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Growth accounting, development accounting and cross-country growth regressions: A conceptual review essay

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Background: This review article sets out to identify certain critiques of growth accounting, development accounting and cross-country growth regressions. These critiques provide insights relevant to the usefulness and policy relevance of these methods.

Aim: The aim of this article was to critically review literature and to provide a synthesis of this literature, deriving certain arguments to contribute to further research.

Method: This article takes the form of a critical review essay.

Results: Growth accounting, development accounting and cross-country growth regressions all have some limitations and knowledge of their strengths and weaknesses may be helpful for those who are undertaking transdisciplinary social science research using these methods. These methods seem to suffer from similar criticisms levelled at neoclassical thinking, which need to be considered more seriously in the literature.

Conclusion: Further research should explore how such methods might complement each other to improve validity of research findings.

Keywords: growth accounting; development accounting; cross-country growth regressions; research methodology; empirical research techniques.

Introduction

A large and growing body of literature is concerned with empirical tests of growth and its relationships with other variables.[1,2,3,4,5] Growth accounting exercises, development accounting exercises and cross-country growth regressions have been used extensively to investigate economic growth and to decompose aspects of the growth process. However, a strong critique of these approaches has emerged over time in the literature. The problem this essay addresses is the lack of clarity or tension, between these two bodies of literature. This review essay therefore seeks to explore this tension and offer certain arguments in order to reconcile these differences. Firstly, it is argued that global poverty and inequality pose certain challenges or costs, both directly and in the form of negative externalities and the incidence of these are typically borne by those who are most vulnerable and powerless. Economic growth is important, as it can lift populations out of impoverished conditions. However, if growth accounting and development accounting exercises and cross-country regressions proceed on the basis of incorrect assumptions or under conditions that are unsuited to their effective use, then further costs accrue to theorists and policymakers who are dependent on the results of the use of these methods. Secondly, without an understanding of strengths and weaknesses associated with each of these methods, theory development will not be able to proceed from a sound base. Thirdly, knowledge of the deficiencies and strengths of these methods allow for their judicial use in appropriate contexts and circumstances, the avoidance of inappropriate use and the attendant consequences.

This article proceeds as follows. Firstly, the methodology of the article is introduced and discussed. Secondly, literature relating to growth accounting is reviewed. Debates regarding growth accounting are then discussed and issues relating to the concept of technology itself, measurement issues and contemporary thought on growth and development accounting related problems are highlighted. A consideration of development accounting and its criticisms is then followed by a discussion of criticisms of growth regressions. This review essay then concludes with a summary of the main arguments derived from the analysis.

It should be observed from the outset, however, that many of the arguments for and against growth and development accounting, as well as growth regressions, are cross-cutting and in order to avoid duplication, or redundancy, are dealt with in the growth accounting section, and these discussions are not repeated in the growth accounting or growth regressions sections. The methodology of the work is introduced and discussed in the following section.

Methodology

This article applies a conceptual essay methodology, which is appropriate for studies seeking to present arguments and perspectives relevant to a field of study. It extends previous literature to clarify and discuss certain strengths and weaknesses associated with growth accounting, development accounting and cross-country growth regressions and derives recommendations for further research and practice.

Growth accounting

According to Barro,[6] the growth accounting method decomposes (economic) growth into component 'parts' reflecting changes of factor inputs and a residual that is taken to represent technological progress. Growth accounting is therefore an important initial process analysing what contributes to economic growth.[6] Barro's work builds on a stream of literature that extends the work of Nobel Laureate Solow,[7] who derived a model for economic growth. This model served as the basis for work by others, who have amended or augmented his model to incorporate additional factors contributing to growth. For example, Nobel Laureates such as Lucas,[8] Romer[9] and others. This stream of research has been described as neoclassical and it has been influential, particularly in macroeconomics.

Arguably, growth accounting provides a 'first stage' in the growth analysis process. The final step in the growth accounting process involves relating growth rates of factors, shares of factors and technological change (captured as a residual), to other variables such as 'government policies, household preferences, natural resources, initial levels of physical and human capital, and so on' (p. 1).[6] A definitional example of this residual is the variance that is not explained in growth when growth is regressed on human and physical capital. This residual would capture the effects of how well human and physical capital are combined, which Solow terms technical progress. Solow's model considered technical progress to be exogenous to the model because it was not explicitly considered. This led to it being called a measure of our ignorance,[10] because it was difficult to explicitly describe what comprised this residual. Romer's[9] work is notable because he sought to incorporate technical progress, or technology and knowledge creation, within his model, giving rise to the term 'endogenous growth'. When growth is regressed on human and physical capital this residual value is expected to manifest, or be present in, in the error term of the regression – what is 'left behind'. Thus, the terms residual and error term are synonymous in their use here.

What is particularly valuable about the growth accounting exercise is that it allows for a differentiation between fundamental determinants important for growth rates independent of those important for technological change.[6] This differentiation, however, is contested, and more recent research,[11] challenges the usefulness of orthogonal conceptions of deconstructing these elements of growth equations, instead of a more nuanced approach to understanding complementarities between these elements (a more detailed discussion of these critiques follows in later sections).

There are different forms of growth accounting. It builds on a neoclassical production function $Y = F(A, K, L)$ with A representing the level of technology, K a measure of capital stock and L a measure of the quantity of labour; where the growth rate of output is made up of different components based on technological progress and factor accumulation.[6] By differentiating the equation by time and division by Y and rearranging the terms, changes in factor (social) marginal products for labour and capital, as well as the growth rate in technology can be modelled within the equation.[6] Another approach to growth accounting is the dual approach, in which the Solow residual is calculated based on growth rates of prices of factors instead of quantities.[6] As discussed, growth accounting has its roots in Solow's[12] separation of growth output into growth in output, labour and technological change, starting with production function (Equation 1), in which Y is output, K is capital, L is labour and B is a Hicks-neutral productivity term:

$$Y = BK^{\alpha} L^{1-\alpha} \quad \text{[Eqn 1]}$$

By taking logs and differentiating by time, Equation 2 is obtained, 'the key formula of growth accounting' (p. 45):[13]

$$\frac{\dot{Y}}{Y} = \alpha \frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} + \frac{\dot{B}}{B} \quad \text{[Eqn 2]}$$

According to this equation, output growth is a weighted average, of capital and labour growth in addition to B's growth rate; the latter term in Equation 2 typically termed 'total factor productivity growth' or 'multifactor productivity growth'.[13] By subtracting the labour term from both sides, the growth rate in output per worker can be decomposed into the contributions of (1) physical capital per worker and (2) contribution from multifactor productivity growth.[13] To illustrate this process growth accounting of US data reveals that between 1948 and 2010 private sector output per hour grew on average annually by 2.6% and the contribution from capital per hour was 1.0 percentage points versus 0.2 from the changing composition of the labour force, whilst multifactor productivity accounted for 1.4 percentage points.[13] These results suggest that about half of this growth may have been because of factor accumulation and the other half as a result of productivity improvements in these factors or the 'residual'. As discussed, literature has referred to this as a measure of our ignorance.[13] Interestingly, according to this data, after 1973 the value of this residual dropped, which

might offer some idea of what is included in this term. According to some, this might reflect a structural shift away from manufacturing (with high labour productivity) towards services (with lower labour productivity) or perhaps a slowdown in the late 1960s in research spending; the counterpoint to this is the productivity increases of 1995–2000, reflecting what has been termed the 'New Economy' related to growth in output per hour and multifactor productivity as evidence suggests about half of the increases in multifactor productivity growth may be because of higher productivity in information technology production.[13] Growth accounting provides helpful insights into these relationships, but it is important to stress at this nexus that certain of these assumptions are not uncontested. As discussed later, the neoclassical 'lens' and its related assumptions have been challenged. Some have argued that economic growth cannot be considered in any way to be exogenous or Hicks-neutral and that the relationships between these variables can be interactive. It is important to reconcile these important critiques with the growth accounting literature in order to understand the boundary conditions or important limitations to these methods. The use of a residual is also problematic, as this residual can contain literally anything. It is argued here that growth accounting can be a useful first step in a growth analysis (as acknowledged by Barro), but that it essentially explains very little about exactly what drives growth in the residual term. An example of this lack of clarity is evident in suggestions of Hall and Jones's.[14]

Hall and Jones use an accounting approach and show that variance in physical capital and educational attainment do not fully explain variance of output per worker and large variations of the Solow residual for comparing it across countries; they suggest differences in capital accumulation, the productivity and the output per worker are driven by institutional differences and variance associated with the policies of governments-endogenous 'social infrastructure'. According to Hall and Jones[14] the residual term picks up social infrastructure effects, which may allow individuals to harness social returns to behaviour in the form of private returns. Arguably, this might be taken as evidence to suggest that (1) some causal mechanisms associated with growth and social infrastructure are inherently endogenous and therefore (2) a complementary perspective of these variables might be more useful.[11] Another indicator of this lack of clarity is perhaps the lack of consensus around relative contributions of the different factors in the growth accounting models.

In the decade up to 2003, despite much empirical research on growth and what may cause it, a lack of consensus persisted as to how much of this contribution is due to capital accumulation versus total factor productivity (TFP) improvements in accounting for growth differences over time and across countries.[15] This lack of consensus extends to the role of education and economic policy, with conflicting results from studies; within this context, growth accounting and growth regressions have been criticised and some have argued their irrelevance to policymaking.[15] Bosworth and Collins[15] argue, however, that both growth accounting and growth regressions can provide valuable insights into testing and a lack of attention to measurement and consistency in their use has been problematic; however, with the requisite attention contradictions between findings in the literature can be explained. Bosworth and Collins[15] applied growth accounts and growth regressions in concert, using data across the years 1960–1980 and 1980–2000, to investigate the channels of factor accumulation versus increased factor productivity in their contribution to growth. Other authors, however, contest this, and argued that measurement issues arise from the approach dictated by the neoclassical assumptions applied in growth accounting. This is discussed further in a later section.

What seems to be a well reasoned approach in support of the use of growth accounting (and development accounting) frameworks is Temple's[16] notion that these techniques have value in enabling thought experiments. Given that economists are typically denied the brick and mortar laboratories fields such as chemistry enjoy, frameworks that allow 'what if?' conceptual abstractions have an important place in the field. This notion is less contested. According to Temple,[16] growth models are valuable not in terms of their realism, per se, or the extent to which they reflect reality but because of their ability to support 'thought experiments;' the 'key point is that apparently restrictive assumptions are useful precisely because they allow us to abstract from matters not directly relevant to the problem at hand and to carry out experiments holding certain variables constant' as these models are 'the laboratory we otherwise don't have (p. 500)'.

At this nexus, claims of the successes of growth accounting are considered, before their critiques are introduced and discussed. According to certain research, growth accounting has been successfully applied to analyse fast-growing countries such as South Korea, Hong Kong, Singapore and Taiwan, which have shown growth rates of over 4% from 1960 onwards; growth accounting reveals high growth rates of output per worker but, relative to output per worker, TFP growth rates have not been as high.[13] This suggests that growth in capital and education has a disproportionate influence in these countries. Therefore, this analysis supports the salience of the Solow model,[13] and, hence, growth accountancy as useful and policy relevant tool of analysis.

The extent to which growth accounting is entrenched in certain sectors of the field (and especially neoclassical sectors) is perhaps well illustrated by its results for which some have claimed 'stylised fact' status. According to Easterley and Levine,[17] it is a stylised fact of economic growth that the TFP residual, rather than factor accumulation is responsible for most differences in income and growth across countries. Having outlined literature relating to growth accounting, the focus now shifts to certain critiques of growth accounting.

Criticisms of growth accounting

Growth accounting often allocates observed output growth between factor input changes versus a residual, TFP, measuring both changes in efficiency in input use and technology change; these expose sources of changes in productivity growth and information technology and differences in experiences of countries.[15] However, it has been suggested that its use has failed to settle debates around the relative importance of increased capital per worker versus factor productivity improvements and critics have stressed the following issues:[10] (1) That TFP should not be considered to represent technical change because, measured as a residual, although reflecting output increases relative to inputs as shifts in the production function, as a residual it can include other determinants over and above technological innovation (such as political unrest, external shocks, policy change, institutional change and measurement error). (2) That the growth decomposition process can be based on assumptions which might not hold (such as sufficient levels of competition to allow factor earnings to be proportionate to factor productivity and measured factor shares of income), although estimation might not be unreasonable, given the stability of estimates of factor shares across countries once the labour component of the earnings of the self-employment is accounted for. (3) That accounting decomposition cannot imply causality; growth accounting, in countries experiencing accumulation of capital per worker together with factor productivity, cannot show which causes which.[15] On the basis of these criticisms, one might question some aspects of growth and development accounting, so the notion of usefulness needs to be qualified. It seems that many issues raised regarding growth and development accounting reduce to notions of usefulness at a certain level of abstraction as a starting point of analysis (acknowledged by Barro[6]), or as a thought experiment device to interrogate different outcomes.

A longstanding problem in the literature has been the lack of empirical work to differentiate between different notions of TFP growth because TFP has not been sufficiently modelled and quantified.[17] Residual determinants of growth and income require more research, particularly in terms of the influence of technology (which might have increasing returns) as well as externalities; countries are typically rich because of high levels of A instead of K.[17] According to Felipe,[18] 'the theoretical problems underlying the notion of TFP are so significant that the whole concept should be seriously questioned' (p. 1). Understanding these criticisms can be useful to those using these techniques.

More specifically, Felipe, in a seminal critique,[18] argues that East Asian growth requires other theory to explain its growth other than TFP growth, which was found to be associated with decreasing returns. The decomposition of growth into its subordinate components: factor accumulation and productivity gains, as the core process of growth accounting, has become associated with two different schools of thought; (1) *fundamentalists* who suggest growth in the Asian region was primarily driven by factor increases, or input-driven (mainly associated with capital, with negligible productivity increases in the form of TFP growth [zero in the case of Singapore]) and (2) *assimilationists* who suggest acquiring and mastering foreign technology and operationalising ideas, as key to this growth.[18] According to the assimilationists:

> [*O*]ne 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. (p. 3)

Acquiring and mastering foreign technology entails processes associated with tacit learning.[18] One has to ask if growth accounting is really equipped to authoritatively answer this tension, or if it has helped to create artificial 'camps' of scholars as it does not sufficiently take into account the alternative explanation that complementarity might dominate in the real-life counterpart relationships, which growth accounting attempts to model. An alternative and current approach encompassing complementarity in the literature is offered by Nell,[11] who draws on Kaldor's work in challenging certain of the assumptions of the neoclassical approach to growth accounting.

Why are criticisms of these models important? Theoretical implications of models emphasising the primary importance of technology are different from models that emphasise the role of factor accumulation in economic growth; furthermore, theorists and policymakers need to draw lessons from rapidly growing economies, such as the East Asian nations.[18] An importance of growth accounting is its focus on the analysis of productivity and the resultant shift from emphasis on saving to other factors associated with technological progress as a residual, such as education, research and development, better management and so on.[18] However, for Filipe[18] it:

> [*I*]s 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. (p. 7)

Some, therefore, argue that poor measurement of inputs, especially capital, account for much of the value of the residual, and others have argued that sectoral reallocation is key for productivity growth, as resources move from lower to higher productivity sectors (such as from agriculture to industry, which might tend to have higher capital–labour ratios and a higher marginal product of labour).[18] The fundamental rationale for growth accounting concerns the aggregate production function and the aggregate marginal productivity theory of factor pricing and TFP is decomposed into a technological progress component (changes in the production frontier characterised by best-practice) and a technical efficiency change component (changes in learning by doing, improved management, and how efficient is the use of applications of technology).[18]

Manikew, Romer and Weil[19] found support for the Solow model, with its assumption of decreasing returns to capital, and particularly in terms of its prediction that saving and lower population growth are related to income; more than half of cross-country variance in income per head was explained by saving and lower population. Manikew et al. augmented the Solow model, including human capital and physical capital.

Filipe[18] highlighted theoretical and empirical problems with growth accounting and some are 'generally accepted problems, which were pointed out long ago, but which seem to have been ignored in the current frenzy for estimating residuals' (p. 20). These fall into four categories, namely (1) how technology itself is conceptualised, (2) problems in measurement, (3) making conclusions and (4) implications for policy. It is useful to consider these, as they offer more specific criticisms of growth and development accounting; these criticisms are now considered under the umbrella categories of the concept of technology itself, measurement issues and contemporary thought on growth and development accounting-related issues.

The concept of technology itself

Technological progress has typically been considered to be exogenous, disembodied and Hicks-neutral, as 'manna from heaven' with no relationship to investment and capital accumulation; according to this perspective, technology is a public good, knowledge acquisition is considered costless and time is disregarded as instantaneous technological acquisition occurs.[18] However, it might seem counter-intuitive to think of technological progress as an exogenous process, a disembodied process and a Hicks-neutral process, as there are surely causal feedback mechanisms that make the differentiation of factors in growth accounting models unrealistic.

A further implication of this is that capital is assumed to differ over time only through depreciation and obsolescence; it is not sufficiently acknowledged that capital can differ in its contribution to productivity at different time stages. Furthermore, rewards for technology generation are not accounted for, and income is simplistically ascribed to either capital or labour.[18] The embodiment hypothesis suggests technical knowledge that is new exists primarily in capital goods that are new, with stock that is more recent increasing its weight more strongly; embodied technical innovation reflects fresh designs, inputs and methods, which implies that a production function needs to be differentiated further together with the bundle of inputs it uses.[18] Filipe[18] questions whether it is realistic to consider technical progress to be exogenous, to be disembodied and to be Hicks-neutral; but nevertheless technological progress entails new inputs (which are by definition different methods of production) and what is unclear is how (1) purchasing new machinery can only represent capital accumulation, (2) how well technical progress reflects how well this machinery is used and (3) how these can be separated in analysis. Similarly, others have argued that technical progress is largely embodied in capital goods, but it seems that growth accounting has been used because of its inherent simplicity, whereas theories of embodiment are vastly more complicated and more difficult to test empirically, especially models of embodiment structured in terms of vintage theories, which takes the age of capital stock into account and require measures of change in average level of technology versus best-practice technology and growth in average quality of capital.[18] Arguably, an investigation into growth effects cannot be deterred by the complexity of methods of analysis. It is argued here that the simplicity of the growth accounting approach might have 'shaped' research in this area and might have actually constrained the development of the field. Measurement issues are now considered.

Measurement issues

Certain scholars have questioned the notion that technical progress can be estimated as an independent factor and it is 'pointless and artificial to try and distinguish either between investment and technical change or between shifts in the production function and movements along it' (p. 23).[18] Furthermore, in the real world, the production function is unobservable and only combinations of factors and output can be observed, the combinations of which are dynamic; if capital contributes to introducing technical change in production, then arguing for exogenous technology and offering a specific value for it is nonsensical.[18] These criticisms echo more recent criticisms related to the attribution problem, which challenges the neo-classical attempt to usefully separate sources of growth and particularly the neoclassical growth model's properties of timelessness and also substituting inputs in so orderly a manner along isoquants, particularly when inputs are complementary and interdependent.[18] This neoclassical approach pays scant regard to productivity improvements that occur as localised learning and does not capture the real life way producers typically cut costs.[18] Another challenge facing growth accounting is its assumption that factor prices and social marginal products coincide; if this does not hold true then the estimation of technical change to economic growth will deviate from its true value.[15] This seems to be yet another assumption relating to more detailed usefulness of the growth accounting framework.

It is suggested here that at the heart of the measurement problems facing growth and development accounting are attempts by the neoclassical school to quantify (and elegantly so) certain relationships that can only be quantified if their complexity was fully unpacked. In other words, what seems to be clear here is that at a certain level of focus (such as viewing relationships at a distance vs. close-up) growth and development accounting can be useful as an initial stage of an investigation (at a distance) but as one gets closer to the real-world phenomena its perspective is more difficult to apply without specifying subordinate relationships. At the heart of this problem might be the lack of an interaction

factor or complementarity between constituent factors in these models, as argued by Nell.[11]

Growth accounting also assumes a negligible interaction term between factors and the concept of production cannot be understood without an interaction factor; complementarity amongst inputs is therefore a critically important aspect of a production process of any type.[18] Another serious problem with growth accounting is that TFP production is considered a function of a host of assumptions relating to (1) production functions, (2) choice of output measures (such as between value added or gross output measures), (3) use of capital stock versus capital services flows, (4) cyclical smoothing, (5) the time period and (6) errors of measurement in variables, amongst others.[18]

What is problematic about this is that different assumptions result in very different residuals.[18] Other problems related to growth accounting relate to potential confounds in how real value added is conceptualised; it is taken to be gross output minus intermediate inputs, which does not fit with the notion that it can be deflated to an empirical measure.[18] Furthermore, there is no empirical measure appropriate to capture aggregate output physically and constant price value data have to be used when testing empirical applications.[18] When calculating TFP relationships, stocks of capital in aggregate terms are typically calculated, usually with a perpetual inventory method, which might differ substantially from true stocks of physical capital and measuring capital in an index that is not dependent on relative prices and distribution is also a challenge.[18] It is argued here that these may all be examples of the 'level of abstraction' problem; as growth accounting moves away from its level of abstraction towards real-life predictions or towards smaller-scale phenomena, its weaknesses are more clearly evident. At this nexus, certain contemporary work is now considered, which seems to offer a current perspective of the limitations associated with growth and development accounting.

Contemporary thought on growth and development accounting-related issues

At the core of some criticisms of growth and development accounting approaches might be the fundamental assumptions of the neoclassical school itself. Nell and Thirlwell[20] criticise Solow's orthodox neoclassical growth theory for assuming that there will be identical tastes and preferences across different countries and that technology will be the same, in growth research. They report evidence in support of the assumption that there may be constant returns of models other than the Solow-based growth accounting models, which post decreasing returns to capital. This finding is important *because it contests predictions of convergence associated with Solow models* and instead predicts divergence to some extent between rich and poor countries. It also suggests that policy interventions in the form of policy shocks, although not permanent, *may be effective for extended periods*.

A fundamental challenge faced by growth accounting might be in the way it ignores complementarity. Nell[11] challenges the dichotomy posited by growth and development accounting approaches, which regard technological progress and capital accumulation to be orthogonal and offers a model that captures learning-by-doing effects with technological progress and capital accumulation acting complementarily in long-term growth transitions. This model is found to predict long-term growth in India, incorporating a transition from a phase in which growth is technology-driven between 1980 and 2002 and capital accumulation for the period 2003–2007.[11] This research offers a salient challenge to some of the growth accounting literature, which has typically regarded physical capital accumulation and capital per worker growth, as less important in contributions to growth and development than TFP growth.[11] Modelling relationships similar to those predicted by Kaldor's technical progression function, Nell argues that the TFP perspective of research in India suffers from a fundamental flaw in its use of a single regime framework and did not model initial regime change in 1980. This suggests that previous findings on Indian growth that prioritise TFP at the expense of physical capital accumulation may not be authoritative, thus challenging Granger causality results, which may be structurally unstable because the 1980 regime change represents a structural break. Furthermore, assumptions made that elasticity of output of capital is constant at about 0.33 was not sufficiently substantiated and can overstate the contributions of TFP, whilst the use of neoclassical modelling frameworks takes the growth effect of physical capital accumulation to be temporary.[11]

In order to resolve these issues, Nell suggests a long-run approach rather than transitional dynamics, as a multiple-regime, technical progress function better models and supports the complementarity hypothesis; although in the India context TFP growth might have had an initiating effect in the long-run growth transition, physical capital accumulation overtook TFP as exogenous origin of technological progress in the second or subsequent growth transition stage. Another implication of this research is that profits need to be included to model investment and capital accumulation and following Kaldor, increased saving or investment rates can improve India's economic growth through its progression along the technical progress growth function.[11]

What seems to emerge here is the implication that the growth accounting approach has been critiqued by some, and a more complex approach to growth modelling may be necessary in order to capture real-life effects. An important implication of the complementarity hypothesis is that policymakers should keep up high saving or investment rates, particularly in the post-2008 financial crisis milieu.[11] Although many of the criticisms of development accounting are shared with growth accounting and have been considered in the given sections, literature specific to development accounting and its critiques is also considered now.

Development accounting

Hsieh and Klenow[21] term the proximal contribution of human capital, physical capital and TFP to income as a chain of

causality, termed 'development accounting'. According to Hsieh and Klenow, the:

> [*S*]tate of the debate is as follows: human capital is important (accounting for 10-30 percent of country income differences), physical capital also matters (accounting for about 20 percent of country income differences), and residual TFP remains the biggest part of the story (accounting for 50–70 percent of country income differentials). (p. 207)

This demonstrates the importance of TFP. Hsieh and Klenow argue that important feedback influences exist across human capital measures, physical capital measures and TFP, particularly in terms of differences in TFP levels in different sectors such as investment as opposed consumption or human capital opposed to final goods and that TFP as an aggregate is a function of the input allocation efficiencies over industries and firms. According to Hsieh and Klenow, development accounting allows a linear decomposition of income level differences between countries. An advantage over growth regressions is that TFP is not required to be orthogonal or not related to, physical or human capital. Such an accounting process can offer insight into how many differences in output per person increase because of differences in physical capital per person, effective labour per person or residual TFP whilst keeping two of the latter three factors fixed.[21] There seems to be much agreement in the literature that differences in human capital make up about 10% – 20% differences in country income and physical capital seems to make up about 20% and residual TFP accounts for about 50% – 70%; however, what development accounting cannot explain is why these differences happen; Hsieh and Klenow[21] conclude TFP might not only have both a direct effect upon output but may also have an indirect effect through both human and physical capital by way of reducing pricing of capital and schooling compared with prices of output. They also suggest that a misallocation of inputs can occur, across firms and industries that may account for much of the differences in residual TFP, but development accounting cannot indicate 'what the forces behind the misallocation are'. Problems seem to emerge here too, as the level of abstraction decreases; further critiques are considered as follows.

Criticism of development accounting

Hsieh and Klenow[21] offer a critique of development accounting as physical capital is expected to increase endogenously with increases in effective labour or TFP; physical capital investments are typically in the form of final goods but human capital and TFP are not and so higher output is necessarily associated with higher physical capital and increases in human capital and TFP whilst holding fixed capital per person constant implies a decrease in the physical capital investment rate. With regard to the latter, Hsieh and Klenow[21] suggest:

> [*I*]t is not obvious why this is a useful thought experiment given that the investment rate in physical capital is presumably driven by factors such as the effective tax rate on capital income and the relative price of capital, but not the level of human capital, or TFP, per se. (p. 209)

Yet another criticism is offered by Hsieh and Klenow of an alternative accounting function, which rearranges the production function into intensive form (Equation 3):

$$\frac{Y_i}{N_i} = A_i^{1/(1-\alpha)} \left(\frac{K_i}{Y_i} \right)^{\alpha/(1-\alpha)} \left(\frac{h_i L_i}{N_i} \right). \quad \text{[Eqn 3]}$$

This rearrangement takes the form of a thought experiment and indicates changes of effective labour per person or the residual TFP can allow capital per head, rather than the capital output ratio, to change in response.[21] Useful for comparing large differences across countries, it is compatible with the neoclassical assumption of no human capital or TFP effects on the steady-state capital-output ratio; because of the larger exponents on residual TFP, or the use of 1/1-α instead of 1 in the equation as well as effective labour input, which as a 1 rather than a 1-α argue for a direct effect of these on output as well as an indirect effect of these via capital per worker.[21] However, a criticism of the equation argued by Hsieh and Klenow is the asymmetry of the equation, as it does not take into account the argument that physical capital is an input into human capital accumulation and higher TFP investments. This critique is yet another specific example of criticisms of accounting processes, which together with other criticisms common to both development and growth accounting provide a sense of the primary problems with these methods.

It is argued that the critiques of these models may reduce to two dominant notions: (1) they work as an initial starting point of analysis and at a higher level of abstraction and are therefore useful as thought experiments more than as instruments to get down to specifics and (2) that they do not capture the endogeneity and causal complexity associated with real-life phenomena, particularly in terms of the complementarity of the effects of the factors within these models. Criticisms of growth regressions are now considered; these are considered to the extent that they relate to research related to growth, and the following discussion is delimited to this.

Criticisms of growth regressions

The regression of different indicators of output growth on a host of determinants has been criticised due to instability of parameter estimates; however, Bosworth and Collins[15] argue that this instability simply reflects variance present in samples of different countries, time periods and inclusion of different additional explanatory variables. A problem with growth regressions that has already been discussed here is what it shares with growth and development accounting models, the primary issue perhaps being that neoclassical approaches to quantification arguably reflect an extension of the equilibrium analysis mindset, but certain relationships are intangible by nature,and human behaviour is oftentimes not rational. Conflict and global unrest reflect conditions that are inherently uncertain and capture perhaps some of the irrationality of human actors. To the extent that only the addition of an error term can transform a growth or development accounting equation into a growth regression, certain criticisms discussed here will also extend to growth

regressions. These will not be discussed again here. Growth regressions are useful however, as a method to test these growth or development accounting equations, as shown by Nell and Thirlwell.[20]

In terms of the TFP debate, according to Hsieh and Klenow[21] growth regressions typically require TFP to be separate to human or physical capital; development accounting does not have this drawback.

But overall, Bosworth and Collins[15] argue that a group of explanatory factors usually correlate with economic growth; this rationale formed the basis of their testing based on similar sets of countries, time periods and conditioning variables. A further criticism of growth regressions is endogeneity of explanatory variables other than initial conditions, such as the quality of a country's institutions, how open it is to trade and its other policy measures. Bosworth and Collins[15] used instruments in analysis of institutional quality and their measures of trade-related indicators of openness, although other key macroeconomic policy variables were interpreted descriptively. *If technology growth or the TFP value is inherently endogenous, there is perhaps little chance of instrumenting all of this endogeneity.*

Having introduced and discussed growth accounting, development accounting and growth regressions and certain critiques associated with these methods, a critical synthesis of the ideas discussed here is now provided, to drive key arguments of the work.

Synthesis

Growth accounting exercises, development accounting exercises and cross-country growth regressions have been used extensively to investigate economic growth and to decompose aspects of the growth process. However, a critique of these approaches has also emerged over time. Although it cannot be claimed that this tension is solved, this essay makes a modest contribution by synthesising and evaluating different perspectives in the literature and the following arguments are derived. Firstly, growth and development accounting are undoubtedly useful methods, with some weaknesses and strengths. A social scientist employing these methods should be well acquainted with these and the work here contributes to this objective.

Secondly, these types of accounting suffer from the same criticisms as neoclassical approaches, because they are essentially derived from the neoclassical thinking the Solow model was based on. These criticisms cannot be taken lightly, as certain of these assumptions, such as Hicks neutrality might be difficult to use when investigating technological change or other characteristics of the residual.

Thirdly, what seems to be lacking in theoretical literature seems to be current research that can offer an authoritative perspective on this debate, other than that provided by work which stresses the importance of complementarity between aspects of these models. Growth regressions also have their shortcomings but adding error terms provides a useful way to extend other models of growth for empirical testing. In short, these three groups of critiques should be used as input for opportunities to improve models and address strengths and weaknesses. These findings should be contextualised in relation to other challenges facing empirical work in social science. As more work becomes transdisciplinary to address societal and economic challenges, further knowledge of strengths and weaknesses of approaches to studying growth and development may become increasingly important.

Conclusions, implications and recommendations for further research

The objective of this conceptual essay article was to identify and discuss some critiques of growth accounting, development accounting and cross-country growth regressions and to derive insights about strengths and weaknesses of these approaches. The following conclusions suggest avenues for further research.

Firstly, all these techniques are useful under certain conditions, it is necessary to understand criticisms and to be able to address them or mitigate their weaknesses when conducting research. Further research should seek to explore weaknesses and strengths of methods and to disseminate this knowledge in transdisciplinary literature. This may help Mode 2 research to solve important societal problems because knowledge of methods is made more accessible and shared across disciplines.

Second, if these types of accounting suffer from the same criticisms as some neoclassical approaches, and are derived from the neoclassical thinking like the Solow model, then those using them should be familiar not only with critique such as that considered here but also with heterodox approaches that suggest further critiques, with theoretical and empirical implications. Further research should explore implications of non-neoclassical theory and approaches for the use of these models and inferences one can derive from their use. Transdisciplinary approaches should seek out heterodox perspectives because they may complement orthodox principles based on neoclassical approaches. Further research should provoke critical perspectives to strengthen the capacity of transdisciplinary knowledge to solve knowledge problems.

Thirdly, critiques suggest that certain assumptions, such as Hicks neutrality might not be appropriate for technological change or other characteristics of the residual. Further research should explore more specific conditions under which these assumptions hold or do not hold. Knowledge of these boundary conditions to theoretical predictions can go a long way to assisting those setting out on research using these methods.

Fourthly, the importance of complementarity between aspects of these models should be stressed in future work. Growth regressions also have their shortcomings, but by adding error terms they provide a useful way to extend some other models of growth for empirical testing. In short, these three groups of criticisms should be used as input for opportunities to improve models. Further research should seek not only to identify weaknesses and strengths of models but should also show how they might be used together, to add complementary information to analysis.

Certain further implications derive from these findings. Firstly, future research should seek to as much as possible avoid bias resulting from the use of a single technique by seeking complementary insights into analysis and should try to use causal statistical methods[22,23] wherever possible. Further research should seek to extend work here to identify additional strengths and weaknesses of each of the methods, techniques and approaches discussed here. With increasing knowledge of these, researchers will be better able to negotiate the terrain of methodological challenges to achieve valid findings.

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C.W.C. is the sole author of this article.

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