 below. See also Felipe et al. (2012).

the low-rates thesis: (i) the type of technical progress assumed affected significantly the estimates of total factor productivity growth; (ii) the use of the dual of total factor productivity growth instead of the primal led to higher growth rates; and (iii) the fact that the data used to estimate *TFP* (value data and not physical quantities) resulted in estimates of a distributional accounting identity rather than of productivity. The last discussion is complemented with additional material in the Appendix on "The Accounting Identity in Practice." In this sense, the paper is both a methodological critique and a retrospective on the debate about the sources of growth of East Asia that took place three decades ago. We think the former is necessary to understand and properly assess the latter.

Section 4 discusses other work that we believe more meaningfully explains East Asia's growth, but had less impact on the profession at the time. This includes work on structural transformation, and in this context, we discuss firms' upgrading and improvements in capabilities, and the role of industrial policy. We also discuss the significance of the balance-of-payments–constrained growth rate model. The latter provides a macroeconomic perspective on how these economies grew without encountering balance of payments problems.

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. Growth-accounting exercises and estimation of production functions, and thus the discussion of growth performance in terms of factor accumulation versus *TFP* growth, did much less to advance our understanding of East Asia's growth than the alternative literature discussed in Sect. 4.

2 The debates about total factor productivity growth in East Asia: A review of the literature

The success of the East Asian economies was an open secret by the early 1990s. It became a question of paramount importance to understand how these economies had achieved such phenomenal growth rates since the mid-1960s. The empirical debate over the sources of East Asian growth had important policy implications and was followed by both policymakers and academics. In what follows, we focus on what we believe are the best-known and most representative papers on the debate.

The debate started with a paper by Alwyn Young (1992) on Hong Kong and Singapore. Young compared the performance of these two economies using a detailed growth accounting exercise covering the period 1965–90, when GDP growth was very high in both. The growth accounting methodology based on Solow (1956, 1957) is so well known that we skip the details. It assumes the existence of an aggregate production function $Y_t = A_t F(L_t, K_t)$, where Y is the volume of physical output, K is the stock of physical capital, L is employment, and A is the level of technology (or total factor productivity, also denoted *TFP*), assumed to be Hicks-neutral (i.e., technical progress that leaves the ratio of the marginal products unchanged) and exogenous (i.e., that occurs outside the economic system). We discuss these two assumptions below.

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, and assuming that production is subject to constant returns to scale, that the objective function of the firms in the economy is to maximize profits, and that labor and capital markets are perfectly competitive (under these circumstances, the factor elasticities equal the shares of labor and capital in total output. We discuss this point in Sect. 3.3), the growth rate of output ($\widehat{y}$) is:

$$\widehat{y}_t = \widehat{TFP}_t + s_t^L \widehat{\ell}_t + s_t^K \widehat{k}_t \tag{1}$$

where $\widehat{\ell}$ is the growth rate of employment, $\widehat{k}$ is the growth rate of capital, s_t^L and s_t^K denote the shares of labor and capital in total output (wage bill over GDP and total surplus over GDP), respectively, and $\widehat{TFP}$ is the growth rate of *TFP*. Then:

$$\widehat{TFP}_t = \widehat{y}_t - s_t^L \widehat{\ell}_t - s_t^K \widehat{k}_t \tag{2}$$

The residually measured *TFP* growth ($\widehat{TFP}$) in Eq. (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.[3]

Note that Eqs. (1–2) are truisms, in the sense that they define how something called $\widehat{TFP}$ is to be residually calculated. Hence, it is definitionally true. However, its standard interpretation as an estimate of (aggregate) productivity growth requires the existence of an aggregate production function (discussed below) and the assumption that the output elasticities are equal to the factor shares. Yet, there is nothing in neoclassical production function theory that says that the elasticities must equal the factor shares; that is, one could potentially test it empirically and refute it (as Kim and Lau 1994, discussed in the Appendix, claimed to do). The importance of this assumption, which allows researchers to substitute the shares of labor and capital in output for the elasticities of labor and capital, respectively, should not be underestimated.

Using this methodology (with some adjustments), Young (1992) obtained the surprising result that, while Hong Kong's $\widehat{TFP}_t$ represented around a third of output growth between the mid-1960s and mid-1980s, it was zero for Singapore (Young 1992, Tables 5, 6 and 7).[4] How did Young justify his findings? He argued that market freedom 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. Again, $\widehat{TFP}$ for Singapore was zero. For Hong Kong, Korea, and Taiwan, it was

[3] We do acknowledge the Easterly and Levine (2001) survey on growth. While it contains very useful material, their focus is on *TFP* growth and on the need to expand research to understand this residual.

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

Table 1 Growth accounting for the East Asian NIEs

	Output growth (%)	Capital growth (%)	Labor growth (%)	*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

Young (1995, Tables V, VII, VII and VIII)

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

positive, but not spectacular when put in an international context. Factor accumulation, both capital and labor (the latter especially important in Korea and Taiwan) was the essence of their growth strategy. Table 1 summarizes Young's results.

Less cited is the work of Kim and Lau (1994), who estimated $\widehat{TFP}$ econometrically by pooling data for Hong Kong, Korea, Singapore, Taiwan, and the G-5 countries (France, Germany, Japan, UK, and USA). Kim and Lau estimated a translog production function with inputs expressed in efficiency units, together with the first-order condition for labor.

They selected this less restrictive methodology to test the hypotheses of constant returns to scale and Hicks-neutral technical progress. They rejected both. Kim and Lau's results were even more provocative than those of Young (1992, 1995) because they yielded productivity growth estimates of zero not only for Singapore but also for Hong Kong, Korea, and Taiwan. Moreover, they estimated that the level of technology of these four economies in 1990 was still only about a quarter of that of the United States. We discuss their methodology in detail in the Appendix.

These papers became widely known in academic circles. The debate became a popular controversy when Krugman (1994) explained the discussion in layman's terms. As the region's initial rapid growth was predominantly due to capital accumulation, he argued, 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. 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).[5],

[5] 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.

[6] Krugman's paper set off a "cyclone of protest" in academic journals. Singapore's government even set the goal of achieving a 2% annual increase in *TFP* growth.

These papers triggered a lively debate regarding the accuracy of the estimates and the validity of the inferences and policy implications. These issues were summarized and discussed by Felipe (1999), who offered an extensive review and discussion of many of the estimates of *TFP* growth for the East Asian economies since 1992. The 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.[7]

It is worth emphasizing that in the neoclassical framework 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, p.221). The reality is that capital accumulation responds to technological change. In other words: the cause of growth is technological change, to which capital accumulation responds (as technology improves, the rate of return on capital increases, which leads to capital accumulation). This is an important point that had been questioned earlier (e.g., Kaldor 1957; Pasinetti 1959; Nelson 1981; Scott 1989) and by Klenow and Rodriguez-Clare (1997), but neglected.

The low *TFP* growth ($\widehat{TFP}$) estimates did not square well with the 'conventional wisdom' about these economies' high growth period, which attributed their success to technological catch-up and productivity gains. What was the role, otherwise, of all the foreign direct investment they had received? How was it that the accompanying foreign technology had not translated into productivity gains? Moreover, if productivity growth was not there, what was there to be learned from the successes of these economies? (Rashid 2000, p.152).

The often-implicit assumptions of these papers that technical progress was Hicks-neutral, and exogenous to the economic system, were also criticized for unrealistic. On the first point, Steedman (1985) had proved that Hicks-neutrality is an impossibility, an internally inconsistent concept at the economy level, in the presence of produced inputs. 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

[6] It is worth noting that Krugman (1992), in discussing Young (1992), questioned the latter's results on the basis of measurement issues: "Singapore in particular has an import share well over 100%, 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, p.55).

[7] 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.

technical progress and input growth – are obliged to show explicitly that that assumption is compatible with their other assumptions" (Steedman 1985, 758).

The assumption of exogenous technical progress is clearly unrealistic. Neoclassical authors know this but use it as a simplification. The neoclassical endogenous-growth literature addressed this point.[8] Moreover, Kim and Lau (1994), for example, found that technical progress was capital augmenting. Based on this, they claimed that, until the early 1990s, the East Asian Tigers had not invested in research and development and that most technical progress was embodied in capital goods. This meant that exogenous technical progress had to be negligible, as they found. They also conjectured that the "software" component of investments (managerial methods, institutional environment, as well as supporting infrastructure) lags behind the "hardware" component.

In trying to prove Young and Kim and Lau wrong, journals and books were flooded with alternative estimates of $\widehat{TFP}$ using different data series and slightly different periods, to the extreme 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 contrary. Governments intervened in, for example, wage setting, as in Singapore. Indeed, Stiglitz (2001, p.512) was very critical of Young's (1992) work.[9]

3 What should we make of East Asia's growth accounting exercises and aggregate production function estimations?

As noted earlier, the zero *TFP* growth thesis seemed extremely counter-intuitive to many people. There are three options to evaluate the main results and conclusions of the empirical literature on the sources of growth. The first is to accept the results and the argument that there was nothing miraculous in the way East Asia had attained its very high growth rates. The second is, as documented by Felipe (1999), to come up with a different set of estimates using the same methodology, to justify the opposite view. This was done on many occasions. The truth, however, is that any discussion about growth in the region still today starts from the old Young (1992, 1995) and Kim and Lau (1994) results, and Krugman's (1994) assessment. Finally, a third option is to question not the numbers per se but the methodology used. The

8 These models are very different from the Schumpeterian heterodox models discussed in Sect. 4.

9 Stiglitz (2001, p.512) 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."

remainder of this paper pursues this third option. We discuss here what we consider the most interesting work to address the question of the low *TFP* growth rates. First, we discuss what happens if technical progress is not neutral but biased. Second, we discuss whether undertaking growth accounting from the dual, as opposed to the primal, yields different results. These first two options are still within the realm of the neoclassical model and hence accept all its key assumptions (in particular the existence of an aggregate production function. See below), though Nelson and Pack' arguments contain elements of the evolutionary and Schumpeterian theories. Third, we question the meaning of growth accounting exercises (and econometric estimations of aggregate production functions) on the grounds that the series used in these exercises are related through an accounting identity in value terms. This is a completely different type of criticism that distances ourselves from the neoclassical model.

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 (1995a, b), emphasizing the role of entrepreneurship, innovation, and learning, which were encouraged by East Asian governments. They suggested that investment in human and physical capital was necessary but was only part of the assimilation process that had propelled their 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 $\widehat{TFP}$ paradox? The conventional growth accounting approach uses the Divisia index, where weights are continuously rebased, hence (from Eq. [2]) $\widehat{TFP}_t = \hat{y}_t - \hat{\ell}_t - s_t^K(\hat{k}_t - \hat{\ell}_t)$. In practice and with discrete data, researchers (e.g., Young 1992) use $\widehat{TFP}_t = \hat{y}_t - \hat{\ell}_t - \bar{s}^K(\hat{k}_t - \hat{\ell}_t)$, 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. Nelson and Pack (1999) noted that the observed factor shares in these economies' National Income and Product Accounts (NIPA), had remained approximately constant during the miracle period, despite a substantial increase in the capital–labor ratio.

How could this be explained? In the neoclassical model, this can happen in two cases (Ferguson 1968): (a) if the aggregate technology is Cobb Douglas (so that the elasticity of substitution is one) and 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.

The purpose of growth accounting is to separate the contribution of technological progress from that of factor accumulation (Nelson 1973). This means that the factor shares in Eq. (2), 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 this progress 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 $\widehat{TFP}$. Hence, the puzzle is solved.

The above implies that 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 standard methods would have seriously underestimated $\widehat{TFP}$. Nelson and Pack authors argued that it was difficult to assume that technical progress in East Asia had been Hicks-neutral (see the previous section on this). Rather, they argued, technical progress had been biased and likely labor-saving. Under these circumstances, 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 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):

$$\hat{s}_t^K = [(1 - \bar{s}^K)(1 - \sigma)/\sigma)][(\hat{\lambda}_L + \hat{\ell}) - (\hat{\lambda}_K + \hat{k})] \tag{3}$$

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

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 Eq. (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 $\hat{\lambda}_L - \hat{\lambda}_K = \hat{k} - \hat{\ell}$. 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.

Summing up, 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 Eq. (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. When this was done, results showed that, as time passes (1, 10, 20, 30 years) and the elasticity of substitution increases (until 1), the capital share declines (increases for values above when the elasticity is greater than 1) (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 (Felipe and McCombie 2001, Table 2). However, this did not entirely solve East Asia's low $\widehat{TFP}$ rates. Indeed, when Felipe and McCombie (2001) applied the procedure to a group of advanced countries, $\widehat{TFP}$ also increased for this group, thus leaving things, in relative terms, unchanged.

Two final important implications of this work are as follows. First, if the share of capital was about constant, then the growth rate of capital augmentation has to be $\hat{\lambda}_K = \hat{r} = \hat{y} - \hat{k}$. However, the data used (from Young (1995)) implies that $\hat{\lambda}_K < 0$. 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 through learning-by-doing. With little managerial and organizational capabilities, maybe capital productivity growth was negative. If these economies "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. The second point is that the constant-technology rate of *TFP* growth will tend to the growth of labor productivity as the period under consideration increases (as the share of capital goes to zero).

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 higher $\widehat{TFP}$ (Eq. [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.

To solve this problem, Hsieh (1999, 2002) proposed to calculate the dual measure of *TFP* growth, which we denote $\widehat{TFP}^D$. Theoretically, this is derived from the cost function, that is, the relationship between total cost (C), output (Y), and factor prices (wage rate w; rental price of capital ρ), $C = f(Y, w, \rho, t)$. 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:

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

where s_c^L and s_c^K are the labor and capital shares in total cost, not in revenue as in the primal. 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 $\dot{P}_K$ denotes 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, $\widehat{y}_t = s_t^L \widehat{w}_t + s_t^K \widehat{\rho}_t + s_t^L \widehat{\ell}_t + s_t^K \widehat{k}_t$, or $\widehat{TFP}_t = \widehat{y}_t - s_t^L \widehat{\ell}_t - s_t^K \widehat{k}_t = s_t^L \widehat{w}_t + s_t^K \widehat{\rho}_t = \widehat{TFP}_t^D$. The right-hand side of this expression is the same as Eq. (2), 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 Sect. 3.3, starting with how Hsieh wrote the income accounting identity.

Because the estimate of the rental price of capital calculated by Hsieh did not show a marked decline, he found higher (moderate positive) *TFP* growth rates using the dual than using the primal.[10]

Moving to the next decade, Fernald and Neiman (2011) also contributed to this debate by developing a slightly more sophisticated version of the growth accounting formula. They tried to reconcile the different findings of Young and Hsieh. In the particular case of Singapore, the conflicting results reflect a puzzle. This is that labor's share in income was rather stable, hence the rising capital-output ratio behind

[10] Young (1998), 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. 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 (2002, section IV) 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.

the low primal *TFP* growth in Singapore would imply a sharp decline in the return to capital. However, reasonable rental price measures were flat. Fernald and Neiman argued that this was due to some of the pitfalls inherent in standard growth accounting approaches (embedded in Young's and Hsieh's calculations). They argued that, in distorted economies like Singapore (where capital is subsidized and with different forms of monopoly power), measures of aggregate *TFP* growth capture resource reallocations as well as technology. Their derivation is based on a two-sector model, where the two sectors are referred to as 'favored' (those that received subsidized capital) and 'unfavored'.

The basis for their growth accounting approach was the dichotomization of the operating surplus into the cost of capital and pure profits. Through a series of assumptions, they decomposed overall *TFP* growth into the contribution of what they referred to as "true" aggregate technology and two terms that reflect differences in market power (profits) across different sectors of the economy (related to differences between GDP and cost shares), and sectoral reallocation of capital across uses. Their point is that to measure properly aggregate technology growth; one needs to use sectoral data, as aggregate *TFP* growth depends not only on aggregate technology but also on an adjustment for whether input use is growing faster in a high-profit sector or in a low-profit sector.

Fernald and Neiman found that for firms receiving preferential treatment, *TFP* growth was even lower (more negative) than Young's primal results indicated. The unfavored sector, on the other hand, registered positive *TFP* growth. With sectoral distortions, the observed factor-price data may be unrepresentative of the aggregate economy hence they argued that the primal estimates were more accurate. Overall, Fernald and Neiman concluded that technology growth in Singapore was slightly negative and, despite sizeable distortions, was not in fact much different from Young's primal estimates. These authors also show how pure profits and unobserved heterogeneity in rental prices can quantitatively resolve the mismatch between Young's primal and Hsieh's dual calculations for Singapore.

3.3 The aggregate production function and the accounting identity: Felipe and McCombie (2003)

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 of 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. Their view of the $\widehat{TFP}$ discussion was rather *nihilistic*. Felipe and McCombie (2003) argued that standard growth accounting analyses and econometric estimations of production functions *assume* that an aggregate production function *exists*. The truth, however, is that aggregate production functions almost certainly do not exist, in the sense that the conditions to generate them are very stringent and actual economies certainly do not satisfy them.

The assumption that an aggregate production function exists is of crucial importance, for it is the *sine qua non* of the exercises discussed in this paper, and yet it was never questioned in the debate on sources of growth in East Asia. It is easy to understand why this is the case: if the aggregate production function does not exist, the whole growth accounting exercise becomes meaningless.

Felipe and Fisher (2003) reviewed and discussed the well-established literature on aggregation in production functions (going back to the 1940s) 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. Specifically, the aggregation conditions for capital, labor, and output, indicate that: (i) aggregate production functions exist if and only if all micro-production functions are identical except for the capital-efficiency coefficient. This an extremely restrictive aggregation condition, one that actual economies do not satisfy; (ii) the existence of a labor aggregate requires the absence of specialization in employment; (iii) the existence of an output aggregate requires the absence of specialization in production – indeed all firms must produce the same market-basket of outputs differing only in scale; and (iv) except under constant returns, production functions are unlikely to exist at all (Felipe and Fisher 2003).

In this context, it is very difficult to understand the modern empirical 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 behavior of total factor productivity" (Nadiri 1970, p.1144).

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 technical changes at the process level can give rise to the kinds of technical change discussed in the literature at the aggregate level?

Second, and based on a neglected argument used by Phelps–Brown (1957), Simon (1979), Samuelson (1979), and Shaikh (1980), among others, to question the usefulness of production function estimations, Felipe and McCombie (2003) then asked if there is any possible interpretation of the estimates of production functions and growth accounting exercises that does not rely on the existence of an aggregate production function. They showed that growth-accounting exercises and the derivation of $\widehat{TFP}$ 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 also Barro (1999), when they claimed that the growth accounting equation could be derived from the national income accounts. Felipe and McCombie's (2003) claims are different from those of Hsieh and Barro, and the differences must be made clear. The full argument about the accounting identity was developed at length in Felipe and McCombie (2013).

The NIPA identity with value data is:

$$Y_t \equiv W_t + \Pi_t \equiv w_t L_t + r_t J_t \tag{5}$$

where W is the total wage bill, Π is the total surplus, r_t is the average profit rate (different conceptually from the user cost of capital ρ_t used by Hsieh, reviewed in the Appendix), w is the average wage rate, and L denotes employment. We now make a few important clarifications: (i) Y here is a value measure (dollars, however deflated), not a physical measure of output (number of automobiles) (we keep the same symbol Y for both physical and value measures of output in order not to complicate the notation); (ii) J is the *value* of the stock of capital, dollars (not the physical stock K, which, at the aggregate level, is a controversial concept), what authors use in empirical applications (not physical measures); (iii) the symbol ≡ indicates that Eq. (5) is an accounting identity. In empirical applications, researchers use series consistent with Eq. (5). Likewise, Eq. (5) is not derived from Euler's theorem, the validity of which (interpretation) depends on the existence of the aggregate production function; and (iv) that no assumption is needed to write Eq. (5). It holds always, and average wage and profit rates may or may not equal the corresponding marginal productivities.

Now write Eq. (5) in growth rates (denoted by ^) as:

$$\widehat{y}_t \equiv s^L_t \widehat{W}_t + s^J_t \widehat{\Pi}_t \equiv s^L_t \widehat{w}_t + s^J_t \widehat{r}_t + s^L_t \widehat{\ell}_t + s^J_t \widehat{j}_t \tag{6}$$

Now compare Eqs. (1) and (2), derived from the production function, with Eq. (6). Because the latter is an identity, it must be true that $\widehat{y}_t - s^L_t \widehat{\ell}_t - s^J_t \widehat{j}_t \equiv s^L_t \widehat{w}_t + s^J_t \widehat{r}_t$. $\widehat{y}_t - s^L_t \widehat{\ell}_t - s^J_t \widehat{j}_t$ is what Eq. (2) calculates as total factor productivity growth (primal), where $\widehat{j}$ is the growth rate of the capital stock in value terms and $s^J = rJ/Y$ is the capital share. As noted in Sect. 2, the derivation of the growth accounting equation from the production function requires the assumption that factor markets be perfectly competitive (so as to equate the factor elasticities to the shares in output). Yet, Eq. (6) shows that this is assumption is irrelevant. The reason is that Eq. (6) holds for any economy and irrespective of the state of competition. The calculation in Eq. (6), and hence in Eq. (2), is correct. Therefore, any test using the neoclassical framework (estimation of the aggregate production function), if done properly, must indicate that the estimated elasticities equal the factor shares. This result could erroneously be interpreted as a verification of the hypotheses of perfectly competitive factor markets and constant returns to scale, although none of this is necessarily true. It is the result of the accounting identity and the use of value data. Naturally, this argument questions the empirics of the endogenous growth models. See Felipe (2001) and Felipe and McCombie (2020).

The arguments above pose a very serious problem not for the calculation of total factor productivity growth (either as $\widehat{TFP}_t = \widehat{y}_t - s^L_t \widehat{\ell}_t - s^J_t \widehat{j}_t$ or as $\widehat{TFP}^D_t = s^L_t \widehat{w}_t + s^J_t \widehat{r}_t$, which are obviously identical) but for its unwarranted interpretation as a measure of productivity growth. In the neoclassical model since Solow (1956, 1957), the notion of total factor productivity growth is intimately linked to that of the aggregate production function. Recall that in this framework, $\widehat{TFP}_t$ is supposed to measure the shift in the production function keeping inputs constant. Yet, if this conceptualization cannot be defended (resulting from the aggregation problem), all that remains then is the accounting identity explanation. Surely, the calculations are correct. What is questionable is the interpretation, as most authors do, as the shift in the alleged underlying aggregate production function. This argument also invalidates Barro (1999) and Hsieh's (1999, 2002) claim that total factor productivity calculations do not rely on the production function.

Further, suppose one integrates the identity Eq. (6), $\hat{y}_t \equiv s_t^L \hat{w}_t + s_t^J \hat{r}_t + s_t^L \hat{\ell}_t + s_t^J \hat{j}_t$, by simply assuming that factor shares s_t^L and s_t^J are constant, which we denote α and $(1-\alpha)$ as they add up to 1. This yields: $Y_t \equiv A w_t^{\alpha} r_t^{1-\alpha} L_t^{\alpha} J_t^{1-\alpha}$, the accounting identity in levels. Felipe et al. (2008) and Felipe and McCombie (2020) discuss what occurs when researchers estimate $Y_t = A L_t^a J_t^b u_t$, where u is the error term. This regression can interpreted as the identity but omitting the wage and profit rates. This becomes a case of omitted variable bias (but the variables omitted, w and r, know). Felipe et al. (2024) provide simulations that enlighten the issue and show the different results obtained estimating a production function with physical quantities ($Y_t = A L_t^a K_t^b u_t$, where Y here is a physical measure with K) and with values ($Y_t = A L_t^a J_t^b u_t$, where Y here is a value measure with J).

This deceptively simple argument is very damaging for all applied work using the neoclassical production function, including the work discussed in Sects. 3.1 and 3.2. It now becomes straightforward to correctly interpret all this body of work. The question is not whether or not Young, for example, made a computational mistake. It is much more serious. It is that, in the light of the aggregation problem, growth accounting exercises are theoretically very dubious. Furthermore, the accounting identity argument shows that all these exercises do is manipulate an accounting identity.

To be precise, Eq. (6) can certainly be used as an organizational device, but this requires admitting that Y and J are not physical quantities, and that the decomposition is not theory-based, which is what neoclassical economics maintains. As a matter of algebra, it is true that output growth can be decomposed into the growth of the wage bill plus that of total profits (appropriately weighted) − it tells us something about the distribution of income between wages and profits. What neoclassical economics does, and this is the heart of the problem, is to link this identity to the 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).[11]

[11] Given the discussion in this section, does the Fernald and Neiman's (2011) (cited in Sect. 3.2) growth accounting exercise solve the conundrum? We believe their discussion of Singapore's economy is very rich. Yet, the quantitative exercise suffers from all the problems discussed above: their two-sector model incurs all the aggregation problems: "favored" and "unfavored" sectors use homogeneous capital and labor, production functions are Cobb-Douglas, and firms have perfect foresight. Their entire derivation assumes all these with complete disregard for the aggregation results and without appreciating that their arguments are embedded in the accounting identity. This is because the output and capital data are values and not physical quantities. These authors, like Hsieh, did acknowledge the accounting identity but also Hsieh did not seem to fully understand the implications. Fernald and Neiman stated: *"If the data satisfy the accounting identity (i.e., they are internally consistent)…."* (Fernald and Neiman 2011, p.36; italics added). That is, they acknowledge that there is no guarantee that Y_t equals $\overline{w_t L_t + \rho_t K_t}$. However, in making this statement, they seem not to realize that one can construct identity $\overline{Y}_t \equiv w_t L_t + \rho_t K_t$, where $\overline{Y}$ denotes output consistent with competitive markets. See Appendix, Example 3.

To put the argument in even starker terms, the Appendix ("The Accounting Identity in Practice") discusses a series of examples (*TFP* growth estimates for the economies discussed in the paper) through the prism of the accounting identity critique.

4 If not *TFP* growth versus factor accumulation, how can we explain East Asia's fast growth?

Given that standard growth accounting exercises cannot satisfactorily explain East Asia's growth (and growth in general), the natural question is: how can East Asia's high growth between the mid-1960s and mid-1990s be understood? Our view is that it is impossible to comprehend it without bringing into the discussion the significant structural transformation that these economies underwent between the mid-1960s and the early 1990s, both from the point of view of output and employment. Second, the shift of workers out of agriculture into industry and services happened because these economies created companies with the capabilities to manufacture products of increasing complexity. These capabilities allowed these economies to upgrade their export structures. Third, the role of the government in facilitating and encouraging structural transformation through different tools of industrial policy was also key. We close the section by providing a macroeconomic perspective of how the East Asian economies managed to attain such high growth rates without running into balance of payments problems. We do this with a reference to the balance-of-payments-constrained-growth model, which relates structural upgrading (shifting into exports with a higher income elasticity of demand) and market expansion to the relaxation of balance of payments constraints.

(i) Structural transformation and upgrading

The economic transformation of the successful East Asian economies is best summarized in the transfer of workers out of agriculture (the sector with the lowest productivity) into industry (manufacturing growth) (Kaldor 1967); and second, in the diversification and upgrading of their export baskets. As documented by Felipe et al. (2016), the share of agricultural employment in total employment in Korea and Taiwan, declined much faster during their period of high growth, at about one percentage point per annum, than it had done in the Western advanced economies in the 19th and 20th centuries. This is the essence of what development was about during the 19th and 20th centuries: the movement of workers out of low-productivity activities into high-productivity activities, in particular into manufacturing. The decompositions of productivity growth into the 'within sectors' and 'structural transformation' (the shift of workers from sectors of lower into sectors of higher productivity) components undertaken by the Asian Development Bank (2013) and Rodrik et al. (2017) are very helpful to understand the sources of growth. They indicate that both components (within sectors productivity growth and structural transformation) were significant in these economies. Szirmai (2012) documented that all historical examples of success in economic development and catch-up since 1870 have been associated with successful industrialization. The Asian Development Bank (2013) provided a thorough analysis of Asia's economic transformation and highlighted the significant differences across economies. Industrialization played a key role in East Asia's development in the 20th century but not in most other Asian countries. Szirmai and Verspagen (2015) also highlighted the importance of manufacturing for development (the engine of growth hypothesis) and documented interaction effects of manufacturing with education and income gaps.[12]

Apart from the changes in the employment structure documented above, another key contributing factor to East Asian growth was the change in the product mix. The recent literature on the product space of Hidalgo et al. (2007), and the concept of complexity of Hidalgo and Hausmann (2009), make the very important point that not all products have the same consequences for development. This work explains economic development as a process of learning how to produce (and export) more complex products. Using network theory methods, they have shown that the development path of a country is strongly influenced by its existing product mix: some pairs of products are more closely related to each other than others, and it is easier to learn to make products related to those that a country already produces. In addition, countries with initial comparative advantage in complex products are able to branch out into more products. Branching out, or achieving dynamic competitive advantage, is a core goal of development, partly because the production of more complex products is associated with higher national incomes and wages and also because countries that establish a presence in a new export industry tend to then converge towards global productivity levels in that industry (Hausmann et al. 2007). 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.

While the East Asian economies' export mixes in 1962 were somewhat more diverse and complex than those of other countries in the region (e.g., the Philippines and Indonesia provide a contrasting comparison), their dynamism was far greater. All four East Asian economies developed comparative advantages in many more

[12] We add that Szirmai and Verspagen (2015) concluded that since 1990, manufacturing has become a more difficult route to growth than before. This last finding was corroborated by Felipe et al. (2019b) in the context of the recent discussions about deindustrialization. They also showed that attaining a minimum share of manufacturing employment in total employment (18–20%) for some time was much more important than attaining a high manufacturing output share, in order to attain high income per capita. While deindustrialization is a phenomenon well documented in the advanced economies, the recent literature has shown that it is affecting many developing countries but at lower levels of income per capita, hence the reference to premature deindustrialization. Indeed, while developed countries could ride the manufacturing escalator up to relatively high levels of per capita income, and the manufacturing employment share attained was very high (about 30%), today's developing countries reach a much lower manufacturing peak (about 15%) and at a lower income per capita. Felipe and Mehta (2016) argue that this is not because the world has deindustrialized – manufacturing's shares of worldwide output and employment have remained constant. What has happened is that manufacturing production has shifted particularly to China, and so no country can achieve a large manufacturing employment share.

products and in more complex products over the course of the next three decades, and grew rapidly as they did so (Hausmann et al. 2014).

The product space and the complexity literature has interpreted the fact that diversity and complexity predict growth in causal terms. The presumed mechanism is the development of capabilities (Hidalgo and Hausmann 2009).[13] Capabilities could be (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 which the firm would be excluded from the market, and not export (see also Kremer 1993). Therefore, capabilities are largely non-tradable inputs. Khan (2015) argues that because they reflect mostly tacit knowledge, the way to acquire them is through learning-by-doing (LBD). Such LBD requires external (to the firm) financing, i.e., it has to be subsidized. Simultaneously, it requires efforts on the part of both the firm and worker.

Through this lens, economic development is a process that requires acquiring more complex sets of capabilities to move toward new activities associated with higher levels of productivity. In the case of the East Asian economies, the implication is that their success in industrial upgrading ignited processes of capability improvement, including some measure of technology development, human capital accumulation, and institutional development.

The literature on structural transformation and the product space empirically link growth in the East Asian economies to success in changing what they produced (towards more complex manufactures), and highlights the cumulative, path-dependent nature of these changes. However, they are agnostic about which capabilities matter and provide no specific explanation of *how and why* these changes came about.[14] This matters because almost every other developing economy has attempted to alter its production mix, but few have succeeded. The two key barriers have been how to ensure that firms introducing products and technologies that are new to the country thrive; and maintaining stability on the balance of payments during the industrialization process.

[13] There is now well-established literature on the importance of capabilities in various contexts, and from different schools. 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 development, and Lall (1992) and Bell and Pavitt (1995) analyzed the role of capabilities from an innovation and development point of view.

[14] See Lee (2013) and Lee and Lee (2019) on this point.

Schumpeterian work on technological development has helped dispel naïve the view that simple price advantages – undervalued currencies and wage advantages – and the ability to imitate widely used technologies could explain success in industrialization. It emphasizes that adoption of new production technologies happens under specific conditions (`windows of opportunity'), and that economies whose firms are able to adopt less mature technologies are more likely to undergo techno-economic paradigm shifts (including institutional changes), that produce durable economic leads. Success in young technologies is therefore difficult and rare, but valuable (Saviotti and Pyka 2011; Malerba and Lee 2021; Lee 2024).

Perez and Soete (1988) provide a classic description of the circumstances under which firms and countries are able to adopt new production technologies and produce new products (i.e., in their terms, "leapfrog").[15] They emphasize that success requires overcoming multiple thresholds, each being a function of the technology and its maturity, and that firms and the countries that host them are differentiated in their capacities to overcome these constraints. Specifically, they argue that as technologies mature, adopting them comes to require less scientific knowledge and fewer locational advantages – and therefore less government support. However, adopting a mature production technology requires more investment than adopting a young technology, and the amount of tacit knowledge and experience required to adopt a technology increases and then decreases over its life cycle.

As a consequence, the most mature technologies, like those involved in garments, footwear, and assembly manufacturing, are easy to adopt, provided that adequate investment capital can be secured; but offer fewer opportunities for learning and fierce competition. Mid-maturity technologies like cars, steel, and petrochemicals, between the 1960s and 1990s, are the most difficult to adopt, requiring extraordinary amounts of tacit knowledge and heavy investment. Younger technologies, like, at the time, those involved in making electronics, were possible to adopt in countries with access to an adequate scientific workforce and governments capable of creating locational advantages, even if they lacked capital. Moreover, early adopters of these young technologies were often able to build durable knowledge leads, cemented by increases in R&D and institutional changes manifest in national innovation systems and education expansions (Freeman 1988). These, in turn, spur entry into new sectors – a process that matches the empirical patterns picked up in the complexity literature (Saviotti and Pyka 2011).

[15] Later contributors to this literature emphasize late-stage developments in latecomer economies, including R&D expansions and role reversals wherein their firms in latecomer economies become technology leaders (Malerba and Lee 2021; Lee 2024). Here, we work with the classic literature that focuses more on earlier phases of capability development more typical of the East Asian economies prior to the 1990s.

This body of Schumpeterian theory helps explain the East Asian economies' success in the 1960s, 1970s and 1980s.[16] All four economies had business-friendly, pragmatic governments (and some had FDI-friendly policies), willing to deploy industrial policies to reduce locational disadvantages in order to facilitate technological change. Singapore, also benefited from its position on the Malacca Strait, while Korea and Taiwan's close ties to the United States facilitated investment (Studwell 2013).

Under these circumstances, it is not surprising that electronics – the key young technology between the 1960s and 1990s – featured prominently in all four countries export mixes by 1990. In Singapore, Taiwan, and Korea, this early success in electronics, built through collaboration with Western multinational firms, has manifestly translated into durable technological leads. The East Asian economies also made some inroads by the 1990s into technologies of middle maturity – Korea into cars, and all of them in products manufactured from petrochemicals like plastic products and synthetic rubber, fiber, and fabric. These industries are linked backwards to chemicals and metallurgical products, which were produced in modest amounts by all four East Asian economies in the 1960s.[17]

Having said this, the process was not easy. Hobday (1995a) described in detail how East Asian firms from Hong Kong, Korea, Singapore, and Taiwan climbed the ladder by slowly learning by doing. In the specific case of the electronics industry, he concluded that the East Asian latecomers engaged in a painstaking and cumulative process of technological learning (Hobday 1995b, 1188). Kim (1997, 129) described Hyundai's efforts to produce a car after it had purchased foreign equipment, hired expatriate consultants, and signed licensing agreements with foreign firms. Despite the training and consulting services of experts, Hyundai engineers repeated trials and errors for 14 months before creating the first prototype. They had to implement 2888 engine design changes.

The actions taken by the East Asian firms and governments to produce these successes in nascent and mid-stage technologies are noteworthy. They include firm-level efforts to imitate and innovate and governments industrial policies. Dosi et al. (2020) explain why these activities by firms and governments are complementary.

(ii) The role of industrial policy

Arguably, this is the most contested ingredient of East Asia's success, and it is difficult to present an unbiased account of this topic. We already mentioned earlier

[16] Ang and Madsen (2011) tested the power of two second-generation endogenous neoclassical growth models, to explain growth of the East Asian miracle economies. They conclude that the Schumpeterian model, where innovative activity and R&D play a fundamental role, can explain these economies' growth. Naturally, these models are still based on the aggregate production function and all its assumptions, as discussed here. Hence, they are subject to the same criticism made in Sect. 3.3. See Felipe and McCombie (2013) on this.

[17] Certainly, industries already operating with mature technologies at the time, like garments, footwear, luggage and toys –, became very important in Hong Kong, Korea, and Taiwan, where labor was not a constraint, but this was also true in less successful Southeast Asian economies, as predicted by theories of technology life cycles.

that Young's (1992) thesis about Singapore was that its lack of *TFP* growth had been caused by its industrial policies. This view was heavily contested at the time. The World Bank (1993) *East Asian Miracle Report* itself ended up containing a mix of somewhat contradictory statements on the role of industrial policy. Pack and Saggi (2006) reviewed the empirical evidence in support of the use of industrial policy for correcting market failures that plague the process of industrialization. They concluded that public interventions played a limited role.[18] On the other side of the story, Wade (1990) and Jomo and Wah (1999) provide detailed accounts of the instruments and role of industrial policy in East Asia.

Although historically many cases of industrial policy failed, we also believe that achieving growth rates that approached 10% per annum for long periods required more than deciding to export and to get into manufactures. Authors like Amsden (1989), Wade (1990), and Cimoli et al. (2009) have argued that this additional ingredient was active governments that directed and consciously accelerated industrial development by implementing policies that defied comparative advantage based on static allocative efficiency, which leads developing countries to specialize in labor-intensive products. Proponents of pursuing static allocative efficiency are silent on the question of what countries should do as labor becomes scarce and expensive, which forces them to enter capital-intensive sectors. Instead, the East Asian governments promoted dynamic efficiency. This is based on the idea that firms (and ultimately a country) adapt and improve productivity over time in response to changing markets, technologies, and customer preferences. Dynamic efficiency involves continuous improvement, investment in new technologies, and a focus on long-term growth. Stiglitz (1996) also argued that East Asian governments undertook major responsibility for the promotion of economic growth. He admitted that it is difficult to ascertain which specific policies contributed to the success of these economies (the attribution problem), and also to guess what would have happened in the absence of such policies. Moreover, that the government subsidized a sector that grew rapidly does not imply that the growth should be attributed to the government's action. Because the ingredients that led to success were interactive (i.e., contrary to what growth accounting does) and because they were introduced in conjunction with other policies, the role of government has to be evaluated in the context of a package.

The intellectual underpinnings of government intervention in Asia go back to Gerschenkron's (1962) *latecomer model*, the idea of which is that, without the government pushing to alter the structure of production of the economy toward advanced industries (from light manufacturing and agriculture into ships, steel, autos, industrial machinery, and electronics), growth and development would have happened much more slowly in these poor (latecomer) countries. What this means is that the ultimate purpose of industrial policy and targeting certain sectors was more than addressing market failures but to induce distortions in the short term in order to

[18] We note two points on the critical evaluation of industrial policy by Pack and Saggi. First, they cite authors who studied the impact of industrial policy on *TFP* growth, a measure questioned in this survey. Second, they highlight experiences like that of India, perhaps not the most enlightening.

realize gains in the long term. Two decades later, Johnson (1982) referred to these states as *developmental states*.

Amsden (1989, 1995) used this model to explain East Asia's success. The experience of East Asia's latecomers shows that they focused on industries that had dominant technologies. These are industries where competition is based on cost minimization and on the building of mass production capacities as fast as possible. The experience of Asia's late industrializers (starting with Japan after WWII) also shows that they all had effective developmental states that provided extensive support to their firms, not only by boosting the profits of those firms that were prepared to enter the competitive arena, through subsidies, tax breaks or low interest rates loans but also through mechanisms designed to curb rent-seeking. Some of the most cited cases are those of Korea and Taiwan, where governments provided support in terms of subsidies or tax breaks *in exchange* (i.e., reciprocity) for firms achieving certain export targets. Failure to meet these targets would lead to withdrawal of the support. This was very much a results-oriented performance mechanism. It proved to be a powerful means to discipline both government and firms, and to control rent-seeking. All this assistance to their firms was complemented by a complex set of catch-up institutions, such as Singapore Economic Development Board, or Taiwan's Industrial Technology Research Institute, whose goal was to capture technologies and raise the skills levels. The industrialization problem, namely whether the development of a modern capitalist industry can be possible in a backward country (e.g., Cambodia, Lao PDR, Bangladesh, India) is as relevant today as at the turn of the 20th century.

Comparing the old advanced economies (including Japan) with Hong Kong, Korea, Singapore, Taiwan (as well as with Indonesia, Malaysia, and Thailand), Amsden (1995) elaborated upon the latecomer industrialization model, and highlighted some important differences. First, on the question of why latecomers needed more government, she claimed that "industrial policy was invented to raise productivity levels" (Amsden 1995, p.792), given that the two other options to lower unit labor costs were to lower nominal wages, or to miss industrialization altogether. Second, Amsden argued that the actual experience about the degree of government intervention in the economy did not squarely follow Gerschekron's prediction that there would be more intervention the more backward the country. Rather, intervention was greater in countries with smaller *competitive assets* in relation to global competitive needs. A competitive asset is anything that contributes to the international competitiveness of raw labor power and raises labor productivity, e.g., being a port, being endowed with natural resources.[19]

Finally, recent years have witnessed a revival of the work on industrial policy. Using input-output data, Lane (2022) provides novel evidence of the positive role

[19] Additionally, Amsden (1995) argued that the governments of Japan and Hong Kong, Korea, Singapore, and Taiwan did a better job than those of Indonesia, Malaysia, and Thailand, because they were much more forceful applying the reciprocity principle of providing subsidies in exchange for performance standards, often in the form of export targets. This system of reciprocity disciplined both firms and the government itself. Interventions in the first group were of higher quality because their bureaucracies were of higher quality.

of industrial policies in Korea. Juhász et al. (2023) survey the recent literature on the subject and offer a positive take on industrial policy. They argue that industrial policy is being reshaped by a new understanding of governance, a richer set of policy instruments beyond subsidies, and the reality of deindustrialization.

(iii) The balance-of-payments constrained growth rate model

The East Asian economies considered in this paper also grew fast and for a long time because they did not run into balance of payments problems, as argued by the balance-of-payments-constrained-growth model. This model relates structural upgrading (shifting into exports with a higher income elasticity of demand) and market expansion, to the relaxation of the balance of payments constraint (Thirlwall 1979). The successful East Asian economies started their development after WWII by following different versions of import substitution. This was a consequence of the economic situation after independence, especially the acute shortage of foreign exchange. In the case of South Korea, for example, the priority industries before the 1960s were sugar, fertilizer, spun yarn, cement, and glass. This was also the case of Taiwan, which, to support its import-substitution policy, controlled foreign exchange, erected protective tariffs, imposed import restrictions, and had multiple exchange rates. Under these conditions, there was a conscious effort to replace imports of non-durable consumer goods with domestic production. This way, the production of synthetic yarn, bicycles, flour, plastic, artificial fibers, glass, cement, fertilizers, apparel, wood, leather, and cotton textiles, increased significantly. Even Singapore toyed with import substitution before 1965. After independence, the government concluded that the shift in industrialization that the country needed could only be induced by implementing an export-led program. Officials realized that a small economy like Singapore had to think in terms of selling to the markets of the industrialized economies.

The balance-of-payments-constrained-growth (BOPC growth) model is a demand-driven model in which the key growth constraint is the need to maintain a dynamic equilibrium in the current account because most developing countries cannot permanently finance current account deficits – not the availability of factors of production. The simplest version of this model is that the BOPC growth ($\hat{y}_B$) rate is $\hat{y}_B = \left(\frac{\varepsilon}{\pi}\right)\hat{z}$, where ε and π are, respectively, the income elasticities of demand for exports and imports, and $\hat{z}$ is the growth rate of the country's trading partners. This expression means that to attain a faster actual growth rate without facing current account problems, a developing country has to increase its balance-of-payments-constrained growth rate $\hat{y}_B$. This rate will increase as a result of a higher growth rate by its trading partners ($\hat{z}$), and/or 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). 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 exported to economies that were expanding and growing fast, and transformed their export structures, and this showed up in a higher $\left(\frac{\varepsilon}{\pi}\right)$. This result and idea is consistent with the notion of an increasing complexity as explained above. This higher ratio allowed these economies to grow faster and, at the same time, relax the balance-of-payments constraint. Hussain (2004, Table 14.5) provides estimates for Korea and Hong Kong for 1971–1990. During this period, Korea's balance-of-payments-constrained growth rate reached 10.17%, and Kong Kong's 9.28%, both slightly above their actual growth rates.[20]

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 analyzing the sources of growth in East Asia during the period of high growth. This literature relied on estimating the contributions of factor accumulation and total factor productivity growth. The most cited papers concluded that the bulk of growth could be accounted for by capital accumulation, and very little if anything, by total factor productivity growth. This result originated a debate, as it defied the logic that the high growth rates and significant economic transformation attained by the East Asian economies could not have been achieved without productivity growth and accumulation of capabilities.

If total factor productivity growth is a correct measure of technical progress or productivity growth, it could not have been zero. One option within the neoclassical paradigm to solve this conundrum was to argue that as technical progress was biased and not neutral (as often assumed), the zero *TFP* growth estimates were incorrect. Once total factor productivity growth is recalculated assuming that technical progress was biased, it is higher, A second option, also within the neoclassical paradigm, was to argue that capital stock figures were dubious, hence the dual of *TFP* growth was a more reliable measure. This produced higher estimates. A third option, our preferred one, was to argue that, by default, these exercises use value data (constant-price value terms) as opposed to physical quantities (i.e., researchers do not use physical quantities because these do not exist). The problem is that an underlying accounting identity that relates definitionally the same variables that appear in the production function (output and inputs) but in constant-price value terms, makes the interpretation of *TFP* growth as a measure of true productivity growth very problematic, to say the least.

Consequently, we have argued that there was nothing to be learned from further refinements of this type of growth decompositions. Franklin Fisher (2007), referring to the neoclassical model, put it vividly in the title of his paper, "Is growth theory a real subject?" The reader should not have problems guessing what the answer was. Ultimately, this review matters because it shows that neoclassical economics continues working with a problematic notion of technological progress and productivity growth. The orthodox discussions of the East Asian miracle largely missed the key

[20] Felipe et al. (2019a) used this model to discuss Indonesia's growth, and Felipe and Lanzafame (2020) used it to discuss China's.

questions about these economies' fast development and growth, namely how to stimulate structural transformation and acquire capabilities. In retrospect, all that one can learn from these discussions is that neoclassical growth accounting is not useful.

We conclude that East Asia's growth between the mid-1960s and early 1990s is better understood through the very rich literature on structural transformation, accumulation of capabilities and learning (and the related recent concepts of the product space and complexity), the balance-of-payments-constrained growth rate, and the role of industrial policy.

Appendix: The accounting identity in practice

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 where $\widehat{TFP}$ is calculated residually

Young (1994) estimated a cross-country production function using data from 118 countries between 1970–85. The growth-accounting regression estimated was $\hat{y}_t = \hat{\varphi} + \gamma_1 \hat{\ell}_t + \gamma_2 \hat{j}_t + u_t$, or $(\hat{y}_t - \hat{\ell}_t) = \hat{\varphi} + \gamma_2(\hat{j}_t - \hat{\ell}_t) + u_t$, under the assumption that $\gamma_1 + \gamma_2 = 1$. $\hat{\varphi}$ is the world's average growth rate of *TFP*, assumed to be a constant.

As argued above, this is thought to be a model in the sense that it can be tested and potentially refuted. Each country's estimated residual, $\tilde{u}_i$, is thought to measure the growth of country *i's* total factor productivity less the world average. That is, the per-country *TFP* growth rate is $\tilde{\varphi}_i = \tilde{\varphi} + \tilde{u}_i$, where the symbol ~ denotes the estimated coefficient. Young obtained the following result:

$$(\hat{y}_i - \hat{\ell}_i) = -0.21 + 0.45(\hat{j}_i - \hat{\ell}_i) + \tilde{u}_i \tag{7}$$

Young noted that the residuals for the East Asian economies $(-0.21 + \tilde{u}_i)$ were very close in value (low) 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 Eq. (6) that $\hat{y}_i \equiv s_i^L \hat{w}_i + s_i^J \hat{r}_i + s_i^L \hat{\ell}_i + s_i^J \hat{j}_i$, or $(\hat{y}_i - \hat{\ell}_i) \equiv s_i^L \hat{w}_i + s_i^J \hat{r}_i + s_i^J(\hat{j}_i - \hat{\ell}_i)$, 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 $(\hat{y}_i - \hat{\ell}_i) \equiv \mu_1[s_i^L \hat{w}_i + s_i^J \hat{r}_i] + \mu_2[s_i^J(\hat{j}_i - \hat{\ell}_i)] + u_i$, it should be obvious that the result must be $\tilde{\mu}_1 = \tilde{\mu}_2 = 1$ and $R^2 = 1$, as there is no error term $(u_i = 0)$ for all the observations. Consequently, if one estimates:

$$(\hat{y}_i - \hat{\ell}_i) \equiv \hat{\varphi} + \gamma_2(\hat{j}_i - \hat{\ell}_i) + u_i \tag{8}$$

as Young did, it should be apparent that the estimate of γ_2 will approximate the average value of the share of capital in the sample $(\bar{s}_i^J)$. The sum of the actual error $(\tilde{u}_i)$

plus the estimate of the constant ($\widetilde{\varphi}$) will, by definition, provide an estimate of the weighted average of the growth rates of the wage and profit rates ($\widetilde{\varphi}_i = s_i^L \widehat{w}_i + s_i^J \widehat{r}_i$). Of course, the estimates may be subject to some bias if $\widetilde{\varphi}_i$ is not orthogonal to $(\widehat{j}_i - \widehat{\ell}_i)$. Note that now Eq. (8) contains the error term u_i. This is not zero as in the accounting identity because Eq. (8) proxies $(s_i^L \widehat{w}_i + s_i^J \widehat{r}_i)$ by the constant term c, and s_i^J by the coefficient b (also constant). To the extent that these two variables are not constant, the left and right-hand sides in Eq. (8) 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 $\widehat{TFP}$ of the East Asian economies from the regression exercise must be virtually identical to those from the accounting identity; the latter shows that it cannot be otherwise. It follows that Young's estimates of $\widehat{TFP}$ simply captures a weighted average of the growth rate of wages and profits, not productivity growth.

Example 2 Kim and Lau (1994) provided *TFP* growth estimates also derived from the econometric estimation of the aggregate production function. In their case, they pooled data for Hong Kong, Korea, Singapore, and Taiwan, and for the G-5 countries (France, Germany, Japan, UK, and USA). Kim and Lau hypothesized a translog production function with inputs expressed in efficiency units:

$$lnY = lnA_0 + \alpha lnA_{Lt}L_t + \beta lnA_{Jt}J_t + \gamma(lnA_{Lt}L_t lnA_{Jt}J_t) + \delta(lnA_{Lt}L_t)^2 + \phi(lnA_{Jt}J_t)^2 \tag{9}$$

where A_{Lt} and A_{Jt} are the levels of factor-augmenting technology (allowed to differ across economies), such that $lnA_{Lt} = lnA_{L0} + \widehat{\lambda}_L t$ and $lnA_{Jt} = lnA_{J0} + \widehat{\lambda}_J t$, where A_{L0} and A_{J0} are the initial levels, and $\widehat{\lambda}_L$ and $\widehat{\lambda}_J$ are the rates of labor and capital-augmenting technical change. Substituting these expressions into the production function leads to an expression that can compressed into:

$$lnY = c + b_1 lnL_t + b_2 lnJ_t + b_3(lnJ_t)^2 + b_4(lnL_t)^2 + b_5(lnL_t lnJ_t) + b_6(tlnJ_t) + b_7(tlnL_t) + b_8 t + b_9 t^2 \tag{10}$$

where c and $b_1 ... b_8$ are functions of the coefficients in the production function. As A_{L0} and A_{J0} differ across economies, the coefficients c, b_1, b_2 … b_8 are country-specific constants. Equation (10) was estimated by Kim and Lau in first differences together with the corresponding first-order condition for labor, i.e., a system of two equations. This follows from the argument that estimation of the production function alone is inappropriate as it treats labor and capital as exogenous variables. The first-order condition for labor is obtained by differentiating the production function with respect to labor, that is:

$$\partial lnY / \partial lnL = (\alpha + \gamma lnA_{J0} + 2\delta lnA_{L0}) + (2\delta \widehat{\lambda}_L + \gamma \widehat{\lambda}_J)t + 2\delta lnL_t + \gamma lnJ_t \tag{11}$$

If profit maximization and perfect competition hold, this elasticity will be equal to the share of labor in GDP, i.e., $\partial lnY / \partial lnL = s^L$. Therefore, the test of the assumption of a competitive labor market is whether the output elasticities equal the factor shares.

This methodology allowed them to test the degree of returns to scale and the type of technical progress. This way, they avoided the problem of imposing the seemingly restrictive assumptions of standard growth accounting exercises, that is, constant returns to scale and Hicks-neutral technical progress. Kim and Lau's (1994) results rejected both hypotheses. 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. Moreover, these authors also calculated the level of technology of the four East Asian economies and concluded that in 1990, it was still only about a quarter of that of the United States.

However, Felipe and McCombie (2003) showed that Kim and Lau's (1994) method is also invalidated by the accounting identity. To see this, differentiate Eq. (9) with respect to time to express it in growth rates. This yields:

$$\widehat{y}_t = \alpha_t^{'}\widehat{\lambda}_L + \beta_t^{'}\widehat{\lambda}_K + \alpha_t^{'}\widehat{\ell}_t + \beta_t^{'}\widehat{k}_t \tag{12}$$

with

$$\alpha_t^{'} = (\alpha + \gamma lnA_{J0} + 2\delta lnA_{L0}) + (2\delta\widehat{\lambda}_L + \gamma\widehat{\lambda}_J)t + 2\delta lnL_t + \gamma lnJ_t \tag{13}$$

and

$$\beta_t^{'} = (\beta + \gamma lnA_{L0} + 2\phi lnA_{J0}) + (2\phi\widehat{\lambda}_J + \gamma\widehat{\lambda}_L)t + 2\phi lnJ_t + \gamma lnL_t \tag{14}$$

where $\alpha_t^{'}$ and $\beta_t^{'}$ are the respective output elasticities. It thus follows from the first-order condition and Eqs. (13) and (14) that if the labor market is perfectly competitive, the following must be true:

$$\widehat{y}_t = s_t^L\widehat{\lambda}_L + s_t^J\widehat{\lambda}_J + s_t^L\widehat{\ell}_t + s_t^J\widehat{j}_t = \widehat{\lambda}_t + s_t^L\widehat{\ell}_t + s_t^J\widehat{j}_t \tag{15}$$

Now compare Eq. (15) with the identity Eq. (6), i.e., $\widehat{y}_t \equiv s_t^L\widehat{w}_t + s_t^J\widehat{r}_t + s_t^L\widehat{\ell}_t + s_t^J\widehat{j}_t \equiv \widehat{\lambda}_t + s_t^L\widehat{\ell}_t + s_t^J\widehat{j}_t$. It should be obvious that (Eq. 15) will always hold by virtue of (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, i.e., that the labor market is perfectly competitive. This also shows that the Kim and Lau procedure must indicate that there are constant returns to scale.

Given the above, how did Kim and Lau claim to have refuted the growth accounting underlying assumptions? Suppose factor shares do not follow the paths in Eqs. (13) and (14) closely, and recall that Kim and Lau pooled data for the four East Asian economies and the group of G-5 countries (France, Germany, Japan, UK, and USA), 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 3 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 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 that seemed to yield more intuitively acceptable results.

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 papers, however, suggests that underlying his arguments are the aggregate neoclassical production and cost functions upon which the theory of total factor productivity growth is based to interpret his derivation; and naturally output (Y) and the stock of capital (J) are values, not physical quantities.

To see the problem that the identity poses for the dual of *TFP* growth ($\widehat{TFP}_t^D$), let us write the NIPA identity Eq. (5) as:

$$Y_t \equiv w_t L_t + \rho_t J_t + \pi_t \tag{16}$$

where $\rho = (i + \delta)P_K - \dot{P}_K$ and π_t denotes monopolistic profits. Define now total costs (TC) as $TC_t = w_t L_t + \rho_t J_t$. It must be self-evident that $Y_t \equiv TC_t + \pi_t$ and this is identical to $Y_t \equiv w_t L_t + r_t J_t$, with $\rho_t J_t + \pi_t = r_t J_t$. Using instead the identity (16) does not change our arguments as the accounting identity is preserved, and one can write this identity in growth rates too. The difference is that now we would have to split the share of capital $s_t^J = (r_t J_t / Y_t)$ into two parts: (a) $s_{ct}^J = (\rho_t J_t / Y_t)$, and (b) π_t / Y_t. Naturally, if one writes the identity as Hsieh did, $Y_t = w_t L_t + \rho_t J_t$, this need not be equal to $Y_t \equiv w_t L_t + r_t J_t$, unless $\pi_t = 0$, which would also mean that $\rho_t = r_t$.

Hsieh (2022) was aware of what we can call the "complete identity". What is therefore difficult to understand is why he wrote $Y_t = w_t L_t + \rho_t J_t$, if he admitted that left and right-hand sides are not equal as a result of the existence of other profits (π). For the two sides to be =, either $\rho = r$ (that is, the complete identity), or output on the left-hand side is not the actual one (Y) but one that could be referred to as that consistent with competitive markets ($\overline{Y}$) so that $\overline{Y}_t \equiv w_t L_t + \rho_t J_t$, which is TC, and hence $Y \equiv \overline{Y} + \pi$.

Moreover, his interpretation and arguments are as if he was working with 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 4 Wong and Gang (1994) also tried to dispute Young's (1992) calculations for Singapore. They estimated both primal and dual measures of total factor productivity growth for 27 manufacturing industries. What is interesting for this discussion is that they tested the equality of primal and dual estimates. They estimated the regression:

$$\widehat{TFP}_t = c + d\widehat{TFP}_t^D + u_t \tag{17}$$

for the 27 manufacturing industries and tested whether $d = 1$ (Wong and Gang 1994, Table 5). To calculate the dual $\widehat{TFP}_t^D$, 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.

In a complementary exercise, 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 (Wong and Gang 1994, Table 6):

$$\widehat{TFP} = c + d\widehat{TFP}_t^D + \phi X_t + u_t \tag{18}$$

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: $\widehat{TFP}_t$ and $\widehat{TFP}_t^D$ 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, Eq. [13]). To calculate the rental price, they used the formula $\rho J \equiv \Pi$, 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 $\rho \equiv \Pi / J$, which is identical to $r \equiv \Pi / J$.[21]

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[21] 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 that with only the first two terms.

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Declarations

Competing interests The authors declare no competing interests.

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