Survey Article

Total Factor Productivity Growth in East Asia: A Critical Survey

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This article surveys the recent empirical literature on total factor productivity (TFP) growth in East Asia, and the debate about the sources of growth in the region. It is concluded that: (i) the main merit of this literature is that it has helped focus the attention of scholars on the growth process of East Asia; (ii) the theoretical problems underlying the notion of TFP are so significant that the whole concept should be seriously questioned; (iii) the TFP growth estimates for the region vary significantly, even for the same country and time period; and (iv) research on growth in East Asia based on the estimation of TFP growth is an activity subject to decreasing returns. If we are to advance in understanding how East Asia grew during the last 30 years we need new avenues of research.

I. INTRODUCTION

The revival of the interest in growth theory during the 1980s with the development of the new neo-classical endogenous growth models [*Lucas, 1988, 1993; Romer, 1986, 1990*] has opened new avenues of research and initiated several debates. The attempt to explain how some countries in East and Southeast Asia grew so formidably for 30 years, giving rise to the so-called 'East Asian Miracle', has produced one of the most interesting discussions in the field of growth in this decade. During recent years, we have witnessed a mushrooming of empirical papers trying to explain East

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and Southeast Asia's miracle. Young [*1992, 1994a, 1994b, 1995*]; World Bank [*1993*]; Kim and Lau [*1994*]; Pack and Page [*1994a*]; World Development [*1994*]; Fishlow et al. [*1994*]; Collins and Bosworth [*1997*]; and Rodrik [*1997a, 1997b*] among others, have opened several intellectually stimulating debates discussing how this group of countries grew so spectacularly for such a long time. One such debate has concentrated on decomposing growth into factor accumulation and productivity gains, and has opened the discussion of whether growth in the region was driven by accumulation of factors or by productivity and learning (that is, the relative importance). This paper is concerned with the debate that this line of research has sparked. The central question asked is whether the literature that this exchange has generated has helped us to gain a better understanding of the factors that have propelled growth in the region. Though not perfectly demarcated, and including scholars with heterogeneous views, two groups have so far been involved in the debate. First are the fundamentalists [*Young, 1992, 1994a, 1994b; Kim and Lau, 1994; Krugman, 1994; Collins and Bosworth, 1997*], who claim that growth in the region was mainly input-driven. Second are the assimilationists [*Dahlman and Westphal, 1981; Dahlman et al., 1987; Hobday, 1994a, 1994b, 1994c, 1995; Romer, 1993a, 1993b; Pack, 1993; Pack and Page, 1994a, 1994b; Nelson and Pack, 1996*], who argue that the essential component of the recipe followed by the East Asian countries was the acquisition and mastery of foreign technology, and the capacity to put ideas into practice.

The polemic was ignited by the fundamentalists, in particular Young [*1992*]. This group maintains that growth in the region was input-driven, mainly capital, and that productivity increases were negligible if not zero. Young reached this conclusion by estimating the rate of the so-called total factor productivity (TFP) growth. But without any doubt, it was Krugman's [*1994*] paper that popularised and fanned the debate when, based on the results of Young [*1992*] and Kim and Lau [*1994*], he provided a controversial interpretation of the East Asian Miracle and compared the Asian NIEs to the Soviet Union. The so-called 'Krugman's thesis', that there was no miracle behind East Asia's growth but simple capital accumulation, has important implications for the understanding of the East Asian miracle, namely, that these countries will not be able to sustain their economic growth, and may end up like the Soviet Union. This line of reasoning is neo-classical in nature. In this growth model, output level and growth are a function of a country's resource endowment and the productivity of factors of production, that is, TFP. This has been the dominant paradigm in most explanations of East Asia's phenomenal growth (see *World Development* [*1994*] for a critique) and in the discussion about the sources of growth. This model implies that if in steady state there is no technical progress (and in the absence of exogenous increases such as population growth), and growth results exclusively from the accumulation of resources, then the process will stop as a result of diminishing returns to the factors. Hence the emphasis on productivity.

What from the fundamentalist point of view is the paradox about the East Asian Miracle? It was widely believed that the fast rates of growth of per capita income of the high-performing Asian economies were partly due to the catch-up phenomenon, according to which the rapid growth in per capita income that these countries achieved could be attributed to the high rates of technological change made possible by the diffusion of technology from the more advanced countries. This conventional wisdom, however, was challenged by the empirical work of Young [*1992, 1994a, 1994b, 1995*] and Kim and Lau [*1994*], who claimed that technological progress, measured by TFP, was not spectacularly high. In the special case of Singapore, it was virtually zero.

The fundamentalists' conclusions, however, seem to be very counter-intuitive, and question many of the traditional beliefs about growth in East and Southeast Asia. The assimilationists stress that what made the East Asian countries' performance special and different was how spectacularly well they mastered foreign technology [*Pack, 1993; Nelson and Pack, 1996*]. In order to understand this, the assimilationists claim, one has to go beyond the argument of accumulation embedded in a production function, and discuss how these countries developed new skills and learned how to use efficiently the technology they imported. Most technology is acquired through a long process of learning, since it is often tacit, not codified in a manual. They also tend to emphasise the benefits of government industrial policies aimed at planning the economy [*Amsdem, 1989*].

This debate is relevant for two reasons. First, scholars are engaged in an intellectual discussion about how this geographically concentrated group of countries could achieve such phenomenal growth rates for 30 years. From a theoretical point of view, the debate matters because the implications of models which emphasise the role of technlogy are very different from those of models which emphasise the role of factor accumulation. Furthermore, this is one of the few debates in economics that has attracted people from different fields, and has transcended the academic boundaries. Second, the debate is important because policy-makers in other developing countries are searching for replicable and practical lessons in the experience of East Asia (that is, can government make a difference to the long-term growth rate? See, for example, Temple [*1997*]). In the final analysis, Singapore, with its extremely unfavourable initial conditions —no previous industrialisation and no educated population— took off economically. That is what matters.

With this background, and taking into account that the debate is far from over, the objective of the study is twofold. First, its intent is to provide an overview of the literature published so far, with a discussion of the relevant work in the area of TFP in East Asia. The paper reports estimates of TFP for Indonesia; Malaysia; Philippines; Singapore; Thailand; South Korea; Taiwan; Hong Kong; and Japan. Second, to discuss up to what point this literature has helped us gain a better understanding of the factors that have propelled growth in the region. The organisation of the article is as follows. Section II reviews the notion of TFP, as well as the most widely used techniques to estimate it, namely, growth accounting and the econometric estimation of production functions. Section III summarises the works of Young and Kim and Lau, as representative of the prevailing fundamentalist view, as well as a selection of results of other studies. Some of these offer quite different estimates from those of Young and Kim and Lau. Section IV provides a critical evaluation of this literature by summarising a series of arguments that question the rationale underlying the methodologies used in the estimation of TFP. This gives the study a rather negative and critical tone. It is done in an attempt to put brakes on a literature that continues growing empirically, and which has crossed interdisciplinary boundaries, but which has neglected an appraisal of the methodologies used to estimate the rate of growth of TFP, and a serious understanding of what technological progress is. Section V provides some conclusions and suggests several directions for future research.

II. TOTAL FACTOR PRODUCTIVITY AND ITS ESTIMATION

Growth in the neo-classical framework stems from two sources: factor accumulation and productivity (TFP) growth. The key point of the debate at hand is the relative importance of each of these two components. Most of the debate has, nevertheless, focused on TFP. The reason is that its *modus operandi* is less well known than that of factor accumulation, and the problems inherent in its estimation are not a simple issue. It is thus important to begin by briefly reviewing the notion of TFP and how it is computed (see Diewert [*1992*] for a comprehensive survey).

Concept

Productivity is a technical concept which refers to a ratio of output to input, a measure of the efficiency with which the factors of production are used. When referring to a single input and a single output (that is, partial productivity A_L), typically labour, A_L=Q/L (where Q and L denote output and labour, respectively), the notion of productivity does not pose any serious computational or theoretical problem. It is a theory-free concept in so far as it does not depend on any model or assumption. The idea behind the notion of total factor productivity, however, is to measure productivity taking into account all factors of production. When more than one input is to be taken into account, for example, labour and capital, then the index of productivity is defined as output per joint unit of labour and capital, A=Q/X, where X is some weighted average of capital and labour [*Nadiri, 1970, 1972*]. The important question in this case is how to weight the inputs in the index. It is in this sense that the notion of TFP becomes theory-dependent. However, its computation is so standard that it is virtually never questioned. For classification purposes, we can conceptualise the notion of TFP through an index or through a production function (see Kleiman *et al.* [*1966*] for a derivation of the exact relationship between both approaches). In the first case, one can distinguish between arithmetic indices [*Abramovitz, 1956; Kendrick, 1961*] and geometric indices [*Jorgenson and Griliches, 1967*]. The latter, more widely used, takes the form

$$\varphi_t = \frac{\dot{A}_t}{A_t} = q_t - \alpha\, l_t - (1 - \alpha)\, k_t \qquad (1)$$

where α is the elasticity of output with respect to labour (more will be said below about this weighting scheme in the context of the Divisia indices), q_t, l_t, k_t denote the growth rates of output, labour, and capital, respectively, and φ_t is the rate of *overall* productivity growth.

Solow [*1957*] showed that a measure of TFP could be derived from an aggregate production function (the indices are consistent with different production functions. See Nadiri [*1970*]). In its simplest form, the aggregate production function, assumed to be continuous twice differentiable and linearly homogeneous, can be written as

$$Q_t = F\,[K_t, L_t, t]\,, \qquad (2)$$

Equation (2) expresses value added as a function of the stock of capital, employment, and a shift factor (t), which proxies the effects of technical progress. Assuming that the argument 't' is separable from K and L

$$Q_t = A_t F\,[K_t, L_t]\,, \qquad (3)$$

and then

$$A_t = \frac{Q_t}{F\,[K_t, L_t]}\,, \qquad (4)$$

This way, A_t is referred to as exogenous, disembodied, and Hicks-neutral technical progress, and is measured by how output changes as time elapses with the input bundle held constant, that is, as a shift in an aggregate production function. Therefore, the notion of overall or total factor productivity can be reinterpreted as an index of all those factors other than labour and capital not explicitly accounted for but which contribute to the generation of output. What are these factors? The literature points out that A_t is a measure of elements such as managerial capabilities and organisational competence, research and development, intersectoral transfer of resources, increasing returns to scale, embodied technical progress, and diffusion of technology.

Estimation

The two methodologies used in most papers on productivity growth have been growth accounting and the econometric estimation of production functions. We briefly review the two methods (see Griliches [*1996*] for a short historical note).

Growth Accounting: Growth accounting assumes the existence of an aggregate production function like (2), homogeneous of degree one and positive but diminishing returns to each input. To understand its theoretical underpinnings, let us differentiate (4) and express it in growth rates, that is,

$$T[K, L, t] = \frac{\dot{A}_t}{A_t} = \varphi_t = q_t - \frac{L_t}{Qt}\frac{\partial Q_t}{\partial L_t} l_t - \frac{K_t}{Q_t}\frac{\partial Q_t}{\partial K_t} k_t, \qquad (5)$$

The expressions in front of the growth rates of the factors are the respective elasticities. How does neo-classical economics proceed empirically? By assuming perfect competition and profit maximisation. Under such conditions, the price elasticity of demand is infinite, factor elasticities equal the factor shares in output, and thus (5) becomes

$$\varphi_t = (q_t - k_t) - a_t(l_t - k_t), \qquad (6)$$

where a_t and $(1 - a_t)$ are the labour and capital shares, respectively. This is the so-called Divisia Index weighting system that Solow [*1957*] used. The Divisia index is a weighted sum of growth rates, where the weights are the components' shares in total revenues. Since the national accounts and other statistics provide estimates of all the right-hand side variables, one can easily obtain the rate of productivity growth as a residual category. Expression (6) is the so-called 'Solow-residual', and the procedure is called growth accounting (see Nadiri [*1970*]; Denison [*1972, 1993*]; Nelson [*1981*;

and Maddison [*1987*] for comprehensive surveys of this method). Thus, the objective of this technique is to determine how much economic growth is due to accumulation of inputs and how much can be attributed to technical progress; or, put in different terms, how much of growth can be explained by movements along a production function, and how much should be attributed to advances in technological and organisational competence, the shift in the production function [*Nelson, 1973*]. What makes this procedure controversial is that TFP is treated as a residual category. The development of this method dates back to the pioneering works of Abramovitz [*1956*], Solow [*1957*], and Kendrick [*1961*] who, working with either productivity indexes or production functions, derived similar expressions. Today, standard growth accounting exercises using the Divisia index follow the method developed by Solow [*1957*] in order to estimate the rate of productivity growth in the manufacturing sector of the American economy for the period 1909–49.

The importance of Solow's seminal paper is that it set the pace for the analysis of technological progress as a residual category. Solow's study created the path for the analysis of productivity, and reoriented the discussions of growth policy from an emphasis on savings to a stress on all those factors believed to be in the residual, namely, education, R&D, better management, etc. It is also clear that technology in this framework (neo-classical economics) really means productivity, and relates to the specific bundle of inputs. It is important to stress that the way this notion of technical progress is computed empirically results in a black-box, and that any errors of measurement in the series, especially capital, will automatically appear in the residual. Nevertheless, the possibility of quantifying technical progress through this relatively simple method was a temptation economists could not resist, to the point of pure schizophrenia [*Nelson, 1981*].

Solow's [*1957*] original work was followed by two types of refinements. One was the refinement of the measurement of inputs, and the disaggregation of input composition so as to allow for changing quality. This way, it was shown that the residual disappeared [*Jorgenson and Griliches, 1967*]. In other words, it was argued that the residual had originally appeared, because of a poor measurement of inputs, in particular capital. The second line of research was appreciation that sectoral reallocation of resources was a key factor in productivity growth; the reason is that a part of the growth process consists in transferring resources from low to high productivity sectors, in particular from agriculture to industry, where capital–labour ratios are higher, implying a higher marginal product of labour [*Massell, 1961*]. This, as pointed out above, is included as a part of the rate of TFP in standard growth accounting exercises (see Denison [*1967*]; Chen [*1977*]; Pack [*1993*] for empirical estimates).

With discrete data such as economic time series, researchers use the so-called Tornqvist index. It consists in using as weights the averages of periods (t–1) and t (that is, $1/2(a_{t-1} + a_t)$). This is to take into account that expressions (5)–(6) are derived using differential calculus. Diewert [*1976*] proved that the Tornqvist index is an exact measure of technical change if the underlying production function exhibits constant returns to scale and is a translog. Under these circumstances, it can be shown that the growth in TFP between periods (t–1) and t can be estimated as the logarithmic difference of output and inputs [*Chambers, 1988*], where the weights are the average of the factor shares in periods t and (t–1). Star and Hall [*1976*] provided a simple approximation to the continuous Divisia index using data from only the beginning and end of a long period of time. This approximation has, in most cases, a very small error.

Econometric Estimation of Production Functions: The rationale for the growth accounting approach depends ultimately not only on the existence of the aggregate production function for the total economy like (2), but also on the validity of the (aggregate) marginal productivity theory of factor pricing. Therefore, the direct estimation of the aggregate production function is an alternative to the growth accounting approach. In this case, (3) takes an explicit form with an assumption about A_t. Due to its simplicity, the most widely used form has been the Cobb-Douglas, although other forms are equally valid [*Chen, 1991; Kim and Lau, 1994*] and A_t has usually taken the form of an exponential time trend (although there are other possibilities). This way, technical change is viewed as a shift of the production function over time at a reasonably smooth rate over time. The coefficient of the trend measures the average rate of TFP growth (that is, how the production function has shifted). Thus, the standard form used has been

$$LnQ_t = c + \alpha\, LnL_t + \beta\, LnK_t + \varphi\, t + u_t\,, \tag{7}$$

where φ measures the average growth rate of output holding inputs constant, and u_t is the disturbance term. According to Kennedy and Thirlwall [*1972: 17*], Tinbergen was the first to use this framework. This equation has been directly estimated in most cases using OLS.

In the above framework (expression (7)), the production function expresses the maximum output obtainable from a given combination of inputs. However, empirical models which incorporate random errors taking both positive and negative values, that is, estimates using OLS like in (7), can only obtain estimates of *average* production functions. The *best practice* or production frontier methodology, on the other hand, assumes that there exists an unobservable function (the production frontier or best-practice function), corresponding to the set of maximum attainable output levels for a given combination of inputs. In this context, the idea of maximum output refers to the production function underlying a given group of firms, which might be considered the best available practice or technological frontier. It does not refer necessarily to an engineering blueprint devised in a laboratory. The advantage of this approach is that it allows decomposing the change in TFP into *technological progress* and *technical efficiency change*; the former is associated with changes in the best-practice production frontier, and the latter with other productivity changes, such as learning by doing, improved managerial practice, and changes in the efficiency with which a known technology is applied. This distinction is fundamental for policy actions, especially in developing countries, where identifying TFP growth with technological progress can miss the fact that technical efficiency change seems to be the most relevant component of the total change in TFP, and therefore, the introduction of new technologies without having realised the full potential of the existing ones might not be meaningful [*Nishimizu and Page, 1982; Danilin et al., 1985; Schmidt, 1985; Fu et al., 1998*].

III. THE MEASUREMENT OF TOTAL FACTOR PRODUCTIVITY GROWTH IN EAST ASIA

In this section we briefly summarise some of the most relevant work on productivity growth in East and Southeast Asia. We begin with the works of Young [*1992, 1994a, 1994b, 1995*] and Kim and Lau [*1994*] as examples of the prevailing view that productivity growth in East Asia was zero during the last two to three decades, and that the main source of growth was capital accumulation. Table 1 summarises their results. Their conclusions have become the standard departing point in the discussions of productivity in East Asia (these results already appear in textbooks; see Kasliwal [*1995: 178–9; Jones, 1998: 43–5*]). For example, Lucas says that Young 'demonstrates that output growth in Singapore since the 1960s can be accounted for *entirely* by growth in conventionally measured capital and labor inputs, with nothing left over to be attributed to technological change' [*Lucas, 1993: 257*; original italics] and Rodrik:

> Recent work by Jong-Il Kim and Lawrence J. Lau and Alwyn Young has shown that these were miracles of accumulation rather than of productivity: the sharp increases in physical and human capital as well as in labor-force participation account for virtually all of the rise in output, and consequently the East Asian tigers' performance with

> respect to total factor productivity (TFP) growth does not look outstanding. Of course, for accumulation to have taken place at such rates, the profitability of investment in the region must have been very high, which needs explanation [*Rodrik, 1996: 13*].

In his controversial comparative study, Alwyn Young [*1992*] used growth accounting to estimate TFP growth for Singapore and Hong Kong. He concluded that, in the former, the average value of the residual had been zero, if not negative, for the last 30 years. On the other hand, in the case of Hong Kong, growth in total factor productivity had contributed to a substantial 30–50 per cent of output growth, with an overall contribution of 35 per cent between 1971 and 1990. Young's second controversial finding for Singapore was the enormous decrease in the implied rate of return on capital, from 37 per cent in the mid-1960s, to 13 percent in the late 1980s. This, according to Young, is one of the lowest returns in the world today. For Hong Kong, on the other hand, the decrease was very small, from 28 per cent in 1960, to 22 per cent in the mid 1980s.

Young [*1994b*] conducted a larger analysis including 118 countries. In this case, Young estimated a cross-sectional regression for the period 1970–85 of the growth of output per worker, using the Summers and Heston data set (purchasing power parity values), on a constant and the growth of capital per worker. The capital stock was constructed using the perpetual inventory method with the cumulating investment flows for 1960–69 as benchmark, and a 6 percent depreciation rate. This regression yielded the following result

$$q_i - l_i = -0.21 + 0.45\,(k_i - l_i) + \varepsilon_i\,,$$

where ε_i is the growth of TFP (no significance levels reported). The results confirm Young's previous work, namely, that TFP growth in Hong Kong was relatively high and in Singapore non-existent. These results also allowed Young to conclude that TFP in other East and Southeast Asian countries had not been higher than in many other parts of the world (see Pack and Page [*1994a, 1994b*] for a reply).

Young [*1995*] performed a growth accounting analysis for Hong Kong, Singapore, South Korea, and Taiwan, using the same methodology as in his 1992 paper. The conclusions for Singapore and Hong Kong were very similar to those in his previous work. For South Korea and Taiwan, Young found positive rates of productivity growth for 1966–90. For South Korea, the annual growth rate of TFP for the overall economy for 1966–90 was 1.7 per cent, accounting for 16.5 per cent of overall growth. For Taiwan, the

TFP growth rate for the same period was 2.6 per cent, representing 28 per cent of total growth.

What did Young conclude out of his extensive exercises? He argued that the centralised Singaporean economy had compelled its citizens to save too much and has always pushed itself too fast into new technologies, emphasising movement up the technological ladder, without fully realising the benefits of learning by doing at each stage, thus incurring increasing costs of production. The tone of the paper implies that industrial policy in Singapore was a total failure, and that Singapore has been a victim of its own targeting policies. The implication is that the future of other developing countries trying to pursue and emulate similar policies is rather gloomy. On the other hand, Hong Kong with its *laissez-faire* and hands-off policies, has spent the right time at each stage. According to Young, the main source of growth in Singapore has been capital accumulation, and virtually nothing was due to productivity growth. Young concluded that Singapore, which started its development process much later than Hong Kong, traversed many of the same industries but in a much more compressed time frame. The conclusion of Young's work is the demystification of Singapore as an example of an economy with dynamic gains. The main source of growth has been plain factor accumulation.

Kim and Lau [*1994*] implemented a regression procedure called the meta-production function approach. A meta-production function is defined as the common underlying production function that can be used to represent the input–output relationship of a given industry in all countries. In practice, the approach amounts to estimating a regression pooling time series and cross-section data for several countries. In their study, Kim and Lau pooled data for the G-5 countries (US, Japan, Germany, France, and Britain) and the four NIEs (Singapore, Taiwan, South Korea, and Hong Kong) for data since the mid-1960s to 1990. Although the use of data drawn from more than one country to estimate a production function is a peculiarly hazardous undertaking, partly because relative prices differ from country to country, and partly because the collection of data is never on an exactly similar basis, this method, in the words of the authors, has two advantages. First, it allows to separate the effects of economies of scale and technical progress. And second, since intercountry data normally show more variability than data for a single country (causing multicollinearity), the parameters of the production function can be estimated with more precision. And with respect to growth accounting, this formulation has the primary advantage that it does not depend on the assumptions of constant returns to scale, neutral technical progress, and profit maximisation with competitive output and input markets. Instead, these assumptions are directly tested. For empirical purposes, Kim and Lau [*1994*] fitted a translog production function where technical efficiency was proxied by a time trend. Likewise, their production function included augmentation factors that allowed to test whether technical progress is of the augmenting type. In addition to the production function, Kim and Lau also considered the equation for the share of labour costs in the value of output with a view to testing the hypotheses of profit maximisation and competitive markets. For comparison purposes, Kim and Lau also provided estimates of TFP growth using growth accounting, but they did not furnish details about factor shares and growth rates of the inputs. Lastly, Kim and Lau calculated the *level of technology* of the nine countries in their analysis, taking the US as reference. This was done by estimating the output that each country would produce if it were given the same input bundle as the US.

The main findings of their study were: (i) all nine countries share the same aggregate meta-production function, and technical progress is factor augmenting; (ii) the standard assumptions behind growth accounting, that is, homogeneous production function in capital and labour, constant returns to scale, neutral technical progress, and profit maximisation, were rejected; (iii) all nine countries share the same capital and labour *level* augmentation parameters; (iv) the hypothesis of zero technical progress (that is, zero *rates* of output, capital, and labour augmentation) is rejected for the G-5 countries, but not for the four NIEs; (v) the hypothesis of purely capital-augmenting technical progress in all countries was not rejected, concluding that technical progress can be represented as purely capital-augmenting in all nine countries; and (vi) the technological level of the NIEs in 1990 was only 20 per cent that of the US. Furthermore, this level has been declining since the 1950s, when it was 25 per cent. This led them to reject the hypothesis of convergence in technology.[1]

Kim and Lau provided several reasons which according to them could explain why in their study exogenous technical progress is unimportant as a source of growth in the East Asian NIEs: (i) since the study uses the gross capital stock, to the extent that physical depreciation is significant, the measured capital stock will overstate the correct capital stock, and the estimated capital augmentation rate may underestimate the true capital-augmentation rate; (ii) until recently, East Asian NIEs have invested little in research and development, in particular basic research; (iii) industries in the NIEs employed matured technologies and imported capital goods at prices fully reflecting amortised R&D and other development costs; (iv) the capital goods installed in the NIEs are likely to be on the shelf variety and the possibility for indigenous improvement is limited; (v) it is possible that whatever technical progress exists, it is mostly embodied in the capital goods used in the high-technology industries, and thus the NIEs would not have had the same opportunities to take advantage of it to the same extent

TABLE 1
YOUNG AND KIM AND LAU ESTIMATES OF TFP GROWTH

Country	*Author*	*Period*	*Annual Rate TFP Growth (%)*	*Contribution to Output Growth(%)c*
INDONESIA	Young [1994a]	1970–85	1.2	
MALAYSIA	Young [1994a]	1970–85	1	
THAILAND	Young [1994a]	1970–85	1.9	
SINGAPORE	Young [1992][a]	1966–70	11.66	23
		1970–75	−16.34	−36
		1975–80	2.04	5
		1980–85	−6.00	−20
	Kim and Lau [1994][b]	1966–90	0; 1.9; 0.4	0; 23; 5
	Young [1994b]	1970–85	0.1	
	Young [1995]	1966–70	4.6	35.38
		1970–80	−0.9	−10.22
		1980–90	−0.5	−7.24
		1966–90	0.2	2.29
SOUTH KOREA	Young [1994b]	1970–85	1.14	
	Kim and Lau [1994][b]	1966–90	0; 1.2; −0.5	0; 14; −6
	Young [1995]	1960–66	0.5	6.49
		1966–70	1.3	9.02
		1970–75	1.9	20
		1975–80	0.2	2.15
		1980–85	2.4	28.23
		1985–90	2.6	24.29
		1966–90	1.7	16.50
TAIWAN	Young [1994b]	1970–85	1.5	
	Kim and Lau [1994][b]	1966–90	0; 1.2; 0.8	0; 15;9
	Young [1995]	1966–70	3.4	30.63
		1970–80	1.5	14.56
		1980–90	3.3	42.30
		1966–90	2.6	27.65
HONG KONG	Young [1992][a]	1961–66	22.53	39
		1966–71	10.69	33
		1971–76	22.12	54
		1976–81	9.37	18
		1981–86	7.40	25
	Young [1994b]	1970–85	2.5	
	Kim and Lau [1994][b]	1966–90	0; 2.4; 2	0; 35; 27
	Young [1995]	1961–66	3.5	32.11
		1966–71	2.3	35.38
		1971–76	3.9	48.14
		1976–81	2.2	22.22
		1981–86	0.9	15.51

(continued overleaf)

TABLE 1 (cont.)

Country	Author	Period	Annual Rate TFP Growth (%)	Contribution to Output Growth(%)[c]
		1986–91	2.4	38.09
		1966–91	2.3	
JAPAN	Young [1994b]	1970–85	1.2	
	Kim and Lau [1994][b]	1966–90	2.9; 1	46; 15

[a] Young [*1992*] are not annual rates, but the growth rate for the whole period.
[b] The first estimate for the four NIEs provided by Kim and Lau [*1994*] is based on the estimation of the production function under the following assumptions: single meta-production function for all nine countries, identical augmentation levels of capital and labour, zero technical progress for the NIEs, and purely capital-augmenting technical progress. The second estimate allows the rates of capital augmentation in the NIEs to be nonzero. The third estimate uses growth accounting. For Japan, the first estimate is from the production function (using same assumptions as in the second estimate for the NIEs), while the second is from growth accounting.
[c] Absent figures in CONTRIBUTION TO OUTPUT GROWTH (%) indicate that they are not available.

as the industrialised countries; (vi) it is possible that the software component of investments, that is, managerial methods, institutional environment, as well as supporting infrastructure, lags behind the hardware component. Under these circumstances, the full productivity potential of the capital goods could not be realised; (vii) poor natural resource endowment and lack of advanced scientific manpower, in the NIEs, may have nullified the potential gains resulting from technical progress in the world; (viii) maybe not all output resulting from the inputs is captured by measured GDP.

Following the impact of the work conducted by Young and by Kim and Lau, many other papers have appeared confirming or contradicting their results (see Chen [*1977*]; Ikemoto [*1986*]; Elias [*1990*] for earlier estimates). The TFP estimates of a representative sample of these studies are summarised in Table 2.

It is difficult to draw any conclusions from the work of the World Bank [*1993*]. The reason is that, unfortunately, it provided five measures of TFP growth for the East Asian countries (Figure 1.10, Figure 1.11, Table A1.2 [two estimates], Table A1.3 [a measure of technical efficiency using a very simple application of the notion of production frontier in the context of countries]), using different methods and assumptions. Each consecutive estimate is smaller than the previous one. Cappelen and Fagerberg interpret this exercise the following way: 'The purpose of all this appears to be to support the view that the lion's share of East Asian growth can be explained by conventional sources, i.e., that there is no miracle to explain' [*Cappelen and Fagerberg, 1995: 183*].

Fischer [*1993*] estimated three sets of TFP growth rates using growth accounting, each with a different weight, using the Summers and Heston data. First, the so-called Bhalla residuals, derived from a panel regression, with weights 0.398 for capital, 0.44 for labour, and 0.012 for education (the equation also included regional dummies); second, the Solow residuals, with weights 0.4 for capital and 0.6 for labour; and third, the Mankiw-Romer-Weil residuals (derived from the estimation of a production function) with equal weights of 0.333 for capital, labour, and education. Since all three sets were highly correlated, Fischer decided to work with the Solow residuals. He estimated a TFP growth rate of 1.69 percent for Taiwan for 1961–88 (the highest in East Asia); while for Singapore, the estimate was of –2.82 per cent (the lowest in Southeast Asia). On the other hand, Burma appeared to have the highest TFP rate in South Asia, 1.47 per cent. Fischer concluded that

> the estimates raise obvious questions about the underlying Summers and Heston data, or perhaps the input data. When similar calculations were made using the World Bank income data, the productivity residuals *looked more plausible* ... However, since the Summers-Heston income data are widely used, I chose to work with those, leaving the investigation of the apparent anomalies ... for later research [*Fischer, 1993: 495*; italics added].

Marti [*1996*] disputed Young's results by fitting the same regression as Young [*1994b*] but using a more updated version of the Summers and Heston data base, including data for 1970–90 (five more years than Young) and for 104 countries (Young used 118). The resulting regression was

$$q_i - l_i = 0.000232 + 0.5559\,(k_i - l_i) + \varepsilon_i\,,$$

with a significant coefficient on the growth of the capital–labour ratio (t-value = 11.63). The results of Young and Marti are radically different. The latter estimated, for example, that Singapore's annual rate of TFP for 1970–90 was 1.45 per cent, while Young's estimate was 0.1 per cent for 1970–85. Moreover, Marti also estimated the regression for the period 1970–85, the same as Young. The results indicate that Singapore's TFP rate was 1.49 per cent (similarly and for reference, while Young estimated a TFP growth rate for Uganda of 2.1 per cent, Marti estimated –0.57 per cent). The question one has to raise is whether it is possible that using essentially the same data base, results can vary so much, and if so, what this implies for the methodology and the robustness of the results.

Collins and Bosworth [*1997*] and Klenow and Rodriguez-Clare [*1997*] are the most comprehensive studies carried out recently. Both used growth accounting for a large set of countries. In the first case, the results tend to indicate that while positive, TFP growth in East Asia was not particularly high when compared to that of other regions (although the interpretation of a low or a high residual is subjective). Like the other fundamentalists, Collins and Bosworth reach the conclusion that factor accumulation was more important. Collins and Bosworth used a Cobb-Douglas aggregate production function which included capital (K) and the product of education (H) and labour (L), hypothesising that the benefits of education are labour-augmenting. The formulation assumes Hicks-neutral technical progress. Algebraically,

$$Q_t = A_t \; K_t^{\alpha} \, (H_t \, L_t)^{1-\alpha} , \qquad (8)$$

The assumption of a Cobb-Douglas form led the authors to use fixed weights both across time and across countries with $\alpha = 0.35$ and $1-\alpha = 0.65$. Collins and Bosworth offered the following rationale:

> We believe, from the existing literature, that a plausible range for the capital share is 0.3 to 0.4; and there is also considerable evidence that the capital elasticity is higher in developing economies than in industrial economies. However, to minimise concern about methodological differences in our comparison of growth in East Asia with that in other regions, we use a uniform capital share of 0.35 for the entire sample [*Collins and Bosworth, 1997: 155*].

Klenow and Rodriguez-Clare [*1997*], in another important effort at understanding growth across countries, used a Mankiw et al. [*1992*] growth equation of the form

$$\frac{Q}{L} = \left(\frac{K}{Q}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{H}{Q}\right)^{\frac{\beta}{1-\alpha-\beta}} , \qquad (9)$$

where α is the elasticity of physical capital, and β that of human capital. Their choice of parameters was $\alpha = 0.30$ and $\beta = 0.28$. They used a data-set on output and inputs which led them to estimate very high TFP growth rates for the East Asian countries, in particular for Singapore.[2]

This review of the most relevant studies in the field leads to the conclusion that this work has become a *war of figures*. From the crudest calculations to the most detailed studies, the purpose of this literature is to come up with a number that justifies the author's arguments about growth in East Asia. In many cases these are straight exercises in data mining embedded in fancy empirical methods, arguments and justifications from which very little can be learned. The variation in the estimates of TFP growth is rather large, and the figures are very sensitive to the specific

TABLE 2
OTHER ESTIMATES OF TFP GROWTH FOR EAST ASIA

Country	*Author*	*Period*	*Annual Rate TFP Growth (%)*	*Contribution to Output Growth(%)*[b]
INDONESIA	World Bank [1993][a]			
	Figure 1.10	1960–89	1.6	
	Figure 1.11	1960–89	1.6	
	Table A1.2	1960–90	1.25; –0.79	
	Table A1.3	1960–89	–1.23 (technical efficiency)	
	Kawai [1994]	1970–80	3.1	
		1980–90	–0.1	
	Marti [1996]	1970–85	0.77	
		1970–90	–0.47	–9.57
	Collins and Bosworth [1997]			
		1960–94	0.8	23.52
		1960–73	1.1	44.00
		1973–94	0.7	17.50
		1973–84	0.5	11.62
		1984–94	0.9	24.32
	Klenow and Rodriguez-Clare [1997]			
		1960–85	1.91	49.10
MALAYSIA	Word Bank [1993][a]			
	Figure 1.10	1960–89	1.6	
	Figure 1.11	1960–89	1.5	
	Table A1.2	1960–90	1.07; -1.33	
	Table A1.3	1960–89	–1.77 (technical efficiency)	
	Kawai [1994]	1970–80	2.5	
		1980–90	0.7	
	Marti [1996]	1970–85	0.48	
		1970–90	0.44	12.90
	Collins and Bosworth [1997]			
		1960–94	0.9	23.68
		1960–73	1.0	25.00
		1973–94	0.9	24.32
		1973–84	0.4	11.11
		1984–94	1.4	36.84
	Klenow and Rodriguez-Clare [1997]			
		1960–85	2.00	53.47
PHILIPPINES	Kawai [1994]	1970–80	0.8	
		1980–90	–2.2	
	Marti [1996]	1970–85	–1.11	
		1970–90	–0.42	–37.83
	Collins and Bosworth [1997]			
		1960-94	–0.4	–30.76
		1960-73	0.7	28.00
		1973-94	–1.1	–220.00
		1973-84	–1.3	–108.33
		1984-94	–0.9	300.00

(continued overleaf)

TABLE 2 (cont.)

Country	Author	Period	Annual Rate TFP Growth (%)	Contribution to Output Growth(%)[b]
	Klenow and Rodriguez-Clare [1997]			
		1960–85	–0.65	–46.09
SINGAPORE	Fischer [1993]	1961–88	–2.82	
	World Bank [1993][a]			
	Figure 1.10	1960–89	1.7	
	Figure 1.11	1960–89	1.6	
	Table A1.2	1960–90	1.19; –3.01	
	Table A1.3	1960–89	–3.45 (technical efficiency)	
	Kawai [1994]	1970–80	0.7	
		1980–90	1.6	
	Marti [1996]	1970–85	1.49	
		1970–90	1.45	27.93
	Collins and Bosworth [1997]			
		1960–94	1.5	27.77
		1960–73	0.9	15.25
		1973–94	2.0	39.21
		1973–84	1.0	23.25
		1984–94	3.1	51.66
	Klenow and Rodriguez-Clare [1997]			
		1960–85	3.29	64.38
THAILAND	World Bank [1993][a]			
	Figure 1.10	1960–89	3	
	Figure 1.11	1960–89	2.4	
	Table A1.2	1960–90	2.49; 0.54	
	Table A1.3	1960–89	0.10 (technical efficiency)	
	Kawai [1994]	1970–80	1.2	
		1980–90	2.6	
	Marti [1996]	1970–85	1.27	
		1970–90	1.65	42.52
	Collins and Bosworth [1997]			
		1960–94	1.8	36.00
		1960–73	1.4	29.16
		1973–94	2.1	40.38
		1973–84	1.1	30.55
		1984–94	3.3	47.82
	Kenow and Rodriguez-Clare [1997]			
		1960–85	2.66	71.89
SOUTH KOREA	World Bank [1993][a]			
	Figure 1.10	1960–89	3.5	
	Figure 1.11	1960–89	3.2	
	Table A1.2	1960–90	3.10; 0.23	
	Table A1.3	1960–89	–0.20 (technical efficiency)	
	Kawai [1994]	1970–80	0.7	
		1980–90	2.8	

(continued opposite)

TABLE 2 (cont.)

Country	Author	Period	Annual Rate TFP Growth (%)	Contribution to Output Growth(%)[b]
	Marti [1996]	1970–85	1.60	
		1970–90	1.41	
	Collins and Bosworth [1997]			
		1960–94	1.5	26.31
		1960–73	1.4	25.00
		1973–94	1.6	27.58
		1973–84	1.1	20.75
		1984–94	2.1	33.87
	Klenow and Rodriguez-Clare [1997]			
		1960–85	2.54	47.30
TAIWAN	Fischer [1993]	1961–88	1.69	
	World Bank [1993][a]			
	Figure 1.10	1960–89	4.2	
	Figure 1.11	1960–89	3.9	
	Table A1.2	1960–90	3.76; 1.28	
	Table A1.3	1960–89	0.84 (technical efficiency)	
	Kawai [1994]	1970–80	5.1	
		1980–90	3.9	
	Marti [1996]	1970–85	2.15	
		1970–90	2.09	35.72
	Collins and Bosworth [1997]			
		1960–94	2.0	34.48
		1960–73	2.2	32.35
		1973–94	1.8	34.61
		1973–84	0.9	18.36
		1984–94	2.8	50.00
	Klenow and Rodriguez-Clare [1997]			
		1960–85	3.03	57.17
HONG KONG	World Bank [1993][a]			
	Figure 1.10	1960–89	4.2	
	Figure 1.11	1960–89	3.8	
	Table A1.2	1960–90	3.64; 2.41	
	Table A1.3	1960–89	1.97 (technical efficiency)	
	Marti [1996]	1970–85	2.44	
		1970–90	2.40	48.09
	Klenow and Rodriguez-Clare [1997]			
		1960-85	4.39	79.96
JAPAN	World Bank [1993][a]			
	Figure 1.10	1960–89	3.7	
	Figure 1.11	1960–89	3.7	
	Table A1.2	1960–90	3.47; 1.42	
	Table A1.3	1960–89	0.98 (technical efficiency)	

(continued overleaf)

TABLE 2 (cont.)

Country	*Author*	*Period*	*Annual Rate TFP Growth (%)*	*Contribution to Output Growth(%)*[b]
	Marti [1996]	1970–85	1.19	
		1970–90	0.87	25.81
	Klenow and Rodriguez-Clare [1997]			
		1960–85	3.53	66.60

[a] World Bank [1993], Figures 1.10 and 1.11: Approximate figures, read from the graph. Table A1.2: The first figure comes from a regression pooling data for developed and developing countries. The second estimate is derived from a regression including only developed countries. It appears that what the World Bank did was to estimate the parameters of the production function (it did not impose them). Then it carried out a growth accounting exercise.

[b] Absent figures in CONTRIBUTION TO OUTPUT GROWTH (%) indicate that they are not available.

assumptions of each study. Often, one is led to contradictory results. It seems that re-working the data one can show almost anything. This should be a warning sign in drawing conclusions out of this literature. If anything, it indicates a general fragility about the empirical studies on the nature and sources of growth in East Asia.

IV. A RECONSIDERATION OF THE WORK ON PRODUCTIVITY GROWTH IN EAST ASIA

In this section we provide an evaluation of the above literature by pointing out different theoretical and empirical problems relating to the computation and the meaning of the measures of productivity. Some of them are generally accepted problems which were pointed out long ago, but which seem to have been ignored in the current frenzy for estimating residuals for the East and Southeast Asian countries. In each case we emphasise the implications for the understanding of East Asia's growth. For classification purposes, we have divided these issues into four groups: the concept of technology, measurement problems, conclusions and policy implications, and other arguments.

The Theoretical Concept of Technical Progress

(1) As noted above, technological progress as viewed in most studies is *exogenous*, *disembodied*, and *Hicks-neutral*. Conceptualised this way, technology is viewed as 'manna from heaven', and is completely dissociated from the process of investment and capital accumulation. Technology is considered to be a public good, that is, firms just choose from

a shelf of techniques readily available to the public domain; the acquisition of knowledge is assumed to be costless; and time is de-emphasised by assuming instantaneous acquisition of technology. The disembodied assumption implies that different vintages of capital differ only by a factor associated with depreciation and obsolescence, and disregards the possibility that capital may vary in productivity because it is not of the same vintage. Finally, there is no reward to whoever generated the technology; since income is divided between capital and labour, the cost of generating technology is not accounted for.

Only Kim and Lau [*1994*] hypothesised and tested that technological change was factor-augmenting (or biased), that is, technical change improves input efficiency (though still measured through a time trend). Algebraically, factor-augmenting technical change is expressed as

$$Q_t = F[x^*(x, t), t], \qquad (10)$$

where the notation denotes that production depends on an effective input vector x^*, which is a function of the level of input usage and of the state of technology. For empirical purposes, it is usual to hypothesise that the effectiveness of each input only depends on how much that input is used in production, and that input effectiveness is a numeric function of time, that is

$$x_i^* = \lambda_i(t)\, x_i, \qquad (11)$$

The idea behind this formulation is that input quality varies with time, so that one unit of labour, for example, in year t does not yield the same effective labour units as in year t+1. This formulation, however, still maintains a stable relationship between output, inputs, and time.

The embodiment hypothesis represents one step further in the direction of gaining realism, although none of the studies reviewed considered it explicitly. Embodiment implies that new technical knowledge is present only in new capital goods, and thus more recent additions to the capital stock must be weighted more heavily than earlier additions. New machines are intrinsically different from previous ones. Embodied technical innovation implies new designs, new methods and new inputs, especially capital, entering the production process (and in cases this leads to a new output). This can only be represented through a new production function. Analytically, embodied technical change requires differentiating the production function itself as well as the input bundle. Algebraically,

$$Q_t = F_t[K_t, L_t, t], \qquad (12)$$

where $F_\tau [K_\tau, L_\tau, \tau]$ and $F_T [K_T, L_T, T]$, $t = 1, \ldots \tau, \ldots T$ need not be the same functional form, and the input bundles at times and T may also be different. In this framework, the same quantity of physical capital (for example, a truck) has a different meaning at times τ and T if at T the same truck can be obtained from smaller quantities of labour and steel needed to produce the truck. This is not to say that models where technology is embodied, like for example the vintage models, are to be seen as diametrically different from models where technology is disembodied. Like in the latter, in the vintage theories, more recent vintages of capital goods are more efficient because of costless technical progress. In the words of Scott,

> Imagine that, 100 years ago, in a closed economy (or the whole world, say), all investment ceased, and also all population growth. For the next 100 years, capital assets were all maintained, so that each and every output remained constant. Arriving at the present after a century of stagnation, we start to invest again and what do we find? According to standard vintage theory, the machines available will be capable of producing jet aeroplanes, lasers, microcomputers, the whole array of modern drugs, and all the rest. Silently, without the need for any intervening investment, technical progress will have gone on, and the modern vintages actually available will miraculously be available in the hypothetical present too [*Scott, 1989: 95-6*].

(Jorgenson [*1966*] also argued against the embodiment hypothesis on the grounds that the theory has no operational content because technical change cannot be measured from the data). The question regarding the notion of technical progress referred to in the literature on the sources of growth in East Asia is significant. One has to ask whether one can conceive of any type of technical progress as exogenous, disembodied, and Hicks-neutral in real life. This does not mean that such a notion is wrong. As a theoretical conceptualisation of technical progress, and for pedagogical purposes, it is perfectly valid. However, intuitively, most technological progress (if not all) *must be* embodied in new inputs [*Kaldor, 1957*]; that is, the act of purchasing a new piece of machinery (that is, investment) represents technical progress in itself in that it entails a different method of production. It is not clear that purchasing the machinery represents exclusively capital accumulation; that how well one uses it represents technical progress; and that both can be easily split.

Solow [*1960*] and Arrow [*1962*] likewise argued that most technical progress, except for very small improvements (for example, better arrangement of the shop-floor due to learning by experience through the passage of time), had to be embodied in capital goods. These arguments do not deny that factors such as political stability, or the role of institutions, factors not embodied in capital, do not affect growth. The question is whether these factors are captured in the residual. Thus, the reason for using this formulation of productivity must be its sheer simplicity. The models of embodiment formulated in terms of vintage theories [*Solow, 1960; Nelson, 1964; Wolff, 1991, 1996*], are more complicated to implement empirically, since they require estimates of a measure of the change in the gap between the average level of technology and the best-practice technology, as well as of the growth of the average quality of capital. In recent empirical work, Wolff [*1991, 1996*], using regression analysis, concluded that the age of the capital stock affects productivity.

Problems of Measurement

(2) One important strand of work questioned the possibility of estimating the so-called technical progress as an independent factor. In particular, Kaldor [*1957*], and more recently Scott [*1989*], argued that it is pointless and artificial to try to distinguish either between investment and technical change, or between shifts in the production function and movements along it. This cannot be done because in the real world we do not observe the production function, but only actual combinations of factors and output in a dynamic process [*Pasinetti, 1959*]. Capital is the instrument for the introduction of technical change in the production process. Thus, Kaldor continued, saying that the annual growth of (exogenous, disembodied, and Hicks-neutral) technology was x percent for a given period is meaningless. More recently, Nadiri [*1970*], Nelson [*1981*], and Shaw [*1992*] have raised similar concerns under the so-called 'attribution problem', which questions directly the essence of the neo-classical attempt to separate the sources of growth. The neo-classical growth model assumes smooth substitution among inputs along an isoquant. According to expression (6), a one per cent increase in output could be achieved by either a one per cent increase in productivity growth, or a $(1/a_t)$ per cent increase in employment, or a $(1/(1-a_t))$ per cent increase in the capital stock. As a matter of arithmetic, and for very small changes, this is true; but if the inputs exhibit complementarity and are interdependent, this conceptualisation of the production process poses problems. If factors are complements, growth is super-additive in the sense that overall growth from the growth in inputs is greater than the mere sum of the individual growth rates of each input. In the words of Nelson:

> Consider the sources of a well made cake. It is possible to list a number of inputs – flour, sugar, milk, etc. It is even possible to analyze the effects upon the cake of having a little bit more or less of one ingredient, holding the other ingredients constant. But it makes no sense to try to divide up the credit for a good cake to various inputs [*Nelson, 1981: 1054*].

The neo-classical production function with substitution is set in a timeless world. When labour is substituted for capital, it is assumed that the new machines, corresponding to the new technology, can be installed instantaneously and without cost. This ignores that a book of blueprints representing a given state of technical knowledge is something which does not exist in nature. 'In real life techniques are blueprinted only when they are going to be used' [*Robinson, 1970: 255*]. If a firm has a given amount of machinery, adding to it more than the amount of labour for which it was designed, it does not get automatically reshaped to become a more labour-intensive machinery. This means that substitutability is a notion that operates ex-ante. Once a technique is chosen (for example, an oil rig), it cannot be transformed into anything else. In the manufacturing sector in particular, productivity improvements occur at the point of actual practice, reflecting what Atkinson and Stiglitz [*1969*] referred to as 'localised learning'. In real life producers look for ways to reduce costs that save on at least one input, rather than calculating the cost differences of various factor combinations along an isoquant. Therefore, if inputs in the production process are complements, the isoquant would be closer to the fixed-coefficients type, and thus performing growth accounting would be a disputable exercise (see Haltmaier [*1984*] for a measure of technical change when the production function is not differentiable). Growth accounting implicitly assumes that the interaction term between the factors is negligible. What we argue here is that one cannot understand the very notion of production without the interaction factor. The idea of complementarity among the inputs is at the core of any production process. Under these circumstances, it is not clear what the meaning of separating the contributions of inputs such as human and physical capital is (for example, think of a computer programmer and a computer).

(3) An important problem with growth accounting is that the measurement of TFP depends critically on assumptions about production functions, choice of output measure (value added versus gross output), use of capital stock versus flows of capital services, quality of inputs, quality of the deflators (especially for capital), cyclical smoothing, time period studied, errors of measurement in the variables, and so on. Different assumptions yield radically different residuals [*Norsworthy, 1984; Maddison, 1987; Fishlow et al., 1994: 61*]. Krugman, in fact, pointed out this issue in his comment on Young's [*1992*]:

> 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 here is that in fact Singapore grew more rapidly than the numbers suggest [*Krugman, 1992: 55*; italics added].

Taking Krugman's comment to its ultimate conclusions, the question is 'what is *real value added*?' Does this notion make any sense? Value added is an economic number without physical interpretation. Firms do not produce value added, but gross output. Value added is constructed by subtracting intermediate inputs from gross output. But this is, by definition, the sum of wages and profits, a value concept whose deflation does not yield an equivalent to a physical volume. Empirically, there is no measure of aggregate output as a physical quantity. Thus, it is necessary to use (constant price) value data in applied work.

(4) In the debate about the sources of growth in East Asia, some authors have complained about 'the unreliable capital stock figures' [*Dowrick, 1995: 28*; also *Pack and Page, 1994b: 253*]. Scholars usually estimate the stock of capital using the perpetual inventory method (or variations of it). The initial stock of capital is the sum of past (available) investment and a depreciation rate is assumed. This procedure has been found in simulation analyses to be robust to changes in the depreciation rate and the beginning of capital accumulation [*Sarel, 1995*]. However, it is not clear what the rationale for the above complaint is, other than pure instrumentalism. The growth rates of the stocks of capital of the countries in the region tend to be rather high, making the TFP growth rate appear smaller. But these estimates are no worse than others which would lead to highly positive rates of TFP growth. The question at stake here is that the aggregate stocks of capital estimated using the perpetual inventory method are in no way close to the true stocks of physical capital. The Cambridge controversies of the 1950s and 1960s brought up, among others, the problems inherent in defining and measuring capital [*Robinson, 1971b; Creamer, 1972; Rymes, 1972; Harcout, 1969, 1972*]. The problem stems from the difficulties in finding a unit in which capital may be measured as a number, that is, an index independent of relative prices and distribution. The Cambridge-England side argued that the aggregate stock of capital can only be measured by a value-related concept, and that the deflation process does not lead to physical volumes. The stock of capital, however deflated, is still a value notion which is affected by changes in the relative factor prices, the interest rates, and wage rates. The value of capital is the sum of its discounted stream of future net revenues, a sum that will vary as interest rates and price expectations are altered. Consequently, there is no unique capital stock

[*Robinson, 1970, 1971a*]. The same problem applies to aggregate output. At the aggregate level, the only way to express total physical output is through its value, and deflating it does not lead to the volume of output. Only labour can, in principle, be measured in a physical, technical unit (although one can also pose similar problems for aggregating different types of labour). Thus, with this amalgam of units, it is difficult to know what the units of the economy-wide TFP are.[7]

These issues have been completely ignored in the debate of the sources of growth in East Asia. However, once one realises that what statistics measure is simply the 'value' of capital, not the 'quantity', things must fall into place. These figures cannot be made to correspond to a meaningful physical equivalent. Sarel [*1996*] showed that by varying the capital's share within a range of 0.3 to 0.5 (together with some assumptions), one can obtain a wide range of productivity growth estimates for the Southeast Asian countries (see also Dowling and Summers [*1997*] for an analysis of results with two data bases). Much misunderstanding would have been avoided by recalling Joan Robinson's [*1971b: 598*] rhetorical question, 'In what unit is "capital" to be measured?'

(5) The appropriateness of the growth accounting method hinges on how well the assumption of perfectly competitive markets approximates the real economy at the aggregate level. If such an approximation is not close, then one cannot use factor prices to approximate marginal products of inputs and consequently, weighing growth rates of various contributing factors by their factor shares in national income to account for total growth becomes problematic. If markets are not competitive, the output elasticities will not equal their respective factor shares. In the particular case of the East Asian countries, could it be that the factor shares applied to the growth rates of the factor inputs (in growth accounting exercises), in particular that of capital, are too high? This argument is implicit in Pack and Page [*1994a, 1994b*] criticism of Young [*1994a*], and in Nelson and Pack [*1996*]. Also recently, Stiglitz asked: 'Does anyone who has studied wage setting in Singapore, for example, really believe that wages are set in a competitive process, so that the real wage equals the marginal product of labor, as most of the studies assume?' [*Stiglitz, 1997: 16*], and Maddison, despite being a clear advocate of growth accounting, pointed out: 'One has only to look at the empirical basis from which the weights are derived to see that the neo-classical assumptions are very crude' [*Maddison, 1987: 658*].

Factor markets can be distorted in developing countries due to many reasons, such as regulations concerning job security, existence of social security schemes, minimum wage legislation, and wage and employment policies in the public sector [*Balassa, 1988*] (although lack of unionisation and employment rights characterises the labour market of many developing economies, thus bringing down the labour share). This may be the case of the rapidly industrialising economies of East and Southeast Asia where most likely there are market imperfections causing a divergence between the price per unit of each employed factor and its marginal value product. In fact, Chen [*1991*] rejected this hypothesis for Singapore and Kim and Lau [*1994*] for the G-5 and the four NIEs (see, however, Felipe [*1998a*] for a discussion of the tests). Under conditions of imperfect competition the output elasticities do not equal the factor shares, but the product of the latter times a factor that is a function of the price elasticity of demand for output, and the supply elasticities of labour and capital. Since in general this factor is greater than one (since no profit maximising firm will produce at a point on the demand curve where demand is inelastic), the use of factor shares under conditions of imperfect competition leads to underestimating the role of resource mobilisation and overestimating that of technical progress. This does not directly explain the results encountered for the East Asian countries, since for them the residual tends to be small; it does point out, however, that unless the above elasticities are infinite (case of competitive markets), the procedure of weighing the growth of inputs by their factor shares is wrong, and Solow residuals do not correctly measure the productive contribution of inputs if constant returns and/or perfect competition fails.

Conclusions and Policy Inferences

(6) It is far from clear that there is a theoretical link between a zero TFP growth in Singapore and the possibility that the city-state may have pushed itself into technologies too far ahead of itself to benefit from learning by doing (and the same applies to the arguments about the merits of laissez-fair in Hong Kong). Likewise, the theoretical link between a zero residual and the deleterious results of industrial policies [*Young 1992*] is obscure. And there is no empirical evidence of such link. Finally, why do these results imply that countries in East Asia have to devote greater proportions of their resources to research and development, as suggested by Kim and Lau [*1994*]? This last point presupposes, somehow, the validity of the so-called linear or science-push model of innovation, according to which the latter is driven by pure scientific research; R&D laboratories and the like apply this research to practical industrial problems, and then firms take up the applied results and diffuse them. However, it is now recognised that 'to represent the innovation process as linear and science-driven is hopelessly inaccurate and simplistic' [*Hall, 1994: 22*]. Technology is not an automatic by-product of production capacity. But even in advanced countries, research is rarely the core activity in accumulating technology. It is not only scientific and

engineering knowledge which lead to advancement, but also knowledge of accounting, management, control, information, credit, finance, and legal systems [*Scott, 1992*]. Growth accounting exercises are just that, accounting exercises where there is no formal test of any hypothesis. There is no presumption of a causal behavioral relationship from factor input growth or from the residual to output growth. Exogenous increases in technology could cause both output and capital to grow. The problem is that most studies confound this decomposition of the overall growth rate with its explanation. This tendency stems from the indisputable association between the residual and the idea of technical progress, when it is not clear that there is any. In the words of Griliches and of Scott, 'Despite all this work, there is still no general agreement on what the computed productivity measures actually measure, how they are to be interpreted and what are the major sources of their fluctuations and growth' [*Griliches, 1988: 363*] and:

> The question then to be answered is whether the residual effect of 'technical progress' corresponds to anything interesting. I rather doubt it. There is no reason to suppose, for example, that technical progress, so defined, measures the effect of research and development expenditures. Indeed, I cannot think what it measures, except (tautologically) the difference between an actual increase in output and a purely hypothetical increase, which is based on a set of definitions that I can see no reason for using [*Scott, 1989: 88*].

This has been the case in the recent analysis of growth in East Asia, and it has important implications for (the lack of) policy analysis, since by definition we cannot explain what we do not know, namely, the residual. It is surprising, therefore, that much of the East Asian controversy concentrates on the role of policies that are supposed to operate by promoting growth in TFP. In the words of Sudit and Finger: 'Public exhortations for deliberate efforts to "improve" the rate of growth in aggregate productivity suffer from an underlying contradiction in logic. We simply cannot hope to affect consciously something that is defined to measure our lack of knowledge' [*Sudit and Finger, 1981: 7*].

Nevertheless, authors tend to interpret the TFP estimates as measures of technical progress, and try to derive conclusions about the validity of different policies and growth strategies [*Mowery and Oxley, 1995: 69; Collins and Bosworth, 1997: 138*]. Growth and development policies should promote higher savings, better education, and a more skilled labour force, regardless of TFP. This tendency achieved its climax in Krugman's [*1994*] article, which provided a rather negative evaluation of the growth model of the East Asian NIEs based on the results of Young and Kim and Lau. In some cases, authors also run regressions of the TFP growth rate as the dependent variable on variables such as openness, inflation, and government expenditures [*World Bank, 1993; Fischer, 1993; Collins and Bosworth, 1997; Thomas and Wang, 1997*]. This type of regression, apart from having problems of interpretation, incurs serious econometric problems. Since the dependent variable is measured with error, and most likely so are the right-hand-side variables, the ordinary least squares estimates are biased and inconsistent. Levine and Renelt [*1992*] have also pointed out the fragility of these regressions with respect to alternative specifications, the choice of countries, and data-sets.

Other Arguments

(7) The assimilationists have pointed out that the analysis based on the calculations of residuals or the estimation of production functions, although useful in some sense, misses the core of what has been the growth process of East Asia during the last 30 years, and in particular the role of the assimilation of technology from the developed countries. They argue that in order to understand many of the subtleties of the process, one requires a different type of analysis, a different framework more microeconomic in nature and where technical progress, organisation and management, and government policies are explicitly studied. Likewise, the learning process cannot be framed in the ideas proposed by the new neo-classical endogenous growth models, such as learning by doing or R&D, where technology accumulation is a passive and costless activity, just another variable not clearly measured in an aggregate production function [*Hobday, 1995*]. Technological progress is a dynamic process difficult to measure due to the fundamental uncertainty that characterises it. For example, on the application of growth accounting and Young's reasoning about Singapore's inadequate timing of learning by doing and fast movement up in the development ladder, Huff argues

> This fails to understand the quickly-exhausted nature of the learning curve, and so the limited gains available in the particular international division of labor on which Singapore's spectacular manufacturing growth depended. Singapore has in fact benefitted from higher value-added activities (even in some parts of the electronics sector), and Singaporeans were increasingly employed as technicians and in supervisory positions. But for electronics, the bulk of technological progress and learning gains were found in developed countries where research and development and process and product design concentrated [*Huff, 1995: 742*].

Hobday summarised his case studies on the Asian NIEs as follows:

> Rather than leapfrogging from one vintage of technology to another ... TNCs and local East Asian firms engaged in a painstaking and cumulative process of technological learning: a hard slog rather than a leapfrog. The route to software and advanced information technology was through a long difficult learning process, driven by the manufacture of electronics goods for export [*Hobday, 1995: 200*]

and Goh concluded

> The dynamic effects of economic restructuring and scaling the technology ladder appear neglected in the analysis ... A proper assessment of the dynamics of the industrial revolution in the East Asian economies needs to take account of their structural transformation and their sustained investment in human capital [*Goh, 1996: 11*].

(8) In recent work, Nelson and Pack [*1996*] have questioned the results of growth accounting on the grounds that in the standard Tornqvist approximation factor shares are continuously rebased. Nelson and Pack argue that the correct factor shares are not the observed, but those which would have ocurred in the absence of technical change. The reason is that if the latter is biased, then the output elasticities will be affected by the rate of technical progress that occurs throughout the period under consideration. Therefore, the correct factor shares to use in growth accounting should be those that would have occurred with the *base year technology*, which depend on the elasticity of substitution (see Nelson [*1973*] for an early exposition of the problem). If the underlying production function is Cobb-Douglas, however, there is no difference; but if technical change is biased, then the observed and the counterfactual shares will differ. This suggests that unless we know the value of the elasticity of substitution we cannot allocate overall growth between capital intensity and biased technical change. This is an implication of the 'Impossibility Theorem' [*Diamond et al., 1972, 1978*]. Therefore, growth accounting exercises cannot distinguish between two different explanations of the growth decomposition equally consistent with the time series data: one arising from a production function with unitary elasticity and Hicks-neutral technical change, and another arising from a production function with an elasticity less than one, and labour-saving technological change. Under the first interpretation, with a steeper production function due to a sufficiently high elasticity of substitution, relatively less of overall growth is attributed to the shift in the production function. Under the second interpretation, on the other hand, the lower elasticity of substitution means that less of output growth can be attributed to growing capital intensity, and hence more must be attributed to

improved technology. Nelson and Pack argue that the accumulationists think of growth in East Asia with the first interpretation in mind. They believe, however, that the second interpretation reflects better the East Asian experience, and that possibly the region experienced an enormous amount of labour-saving technical progress (see Felipe and McCombie [*1998a*] for an evaluation of these arguments, and for an assessment of their quantitative importance).

(9) Felipe and McCombie [*1997*] note that the debates concerning the determinants of growth in East Asia have been based either explicitly or implicitly on the assumption that there exists an aggregate production function which summarises the technological relationships at the economy-wide level. Such assumption is so standard that it is virtually never questioned. The validity of the notion of aggregate production function as a summary of the alleged aggregate technology is, however, more than dubious in the light of the substantial literature on the so-called aggregation problems [*Harcourt, 1972; Fisher, 1992*]. The main conclusion of this body of literature is that there is no theoretical basis for the concepts of aggregate output, aggregate capital, or aggregate labour, and as a consequence, for the notion of aggregate production function. Does it make sense in a less developed country to sum up the production technologies of the peasant farmer, the small over-crowded sweat shop, and the modern factory of the multinational corporation into a single production relationship? What, in these circumstances, does the 'aggregate' elasticity of substitution mean? These considerations take Felipe and McCombie [*1997*] to question growth accounting as well as econometric estimations of production functions. Indeed, they show that these methods can be viewed merely as algebraic manipulations of the national income accounting identity (that is, value added equals the wage bill plus profits), and that far from estimating the rate of technological progress, they yield only a *weighted average of the growth rates of the wage and profit rates*. This, they prove, need not be identified with the growth rate of technical progress. To see this, note that national income is the sum of the wage bill plus profits. This can be written as

$$Q_t = w_t L_t + r_t K_t , \qquad (13)$$

where Q, w, L, r, and K are national income, average wage rate, employment, average profit rate, and stock of capital, respectively (this is an ex-post relationship that holds always). Expressing (13) in growth rates one obtains

$$q_t = a_t \varphi_{wt} + (1-a_t)\, \varphi_{rt} + a_t l_t + (1-a_t)\, k_t = \varphi_t + a_t l_t + (1-1a_t)\, k_t , \qquad (14)$$

where lowercase letters denote growth rates, a_t and $(1-a_t)$ are the labour and capital shares, and φ_{wt} and φ_{rt} are the growth rates of the wage and profit rates, respectively. The important aspect to remark is that the first part of (14), that is, $\varphi_t = a_t \varphi_{wt} + (1-a_t) \varphi_{rt}$, is equivalent to expression (6) above, the Solow residual, derived from an aggregate production function assuming perfect competition and profit maximisation. The same expression, without recourse to any model or assumption, follows directly as an algebraic transformation of the national income accounting identity.[4] Since all has been done is to manipulate an accounting identity, nothing can be said about the rate of technical change. In other words: what is at stake is the *empirical validity* of the aggregate production function (should this exist) as a summary of the aggregate technology. On the basis of these arguments, Felipe and McCombie [*1997*] revisit the works of Young and Kim and Lau, and show how their analyses can be reinterpreted under the prism of these arguments, thus questioning their conclusions (see also Felipe [*1998a*] for a detailed example for Singapore).

V. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

In this article we have surveyed the current state of the literature on productivity growth in the East Asian region. This literature has a clear empirical tone, where the notion of productivity used is the Solow residual, estimated via growth accounting or through the econometric estimation of production functions. The major question that this study has posed is whether we have learned anything about growth in the East Asian region by carrying out these exercises. The answer is rather skeptical. The use of more or less sophisticated quantitative techniques embedded in an aggregate production function with a parameter proxying technological progress have revealed the limits of such a quantitative approach. Contrary to Maddison's [*1987: 677*] assertion that growth accounting, with the possible exception of those Cambridge economists in the Robinson-Sraffa tradition, could be used by most economists, this survey has shown that this methodology suffers from serious drawbacks. And furthermore, the recent application of these techniques to the study of the East and Southeast Asian economies – with their peculiar findings – has been questioned by a wide spectrum of scholars. We have discussed several arguments that justify this conclusion.

First, the notion of technological progress that most papers refer to is exogenous, disembodied, and Hicks-neutral. Although theoretically correct, this view of technical progress cannot be taken as the departing point in the analysis of productivity growth. An important part of technical progress is embodied in the factors of production. Second, there are serious objections as to the intrinsic meaning of decomposing overall growth (the attribution problem) and the validity of this exercise if factors exhibit complementarity. The attempt to separate artificially the contribution of technical progress must be abandoned. Also, if imperfect competition prevails, factor shares and elasticities will diverge. Third, the results of growth accounting exercises or estimation of production functions do not allow us to make an overall evaluation of the industrial policy and government intervention in any country, for example, Singapore *vis-à-vis* the *laissez-faire* policies of Hong Kong, much less to conclude that the latter have proven to be superior. Performing a growth accounting exercise with the aim of decomposing overall growth or fitting a production function is not the same as explaining the ultimate causes of growth. Therefore, most explanations about the growth of the countries under study, advanced ex-post, are unwarranted, and thus, fallacious. In other words, there is an unfilled gap between calculating zero productivity growth and attributing it to the failure of industrial policy. Fourth, the assimilationists have indicated that in order to understand how East Asia grew, one has to understand how technology from the developed countries was assimilated. Fifth, recent work has questioned from different points of view the theoretical underpinnings behind growth accounting, and the use of aggregate production functions. Finally, there is a wide variety of significantly different estimates of productivity growth, calculated using different models and under different assumptions. This is of little use. It is surprising that most researchers investigating the Asian Miracle compute the measures of productivity without warning about the problems of the method used. All in all, we conclude that the rate of TFP is not a *sufficient statistic* to draw conclusions and to make any policy statement about growth in East Asia, much less to predict its future.

The reader should not infer from the previous lines that the work on productivity growth in East Asia has been completely futile. These conclusions do not intend to convey the message that today we do not know more about the nature of growth in the region than five years ago, and that the intense debate about the sources of growth has not had a positive side. The main merit of this literature is that it has focused the attention of scholars on the growth process of East Asia. And, concurrently, it has made countries in the region aware of the importance of productivity. Singapore, for example, has set a target of achieving a TFP growth rate of two per cent a year [*Asian Productivity Organisation, 1997*]. Independently of the problems inherent in the notion of TFP, certainly the intention of increasing 'productivity' must be seen as a positive factor. But this must be true always, as a general principle. Every country, from the richest to the poorest, from the most technologically advanced to the most backward, must strive to increase productivity. What we want to stress is that, perhaps, we have abused and misused the notion of total factor productivity growth, and talked about productivity, and certainly about technical progress, in a very loose and imprecise sense, to the point of making the whole debate useless. Probably too much has been inferred about the policies of the East Asian countries from the simple techniques used in neo-classical economics (as defined in section II) to estimate the contribution of productivity to overall growth. One can discuss technical progress even at the aggregate level. Certainly statements such as 'the level of technology of the U.S. is higher than of Indonesia', are not without meaning. The problem comes when one tries to justify that type of assertions using a number with dubious theoretical underpinning. And without any doubt, at this point, the *Solowresidualization* of the East Asian economies is an activity that one would like to discourage, since it is subject to significant decreasing returns. The arguments put forward by the assimilationists about the importance of understanding how East Asian countries mastered foreign technology are essentially correct. But the analysis of growth and productivity in East Asia has to move beyond the use of aggregate production functions and look into other paradigms. The aggregate production function is a concept with little theoretical justification.

We need to keep studying the experience of these countries. However, if we are to advance in our quest for understanding how East Asia grew during the last 30 years we need new avenues of research in the following directions:

(i) Understanding what technology is, how technical change occurs, and the microeconomic foundations of the process of technology transfer (for example, foreign direct investment) in the region [*Bell and Pavitt, 1993*]. Neither the original neo-classical model nor the recent advances in the form of the new neo-classical endogenous growth models make a true effort toward understanding what technology is (see Pack [*1994*]; Bardhan [*1994*] for criticisms of this class of models). Unlike Marx or Schumpeter, neo-classical economics discovered the importance of technical progress by serendipity. The classical work of Nelson and Winter [*1982*] on evolutionary theory, for example, was a true effort in that direction. In this work, the discovery or creation of a new technology is recognised as an uncertain and costly business, and the ability of firms to imitate the technologies of other firms, a crucial aspect in order to understand how East Asian firms assimilated Western technologies, is specifically considered. Likewise, dynamic competition through continuous innovation and imitation, together with disequilibria, uncertainty, learning, and inter-firm and inter-country differences in behaviour, are central to the discussion. Likewise, Khan [*1998*] is a proposal for modeling technology as a complex non-linear system within a social context, for understanding how countries create and assimilate technology, and how the latter is linked with the process of development.

(ii) Providing a better understanding of the interaction between human and physical capital. The work on endogenous growth is suggestive, but we need more work, and especially more empirical evidence, at the micro-level. The recent work of Hobday [*1995*] on innovation in East Asia, taking the firm as the central player in the accumulation of technology, is a step in the right direction. Mason et al. [*1996*] and Oulton [*1996*] also provide very useful insight into questions such as the workforce skill levels, productivity, product quality, and economic performance, by directly comparing firms; their methodology and type of analysis could be applied to the understanding of the East Asian miracle.

(iii) As pointed out in section II, the notion of labour productivity as an indicator of productive efficiency is a theory-free concept, and can be used at the macro-level. On the basis of this measure, there is little doubt that the East and Southeast Asian countries registered improvements during the last 30 years.

(iv) At the macro-level there are already paradigms, other than the neo-classical model, that can be helpful in explaining how the East Asian countries grew. McCombie and Thirlwall [*1994*] argue that what one has to explain is the rapid increase in capital accumulation and in the labour force (as discussed above, growth accounting is helpless). Since both these variables are endogenous to output, there must be some external force driving the latter. Such force is exports.

The end result of the above proposals would be not the ability to measure something called the rate of productivity growth for the whole economy, but rather a correct and more complete and accurate understanding of the forces that drove East Asia's growth during the last 30 years.

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NOTES

1. Thus, we can see that Kim and Lau's model and assumptions, as well as results, are different from those of Young, and treating them as equivalent is not correct [*Chen, 1997: 22*].
2. Klenow and Rodriguez-Clare [*1997*] also estimated the level of TFP in 1985 with respect to that of the United States. The results are: Hong Kong, 88 per cent; Indonesia, 32 per cent; Japan, 63 per cent; Korea, 54 per cent; Malaysia, 63 per cent; Philippines, 26 per cent;

Singapore, 103 per cent; Taiwan, 75 per cent; Thailand, 33 per cent. These results are a bit dubious. Even more so are those for Mexico, 129 per cent; or Congo, 81 per cent. It is worth comparing these levels of productivity with those estimated by Kim and Lau [*1994*].

3. Scott [*1989*] argues that if the contribution of capital to overall growth were properly measured, there should be no residual in growth accounting exercises. The correct way to measure this contribution is by adding up gross investment.
4. The argument is also extended to econometric estimation of the production function. Note, for example, that if factor shares were constant,that is, $a_t = a$, and the growth rates of the wage and profit rates were also constant, that is, $\varphi_{wt} = \varphi_w$, $\varphi_{rt} = \varphi_r$, then integration of (14) yields a form *identical with* the Cobb-Douglas production function where the exponents are the factor shares (which of course add up to 1). Felipe and McCombie generalise this, and prove that production function fitting must always yield constant returns to scale. If increasing or decreasing returns appear they will be the result of choosing the wrong functional form for the corresponding data-set. But all this is, however, the result of the isomorphism between the production function and the accounting identity. The conclusion is that the estimation of aggregate production functions cannot provide independent evidence regarding the technological parameters.

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