1. OECD WORKSHOPS ON PRODUCTIVITY ANALYSIS AND MEASUREMENT
Conclusions and Future Directions

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Introduction

In the section below, we discuss the role of economic theory in providing solutions to some of the difficult problems that arise in the measurement of productivity.[6]

In the third section, we list some 12 measurement problems where further research is required in order to form a consensus on how to "best" solve these problems.

The last section concludes with 5 recommendations for the OECD on the way forward.

Is there a Role for Economic Theory in the Measurement of Productivity?

When Bert Balk presented an overview of Statistics Netherlands' progress in measuring productivity for the Dutch economy,[7] he was somewhat negative on the standard economic approach or growth accounting approach to productivity measurement and he suggested a preference for the statistical or axiomatic approach to productivity measurement:

"For the calculation of aggregate quantity or volume change of inputs and outputs, an index formula must be selected. In the standard growth accounting approach the index formula corresponds to a certain specification of the production function and TFP change represents technological change. However, such an approach depends on strong (neo-classical) assumptions, for instance that production processes are subject to constant returns to scale and that there is perfect competition. We don't wish to make such strong assumptions, and

5 This note is an extended written version of my Panel Discussion at the final session of the OECD Workshop on Productivity Analysis and Measurement organized jointly with the Swiss Federal Statistical Office and the State Secretary for Economic Affairs of Switzerland held in Bern, October 16–18, 2006. The financial assistance of the OECD and the SSHRC of Canada is gratefully acknowledged. My thanks to Bert Balk, Ulrich Kohli, Dean Parham and Paul Schreyer for helpful comments. None of the above individuals or organizations are responsible for any opinions expressed in this note.

6 By the term "productivity", I mean "Total Factor Productivity" or "Multifactor Productivity" and not "Labour Productivity". TFP growth is an index of the growth of outputs divided by an index of the growth in all primary inputs whereas Labour Productivity growth is an index of value added growth divided by the growth in labour hours. The problem with the Labour Productivity concept is that it neglects the contributions of nonlabour inputs and hence can give a very misleading picture of a country's actual productivity performance.

7 See van den Bergen, van Rooijen-Horsten, de Haan and Balk (2006).

prefer to select an index formula on the basis of its properties." Dirk van den Bergen, Myriam van Rooijen-Horsten, Mark de Haan and Bert M. Balk (2006; 3).

Balk is quite correct to criticize the standard growth accounting methodology, since as he pointed out several years ago[8], this methodology attributes all productivity growth to (disembodied) technical change and neglects the roles of improvements in technical and allocative efficiency, nonconstant returns to scale and R&D investments that lead to monopolistic behavior on the part of producers. However, I think it would be incorrect to jump to the conclusion that the economic approach to productivity measurement is irrelevant and useless.[9] It seems to me that the economic approach to productivity measurement should be the primary approach and that rather than totally discarding it in the face of the above criticisms, it would be preferable to try and remedy some of the shortcomings of the standard growth accounting methodology. However, this is easier said than done. For example, many authors have attempted to relax the assumption of constant returns to scale in a growth accounting framework but these approaches rely on econometric estimation in order to determine the degree of returns to scale and hence tend to be rather fragile and nonreproducible.[10]

It may appear at first glance that economics is not really required when setting up an axiomatic framework for productivity measurement. In the axiomatic approach, all we need to do is decide on the value aggregates for output and input, pick our favorite functional form for the index number formula and calculate the ratio of the output index to the input index. Thus it seems that there is no real need for economic theory in implementing this approach. However, when we bring capital services into the picture as an input, then it is no longer clear what the corresponding value aggregate should be. For example, present System of National Accounts conventions suggest that general government capital services should be measured by only the depreciation applicable to the government capital in service during the reference period. However, if a government department decides to sell its office buildings and then rent or lease building services from the private sector, then the rents that the government will pay for office services will surely include a return to capital component and hence GDP will go up with this change in ownership. Thus economic theory suggests that the imputed rental for government owned buildings that have an alternative use in the private sector should have an interest rate component in the imputed rental price in addition to the depreciation component.[11] The point is that we will have to rely on economic theory to at least some extent to determine what the appropriate value aggregate is for capital services.[12]

8 See Balk (1998) (2003).

9 It should be noted that Balk did not jump to this conclusion in his presentation!

10 For example, see Diewert and Fox (2004), Diewert and Lawrence (2005a) (2005b) and Fox (2006). Nonreproducibility here is interpreted in a broad sense; i.e., different econometricians, using the same data set, will generally make different aggregation and functional form assumptions and different stochastic specifications, leading to different estimates for the key parameters in the model.

11 Mas (2006) also discusses these issues.

12 In fact, van den Bergen, van Rooijen-Horsten, de Haan and Balk (2006) rely on a considerable amount of economic theory in order to derive their user costs for capital. This theory was developed in Balk and van den Bergen (2006), which in turn drew on Diewert (2005a) and others.

In the following section, we turn to a list of some of the economic measurement problems that were discussed at this conference (or that perhaps that should have been discussed). Economic theory will generally be useful in providing some guidance on how to resolve these measurement problems.[13]

Theoretical Issues in the Measurement of Productivity

We will list some 12 important measurement issues that arise in measuring the productivity growth of a production unit (i.e., of a firm, industry or entire economy) in sections 3.1–3.12 below.

How to Treat R&D Expenditures in a Growth Accounting Framework?

The Canberra Group on Capital Measurement has recommended that the next international version of the SNA should capitalize R&D expenditures.[14] The capitalization of R&D expenditures provides some new challenges for the standard growth accounting methodology as will be explained below. There were two excellent papers on R&D and productivity measurement presented at this workshop: the papers by Parham (2006) and by Edworthy and Wallis (2006). The second paper follows what has become the "standard" methodology for the treatment of R&D investments: namely assume a plausible depreciation rate for these investments and use the Perpetual Inventory method for forming capital stocks to form stock estimates for R&D capital. These stocks would be depreciated over time using the assumed depreciation rates and user costs for inventory stocks could also be formed using the same methods as are used for conventional reproducible capital stock components.[15] However, Pitzer (2004), Diewert (2005b) and Parham (2006)[16] suggested that the treatment of R&D assets is not quite so straightforward as the standard methodology suggests since these R&D assets do not behave in the same manner as ordinary reproducible capital inputs where an increase in the number of "machine" or structures" inputs will generally lead to a positive increment in production. R&D investments create new technologies and once the new technology has been created, the investment has the nature of a fixed cost rather than a contribution factor to normal production of goods and services. Diewert explained these differences between R&D assets and reproducible capital assets as follows:

"R&D is not like other depreciable assets which gradually wear out through use; rather R&D can be viewed as the creation of new technologies. These new technologies may just reduce the cost of producing an existing commodity or they may create entirely new goods

13 Jack Triplett has made this point repeatedly over the years.

14 Another important recommendation of the Canberra Group is that Gross Operating Surplus be decomposed into price and quantity (or volume) components where the price would be a user cost of capital, along the lines pioneered by Jorgenson and Griliches (1967) (1972). This user cost should approximate a market rental price for the same asset.

15 Perhaps the most complete and up to date version of "standard" growth accounting methodology for capitalizing R&D can be found in Corrado, Hulten and Sichel (2005).

16 In addition to questioning whether the "standard" model for R&D accounts is really appropriate, Parham provides a very nice summary of the very extensive econometric work by Shanks and Zheng (2006) on estimating the effects of R&D on Australia's productivity growth.

and services (process versus product innovation). In either case, the R&D "asset" is not like a "normal" reproducible capital asset that depreciates with use. The expenditures incurred in creating the R&D asset are sunk costs and they have no resale value as is the case with a purchase of a reproducible asset. However, a successful private sector R&D venture has created a new product or process that will give rise to a stream of profits in future periods. In many cases, the new technology can be licensed and the rights to use the new technology can be sold. Thus in the case of successful private R&D ventures, a new asset has been created: the rights to a (monopoly) stream of future incremental revenues. However, once a new successful technology has been created, expiry of patents, diffusion of knowledge about the innovation, even newer innovations by competitors and changing tastes all combine to reduce the stream of monopoly profits over time. Note that the effects of these factors, which reduce the value of the R&D asset over time, are difficult to forecast.[17]"

"To summarize the above discussion: a private sector R&D asset is much more complicated than a typical reproducible capital asset (like a structure or machine). There are actually two "assets" associated with an R&D venture:

- The first *cost asset* is the cumulated costs of the R&D project and
- The second *revenue asset* is the discounted value of the incremental profits that the R&D project is expected to generate.

For any individual R&D project, it is unlikely that the R&D cost "asset" is equal to the R&D incremental revenue asset but, over a large population of R&D projects, we could expect to see the value of the cost assets to be approximately equal to the value of the revenue assets.[18]"

"As defined above, the cost and revenue assets are defined in terms of nominal dollars. It is relatively straightforward to obtain a constant dollar counterpart to the nominal cost asset, provided that deflators are available for the important components of nominal expenditures on R&D projects, such as scientific and engineering personnel, structures, materials and instruments. However, it is not straightforward to obtain constant dollar estimates for the revenue asset. Since the discounted incremental revenues that the project is expected to yield are in units of today's dollar, the simplest approach to obtaining a constant dollar estimate for the revenue asset would be to deflate the current expected discounted profits estimate by a current general index of inflation.[19]"

"As was mentioned above, the cost asset is not really an asset: it is a sunk cost. In the present system of national accounts, SNA 1993, privately funded R&D expenditures are

17 Many of these points (and more) were made in Bernstein (2002).

18 Adjusting for the risk inherent in R&D projects, we would expect that the value of the cost assets be less than the value of the revenue assets. Thus it is completely reasonable that R&D assets earn higher rates of return on average than reproducible capital assets.

19 A producer price index over the gross outputs produced by the economy could be used but I would recommend the use of a consumer price index as the general deflator. The GDP deflator should not be used since imports enter this index with negative weights and so a large increase in the price of imports relative to other prices can lead to a counterintuitive fall in the GDP deflator; see Kohli (1982; 211) (1983; 142) and Diewert (2002; 556) on this point.

regarded as intermediate business expenses and are written off as they occur. This point of view is defensible, particularly for unsuccessful R&D ventures. However, for successful R&D ventures, it could be argued that it is "unfair" to write down current period income by these expenditures since these expenditures will eventually be recovered in future periods as the project's incremental revenues pour in to the firm. Hence, from this point of view, it makes sense to capitalize these R&D expenditures into an "asset" and depreciate this "asset" in a proportional manner to the future period incremental revenues. From this point of view, the problem is to determine how to *allocate* the cumulated cost of an R&D project over future periods. This accounting problem has a different character than the usual problems involved in depreciating reproducible capital stock investments, where information on used assets can be used if an opportunity cost approach to depreciation is used. For an R&D cost "asset", the problem is one of *matching* current costs with future expected revenues,[20] which is a rather daunting task!" Erwin Diewert (2005b; 6–8).

In addition to the problems outlined above, there are some additional challenges to the conventional growth accounting paradigm:

- Publicly funded R&D that generates new technologies or products that are made freely available to the public may not generate any identifiable revenue streams; rather they may simply lead to valuable new products that are manufactured and sold at cost. Thus the benefits of some R&D expenditures may simply show up as increases in utility (which are extremely difficult to measure) rather than as a stream of monopoly profits.
- The standard growth accounting model, adapted to the R&D context, does not explicitly recognize any monopoly profits.
- The problem of spillovers also needs to be addressed.

The point of the above rather lengthy discussion is this: the standard Solow, Jorgenson and Griliches growth accounting methodology assumes that technical progress is exogenous and any R&D expenditures are treated as current expenditures. This standard model does not really capture the intertemporal aspects of R&D expenditures but just treating R&D expenditures as another type of reproducible capital does not capture the fact that these expenditures partially endogenize technical progress. Thus at present, we do not really have a satisfactory growth accounting methodology that can deal with the complications that arise when we capitalize R&D expenditures.[21]

To sum up: there is a great deal of theoretical work that remains to be done in adapting the standard growth accounting methodology to deal with the complexities that are inherent in the treatment of R&D investments.

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20 Paton and Littleton (1940; 123) argued that the primary purpose of accounting is to match costs and revenues but other points of view are possible. For an excellent early discussion on the importance of matching costs to future revenues, see Church (1917; 193). For a more recent discussion on the problems involved in matching R&D costs to future expected incremental revenues, see Diewert (2005a; 533–537).

21 Parham (2006; 18–19) also makes this point.

Should the Output Aggregate be Gross Output, Value Added or Net Product?

One topic that came up in several papers presented at the conference was the question of what is the theoretically best measure of productivity; i.e., should we use a *gross output formulation* where gross output growth is in the numerator of the productivity measure and an aggregate of intermediate input plus labour input plus capital services input is in the denominator of the productivity measure or should we use a *value added formulation* where the output in the numerator is an aggregate of gross output less intermediate inputs used and the denominator is an aggregate of labour and capital services? Diewert and Lawrence (2006) favored a third productivity concept for their particular purpose; namely a *net product formulation* where the output in the numerator is an aggregate of gross output less intermediate inputs used less depreciation[22] and the denominator is an aggregate of labour and waiting services, so that depreciation was taken out of the primary input category and treated as an intermediate input in this last formulation.[23]

There is a general feeling that economic theory favors the gross output definition of productivity growth because nobody has seen a value added production function in the real world whereas it is natural to regard output as being produced by a traditional production function that has capital, labour, energy, materials and services as inputs.[24] However, if we use the approach to productivity measurement suggested by Diewert and Morrison (1986) and Kohli (1990)[25], it turns out that the assumptions required to justify the translog gross output, the translog (gross) value added and the translog net value added approaches to productivity measurement are all *equally* restrictive[26] and in particular, *no separability assumptions are*

22 This leaves open the question of what to do with the (anticipated) revaluation term; i.e., should it be subtracted from gross investment as well as depreciation? Diewert and Lawrence avoided making a decision on this point because they assumed that the anticipated rate of asset inflation was equal to the CPI inflation rate and hence all they used balancing real interest rates in place of balancing nominal rates less the anticipated revaluation terms. My current advice on this difficult topic is that the Diewert and Lawrence treatment is reasonably satisfactory except for a few assets where "everybody" anticipates either a real devaluation (e.g., any class of assets that uses computer chips intensively) or a real appreciation (e.g., land in economies with growing populations). In these latter cases, I would treat the negative real revaluation terms as depreciation and hence the absolute value of these terms would be treated as an addition to traditional wear and tear depreciation. In the case of a positive real revaluation term, I would add these terms to gross investment, since we are taking an asset from the beginning of the period when it is less valuable to the end of the period when it will be more highly valued. These issues are discussed at more length in Diewert and Wykoff (2006) and Diewert (2006a).

23 These three alternative approaches to measuring productivity were discussed in Schreyer (2001). See also Balk (2003b) on these issues.

24 Strictly speaking, in the context of technologies that produce multiple outputs, we would require a separability restriction which would allow us to aggregate all of the outputs into an output aggregate in order to justify the traditional production function approach.

25 This approach is explained in the paper by Diewert and Lawrence (2006) which was presented at this conference.

26 There is one caveat to this statement that must be mentioned: when we calculate the value added aggregate (net or gross) for the production unit under consideration for the two periods being compared, the two value added aggregates must have the same sign in order to obtain meaningful results using the translog approach,

required for any of these three approaches. All three approaches rely on duality theory, which states that under price taking behavior and constant returns to scale convex technology, the primal technology sets S^t can be equally well described by dual (net) revenue functions $g^t(p,x)$, where p is a gross or net output price vector and x is an input quantity vector.[27] However, the (positive) fact that all three of these translog approaches to productivity measurement do not make any separability assumptions is balanced by a bit of a negative factor and that is the fact that only the geometric mean of two very particular productivity indexes can be identified empirically using this approach.[28] I do not find this limitation to be particularly troublesome but others may disagree.

Given that all three approaches to productivity measurement do not differ in the restrictiveness of their assumptions, which approach should be used in practice? This question is discussed at some length in Schreyer (2001) but I would like to make the following observations:

If we are studying the productivity performance of a particular firm or industry, then perhaps the gross output formulation is most suitable since it will be easier to explain to users.[29]

If we are attempting to analyze the productivity performance of an entire economy or an aggregate of industries, then the gross or net value added approaches seem preferable since economy wide growth in TFP will be approximately equal to a share weighted average of the industry growth rates in value added TFP. Thus the contribution of each industry's TFP growth to over all TFP growth is a bit easier to explain to users if we use the gross or net value added approaches.[30]

since index number theory breaks down when the value aggregate passes through zero. If we use the gross output approach to productivity measurement, this caveat does not apply because both the input and output value aggregates will definitely be positive for the two periods being compared.

27 See Gorman (1968), McFadden (1978), Diewert (1973) (1974; 133–141) and Balk (1998) for various versions of these duality theory results.

28 Referring to Diewert and Lawrence (2006; 6), the two particular productivity indexes, $\tau_L{}^t$ and $\tau_P{}^t$ that are singled out are the Laspeyres type measure that uses the (gross or net) output prices of period t–1, p^{t-1}, and the input vector of period t–1, x^{t-1}, as reference vectors, $\tau_L{}^t \equiv g^t(p^{t-1},x^{t-1})/g^{t-1}(p^{t-1},x^{t-1})$, and the Paasche type measure that uses the (gross or net) output prices of period t, p^t, and the input vector of period t, x^t, as reference vectors, $\tau_P{}^t \equiv g^t(p^t,x^t)/g^{t-1}(p^t,x^t)$. The Diewert-Morrison-Kohli translog approach to productivity measurement can only empirically estimate (using index numbers) the geometric mean $\tau^t \equiv [\tau_L{}^t\tau_P{}^t]^{1/2}$ of these two theoretical productivity indexes. The definition of productivity change used by these authors, which relies on the (net) revenue function, originally appeared in Diewert (1983; 1063–1064) but he did not develop it in any great detail. The other main theoretical approach to productivity measurement relies on the Malmquist productivity index, which was introduced by Caves, Christensen and Diewert (1982). However, this approach does require that the output aggregate be gross output (rather than value added).

29 However, the other two approaches are equally valid from the viewpoint of theoretical restrictiveness.

30 The value added framework for productivity measurement has some additional advantages. For example, productivity growth will be invariant to the degree of domestic outsourcing of business services and will be invariant to the absolute size of the foreign trade sector. For example, the gross output productivity growth of the Netherlands compared to the U.S. will look very poor compared to its value added productivity growth simply because exports and imports in the Netherlands are a very high fraction of GDP compared to the situation in the U.S. Calculating value added productivity growth rates for both countries will make the growth rates comparable across countries.

What about the choice between the usual *(gross) value added approach* to TFP where we use gross domestic product as the output aggregate versus the *net value added approach* to TFP where we treat depreciation as an intermediate input and hence the output aggregate is gross output less traditional intermediate inputs less depreciation? Diewert and Lawrence (2006) clearly preferred the net value added approach because their purpose was to explain the contribution of TFP improvements to the growth in living standards; i.e., they followed Rymes (1968) (1983) in treating depreciation as an offset to gross investment so that depreciation charges no longer appeared as "income" to households. Thus the depreciation term was moved from the primary input category (where it appears as part of user cost in the traditional approach) and placed in the intermediate input category in the empirical work of Diewert and Lawrence. The remaining part of user cost was treated as a primary input and was labeled the "reward for waiting" following Rymes (1968) (1983).[31] Households cannot consume depreciation and so if we want to explain increases in household real income, this net value added approach to TFP measurement seems to be clearly preferable.

It seems to me that the main theoretical issues in this area of gross versus net have been more or less settled but as can be seen from the discussion above, there are many points that are quite subtle and other observers could well argue that more work remains to be done in this area.

Adjusting Productivity Measures for Changes in the Terms of Trade

There is an extensive national income accounting literature on how to measure the effects of changes in the terms of trade (the price of exports over the price of imports) on national welfare.[32] Much of the early literature took a household point of view but Diewert and Morrison (1986), following the example of Kohli (1978) (1991)[33], who observed that most international trade flows through the production sector of the economy, took a producer point of view to modeling the effects of changes in the terms of trade:

"Our alternative approach to the measurement of the impact of terms of trade changes is to consider the problem from the point of view of the producer. In this alternative approach, our objective function becomes real output rather than welfare. We assume that exports and imports flow through the production sector and we show that an increase in the price of exports relative to imports has an effect that is similar to an increase in total factor productivity." W. Erwin Diewert and Catherine J. Morrison (1986; 659).

Thus some 20 years ago, a connection between productivity measures and changes in the terms of trade was made. For many years, there was not a lot of interest in this topic, but the recent increases in the price of oil and other raw materials has again stimulated interest in modeling the effects of changes in the terms of trade in a productivity framework. In addition

31 Diewert and Lawrence's (2006) approach to the construction of user costs was somewhat simplified and did not deal adequately with the issue of obsolescence. For more thorough discussions of the obsolescence problem in the user cost context, see Ahmad, Aspden and Schreyer (2004), Diewert (2006a) and Diewert and Wykoff (2006).

32 See Diewert and Morrison (1986) for references to this early literature.

33 See also Woodland (1982) and Feenstra (2004; 64–98) who used this approach extensively.

to the paper by Diewert and Lawrence (2006) presented at this conference on this topic (and the paper by Diewert, Mizobuchi and Nomura (2005) who took a similar approach using Japanese data rather than Australian data), see Morrison and Diewert (1990), Kohli (1990) (2003) (2004a) (2004b) (2006a) (2006b) and Fox and Kohli (1998). The approaches suggested in these papers, while being broadly comparable, differ somewhat in their details.[34] Since most of the papers in this area are relatively recent, a consensus on which approach is "best" has not yet emerged. It may be useful to have a review paper on this topic that would list the advantages and disadvantages of each approach.

The Effects of Public Infrastructure Investments on Productivity

The paper by Mas (2006) presented at this conference raises some of the issues surrounding the treatment of public infrastructure investments and their effects on private market sector productivity. The issue I would like to raise here is the following one. The public sector makes investments in infrastructure (primarily roads and other transportation facilities), which are surely very useful in facilitating production in the private sector but the public sector in general does not charge for the use of these valuable transportation services. Following Aschauer (1989), we could take a production function perspective and try to directly estimate a private sector production function (or a transportation sector production function) which had road services as an input. This is fine as far as it goes but econometric estimates tend to be rather fragile so it would be useful to also determine the effects of publicly funded infrastructure investments on private sector productivity in a growth accounting framework and Mas (2006) provides such a framework for the economy as a whole. However, since the infrastructure services are provided free of charge to the private sector, economic theory suggests that these free resources should be used so intensively such that the marginal value to the private sector of an extra unit of infrastructure services is close to zero.[35] This observation implies that the shadow price of infrastructure services to the private sector should be close to zero in all periods and hence changes in infrastructure services would have little or no effect on private sector productivity growth in the usual growth accounting framework. This result seems to be intuitively incorrect[36] but we need some additional

34 In particular, when Diewert and Lawrence speak of modeling the effects of changes in the terms of trade, a closer examination of their methodology shows that what they are actually modeling are the effects of changes in the price of exports relative to the price of consumption and changes in the price of imports relative to the price of consumption. The main difference between the Diewert and Lawrence (2006) approach and the recent work of Kohli (2004b) (2006a) (2006b) is that Kohli divides prices by the price of domestic absorption (an aggregate of C+G+I) whereas Diewert and Lawrence (and Diewert, Mizobuchi and Nomura (2005)) divide prices by the price of domestic household consumption C.

35 Diewert (1980; 484–485) made this argument many years ago.

36 Dean Parham noted that Australia imposes a tax on diesel fuel that is meant to be a user fee for the use of its "free" network of roads. Other countries impose similar commodity taxes on fuel inputs and this may be a way to get positive prices for the use of roads into the productivity growth framework. Kohli suggested another way out of this "paradox": "If the public infrastructure is supplied free of charge congestion will set in at some stage (Pigou's wide road might become narrow at certain times of the day). The time wasted by the users will represent the marginal cost to them. The marginal value to the private sector of an extra unit of the infrastructure will therefore not be zero." Ulrich Kohli, private communication.

research on this topic in order to pin down more precisely what the contribution of public infrastructure investments is to private sector productivity growth in a growth accounting framework.

Pricing Concepts for Outputs and the Treatment of Indirect Taxes

The growth accounting framework for the private sector originally developed by Solow (1957) and Jorgenson and Griliches (1967) (1972) relied on the assumption of competitive price taking behavior on the part of producers. In Solow (1957) and Jorgenson and Griliches (1967), outputs were priced at final demand prices, which include indirect taxes. However, Jorgenson and Griliches (1972) noted that this treatment was not quite consistent with competitive price taking behavior on the producers, since producers do not derive any benefit from indirect taxes that fall on their outputs:

"In our original estimates, we used gross product at market prices; we now employ gross product from the producers' point of view, which includes indirect taxes levied on factor outlay, but excludes indirect taxes levied on output." Dale W. Jorgenson and Zvi Griliches (1972; 85).

Thus at the level of the individual firm, indirect taxes that fall on the outputs of the firm should be excluded from the output prices facing the firm, since the firm derives no revenue from these indirect tax wedges.[37] However, indirect taxes that fall on the intermediate (and primary) inputs used by the firm are actual costs to the firm and hence should be included in the corresponding prices of the intermediate inputs. Thus when we apply the growth accounting framework to an individual firm, the pricing concept that is consistent with the underlying theory excludes indirect taxes that fall on outputs but includes these taxes that fall on inputs. Thus at the level of the individual firm, the treatment of indirect taxes is relatively straightforward in the growth accounting framework. However, some problems emerge when we aggregate over firms and we apply the growth accounting framework to the entire private sector. When we aggregate over firms or sectors of the economy in the growth accounting framework in order to form national estimates of final demand output, intermediate input transactions cancel out, *except for the indirect taxes that fall on intermediate inputs*; i.e., a firm producing an intermediate input gets only the before tax revenue for the output but the using firm has to pay this price plus the indirect tax and so aggregating over the entire private sector, we end up with net deliveries to final demand at producer prices (which excludes the final demand indirect tax wedges) *less* indirect taxes on intermediate inputs paid by private sector producers. These taxes on intermediate inputs cause problems when we calculate aggregate market sector output and productivity and attempt to decompose say market sector output into contributions from each industry since these industry contributions will not sum up to the national total.[38] The details of how the industry output aggregates are related to the national aggregate if Laspeyres, Paasche or Fisher indexes are used may be found in Diewert

37 Obviously, per unit of output subsidies that the firm gathers from governments should be added to the prices of the subsidized outputs. I have neglected this complication in the discussion which follows.

38 Diewert (2001; 97–98), following Debreu (1951), noted that these indirect tax wedges on intermediate inputs lead to an economy wide loss of output; i.e., taxes on intermediates generally lead to some deadweight loss for the economy as a whole even though each sector can be efficient.

(2006b). However, the issue of how to interpret the indirect taxes on intermediate inputs "contribution" to national output growth has not been resolved and requires further research.[39] It would also be useful to develop a growth accounting framework that allowed us to relate industry contributions to national private sector productivity growth at final demand prices (rather than at producer prices as in the present theoretical growth accounting framework).

What is the Exact Form of the User Cost Formula?

Since the pioneering work of Jorgenson and Griliches (1967) and Hall and Jorgenson (1967), it is well known that the formula for the user cost of capital consists of roughly four terms:

- An interest rate or opportunity cost of capital term;
- A depreciation term;
- A revaluation or capital gain or loss term and
- Adjustments for income and other taxes on capital.

Although there is general agreement that the above four terms belong in the user cost of capital, there is still no agreement on the precise form for each term. Some of the important issues are:

- Should user costs take an ex ante or an ex post point of view?
- Should user costs be discounted to the beginning, end or middle of the period?
- Should interest rates be in real or nominal terms?
- Should the tax adjustments reflect average or marginal considerations?
- What is the exact form of depreciation that should be used?
- Should the interest rate be an exogenous market rate or a balancing internal rate of return that will make the value of input equal to the value of output?

I have been writing about the above issues for over 25 years[40] but unfortunately, we still do not have a consensus on many of the above issues. As more and more countries embark on official productivity programs, there is a need to achieve a consensus on the above issues so that the productivity estimates will be at least roughly comparable between countries.

39 A practical difficulty should be mentioned at this point. A theoretically "correct" treatment of indirect tax wedges will require detailed information by commodity and industry on where these taxes occur and this information is typically not available in the input output accounts of most countries.

40 See Diewert (1980; 475–485), (2001; 88–96), (2005a) (2006a), Diewert and Lawrence (2000), (2002) (2005a) (2006) and Diewert and Schreyer (2006). See also Schreyer (2001) (2004) and Schreyer, Diewert and Harrison (2005).

Should Depreciation Rates, Interest Rates and Wage Rates be Constant Across Industries?

In some national productivity programs, wage rates are standardized for demographic factors (age, sex, educational attainment and so on) but they are held constant across industries. Similarly, depreciation rates for different asset classes are often estimated on a national level and thus are held constant across industries. Finally, endogenous balancing rates of return on assets could be calculated on an industry basis or on a national level. The question is: which procedure is "best"?

We know that wage rates and rates of return vary greatly across firms and industries. Productivity growth for developing countries is fueled by the migration of labour from the agricultural sector to the modern industrial sector and under these conditions, it is appropriate to allow for industry wage rates to differ, holding constant demographic characteristics. Similarly, it is known that ex post rates of return differ considerably across industries.[41] Thus if possible, sectoral productivity estimates should allow for differences in wage rates and the return to capital.[42]

The situation with respect to depreciation rates is less clear cut. It is quite possible that different industries use various forms of capital more or less intensively and thus depreciation rates should be allowed to be different across industries. However, it is difficult to obtain scientific information on depreciation rates. Historically, a few countries[43] have had periodic capital stock surveys, which allow depreciation rates to be estimated, but they are very expensive and hence have been discontinued. Another scientific method for obtaining depreciation rates was developed by Hulten and Wykoff (1981a) (1981b) (1996) and relies on observations on the sales of used assets. A final possible method for obtaining depreciation rates is for national statistical agencies to add questions on capital stock retirements and resales in their ongoing investment surveys. Canada,[44] the Netherlands[45] and New Zealand

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41 See for example Diewert and Lawrence (2005b).

42 Note that these differences in wage rates and user costs for the same type of input can be a source of economy wide productivity growth if the differentials are narrowed over time. "Individual firms or establishments could be operating efficiently (i.e., could be on the frontiers of their production possibilities sets) yet the economy as a whole may not be operating efficiently. How can this be? The explanation for this phenomenon was given by Gerard Debreu (1951): there is a loss of system wide output (or waste to use Debreu's term) due to the imperfection of economic organization; that is, different production units, although technically efficient, face different prices for the same input or output, which causes net outputs aggregated across production units to fall below what is attainable if the economic system as a whole were efficient. In other words, a condition for system wide efficiency is that all production units face the same price for each separate input or output that is produced by the economy as a whole. Thus if producers face different prices for the same commodity and if production functions exhibit some substitutability, then producers will be induced to supply jointly an inefficient , economy wide joint output vector." W. Erwin Diewert (2001; 97).

43 The Netherlands, Japan and Korea come to mind.

44 For a description and further references to the Canadian program on estimating depreciation rates, see Baldwin, Gellatly, Tanguay and Patry (2005).

45 Actually, since 1991, the Dutch have a separate (mail) survey for enterprises with more than 100 employees to collect information on discards and retirements: The Survey on Discards; see Bergen, Haan, Heij and Horsten (2005; 8) for a description of the Dutch methods.

ask such questions on retirements in their investment surveys and Japan is about to follow suit.[46] Diewert and Wykoff (2006) indicate how this type of survey can be used to obtain estimates for depreciation rates and it would be feasible theoretically to obtain these estimates on an industry basis. However, sample sizes are likely to be small if one attempts to use this survey information to form estimates of depreciation rates by asset class and industry and hence the resulting estimates may be very inaccurate. Thus one may be better off by estimating depreciation rates at a national level rather than at the industry level.

The Problem of Imputing Wage Rates for the Self Employed and Unpaid Family Workers

In the present System of National Accounts, the contributions to production of the self employed and of unpaid family workers are buried in Gross Operating Surplus. However, when constructing productivity accounts, it is necessary to decompose this value aggregate into a capital services aggregate plus the value of self employment labour and unpaid family worker labour. Note that for many advanced economies, the self employed can make up 20 percent of the labour force and for developing economies, unpaid family workers can also be a substantial fraction of the labour force. Thus the problem of imputing wage rates for the self employed and family workers is not an empirically unimportant one.

There are three methods that the Bureau of Labor Statistics has suggested to accomplish this imputation for the self employed:[47]

- Approach 1 to this allocation problem imputes a wage to the self employed that is equal to the wage of comparable employees in the industry and the resulting measure of labour earnings is subtracted from Gross Operating Surplus, leaving what is left over as the return to the capital used by the self employed.
- Approach 2 allocates an industry rate of return to the capital used by the self employed and allocates what is left of net operating surplus as the wages earned by the self employed.
- Approach 3 takes an average of the allocations to labour and capital that are generated by the first two approaches.

The problem with Approaches 1 and 2 is that these allocation methods can give rise to negative compensation for either labor or capital. The BLS uses Approach 3 in its productivity program; i.e., it averages the first two methods of allocation to ensure a positive compensation for both factors of production. However, this procedure is not entirely satisfactory since it ensures that “incorrect” estimates are made if Approaches 1 and 2 differ and one of these two approaches is actually the “correct” one.[48]

46 The Economic and Social Research Institute (ESRI), Cabinet Office of Japan, with the help of Koji Nomura is preparing a new survey to be implemented as of the end of 2006.

47 For a description of the BLS productivity program and an extensive list of references, see Dean and Harper (2001).

48 The BLS procedure also leads to some inconsistencies if an endogenous rate of return to capital is used in constructing user costs.

Which approach is likely to the "correct" one?[49] I would vote for Approach 2 over Approach 1 since workers often become self employed because they *prefer* this type of employment over paid work; i.e., self employed work is not really equivalent to employee work, even after standardizing for the type of job.[50] On the other hand, the user cost of capital should be the same whether workers are employees, self employed or family workers.

In any case, it can be seen that there are still some major unresolved measurement issues surrounding the imputation of wage rates for the self employed and family workers.

The Treatment of Inventory Change in the SNA

In the current System of National Accounts, the treatment of inventory change in real terms is very confusing to users since when nominal inventory change is divided by the corresponding real change, negative implicit prices frequently occur. The meaning of these negative prices is problematical. Diewert (2005c) suggested that this problem is due to the failure of normal index number theory when the value aggregate being deflated can be of either sign in the two periods under consideration. His solution to this problem was straightforward: the value aggregate should be written as the difference between two positive value aggregates and each of the two aggregates should be separately deflated. This is analogous to the treatment of the trade balance which is rarely deflated directly; rather exports and imports are separately deflated and shown as two separate real aggregates in the SNA. Diewert (2005c) also showed how inventory change and the user cost of inventories can be jointly derived in a consistent economic framework due to Hicks (1961) and Edwards and Bell (1961).[51]

The problem of obtaining a more theoretically consistent treatment of inventory change may seem rather minor but inventory fluctuations often drive changes in GDP so a transparent treatment of this part of inventories is important in productivity analysis.

The Measurement of Financial Services Outputs and Inputs

The problems involved in defining the outputs and inputs of banking services (and other financial institutions more generally) have been with us for a long time and there is still no general consensus on what are the "correct" measures. Excellent recent discussions of the issues involved may be found in Schreyer and Stauffer (2003), Fixler, Reinsdorf and

[49] In practice, our choices may be constrained by the availability of data. For approach 1, it is necessary to know the number of workers who are self employed and their hours of work. For approach 2, one needs data on the capital stock that is being used by the self employed.

[50] This preference for Approach 2 over Approach 1 does not solve our measurement problems since if there are say both self employed and family workers in a firm, Approach 2 only gives us an aggregate imputation for the two types of labour rather than a separate imputation for each type of labour. We may have to resort to econometric methods and production function estimation in order to obtain direct estimates for the shadow prices of self employed and family labour.

[51] Diewert's analysis also draws on Diewert and Smith (1994).

Smith (2003) and in Chapter 7 of Triplett and Bosworth (2004).[52] I lean towards the "user cost" school of thought that has been developed by Hancock (1985) (1991) and Fixler and Zieschang (1991) (1999) but a consensus on the "best" theoretical approach to measuring financial service industry outputs and inputs has not yet emerged.

The Effects on Productivity Growth of the Entry and Exit of Firms

How does the entry and exit of firms contribute to productivity growth?[53] This is an exciting new area of research in productivity analysis that is only a bit over 10 years old; see the pioneering contributions of Baldwin and Gorecki (1991) and Baily, Hulten and Campbell (1992). Not only is this area of research of interest from a theoretical point of view, it appears to be extremely important empirically; see Haltiwanger (1997) (2000) , Ahn (2001), Bartelsman (2004) and Bartelsman, Haltiwanger and Scarpetta (2004).

An unresolved issue in this literature on the contributions to productivity growth of entering and exiting firms is *how exactly should we measure these contributions.* Various answers to this question have been proposed by Baldwin and Gorecki (1991), Baily, Hulten and Campbell (1992), Griliches and Regev (1995), Olley and Pakes (1996), Bartelsman and Doms (2000), Foster, Haltiwanger and Krizan (2001), Fox (2002), Balk (2003a; 25–31), Baldwin and Gu (2003) and Diewert and Fox (2006). Again, there is a need for a consensus to form on what is the "best" treatment of this subject.

The Consistency of Quarterly Estimates of Productivity Growth with Annual Estimates

The final measurement problem associated with productivity measurement that has not been definitively resolved is the following one: how can quarterly estimates of productivity growth be made consistent with annual estimates?

The answer to this question is not simple because of three factors:

- The existence of seasonal commodities; i.e., it is difficult (or impossible!) to form estimates of real output growth if some outputs are not available in all quarters and
- The possible existence of moderate or high inflation within the year.
- There are mathematical problems in reconciling sums and ratios which defy easy solutions.[54]

If there is high inflation within the year, then when annual unit value prices are computed (to correspond to total annual production of the commodities under consideration), "too

[52] A summary and comments on Triplett and Bosworth may be found in Diewert (2005d), which is an extended version of a shorter review which appeared in the International Productivity Monitor, Volume 11, Center for the Study of Living Standards, Fall 2005, pp. 57–69.

[53] See Bartelsman, Haltiwanger and Scarpetta (2004) for a review of the evidence on the productivity effects of entry and exit over 24 countries using micro data sets over the past decade. Other reviews of the literature on this topic can be found in Haltiwanger (1997) (2000), Ahn (2001) and Balk (2003; 25–31).

[54] See Balk (2005) on this point in particular.

much" weight will be given to the prices of the fourth quarter compared to the prices in the first quarter.[55] There are possible solutions to this problem but they are rather complex and as usual, there is no consensus on what the appropriate solution should be.

For possible solutions to the above problems, the reader is referred to Hill (1996), Diewert (1998) (1999), Bloem, Dippelsman and Maehle (2001), Armknecht and Diewert (2004) and Balk (2005).

It can be seen that there is a fairly large number of outstanding *theoretical* problems associated with the measurement of productivity growth. Hopefully, in the future, we will make some progress in coming to a consensus on what the "best" solution is to each of these problems.

In the following section, I conclude with some recommendations to the OECD which could help facilitate productivity comparisons between countries.

Recommendations for the OECD

The OECD is my favorite international statistical organization since they provide products that I find most useful in my own teaching and research. Some of the most useful products from my perspective are the following ones:

- The OECD tries to provide standardized national accounts data for its member countries back to 1960.[56]
- The OECD is *the* source for tax data on a harmonized basis.[57] Thus when international comparisons of taxation are made, the OECD data base on taxation is always the first source that researchers turn to.
- The OECD provides very useful advice to its member countries in its annual country reports.
- The OECD has specialized in providing R&D data for its member countries and in examining the role of R&D in productivity growth.

55 See Hill (1996) and Diewert (1998) for a discussion of these problems.

56 In my applied economics course that I teach to MA students, each student has to pick an OECD country and develop a set of productivity accounts for his or her country back to 1960. They find the OECD national accounts and tax data invaluable.

57 However, Kohli points out that these taxation data must be used with some care to ensure that like is compared to like: "The OECD always ranks Switzerland among the low tax countries, but by the time you have added up the premia for unemployment insurance, disability insurance, accident insurance, medical insurance, and pension funds (all of which are compulsory, but not financed by general government revenues), the picture is quite different." Ulrich Kohli, private communication.

Thus the OECD is already in the business of providing standardized data on its member countries. My recommendations below suggest that this role should be expanded in the following ways:

- The OECD should provide some guidance on "standard" assumptions for the construction of user costs and provide these standardized user costs for its member countries. Also the OECD should fix the inventory change problem mentioned in section 3.9 above and provide "standard" user costs of inventory in a theoretically consistent framework.
- The OECD should provide "standard" depreciation rates for capital stocks and provide "standard" estimates of the flow of capital services for member countries.[58]
- The OECD should provide "standard" estimates for the imputed labour income of the self employed and unpaid family workers. The methods used to do this will not be exactly right, but someone has to make a start on this difficult problem.
- The OECD should continue to cooperate with the EU KLEMS project.[59] As a start, it would be very useful for the OECD to provide data on the price and quantity of inputs and outputs for the market sector in each member country; i.e., once we have the sectoral data on the market and nonmarket sectors from the KLEMS project, it would be straightforward to calculate productivity levels for the market sector of each OECD economy and compare these levels across countries.[60] In short, an expansion of the EU KLEMS project to cover all OECD countries would allow us to make international comparisons of productivity for the *market sector* in each member country's economy.
- The OECD should continue to sponsor these meetings on productivity so that member countries can continue to report on their practical experience in setting up productivity accounts and so that interested researchers can interact with the practitioners and hopefully provide solutions to some of the difficult measurement problems mentioned above.

58 Once the standardized depreciation estimates are in hand, it would also be useful to the OECD to publish net value added productivity growth rates for member countries along the lines recommended by Diewert and Lawrence (2006).

59 See the papers by van Ark, Timmer and Pilat (2006), van Ark, Timmer and Ypma (2006) and Timmer and Inklaar (2006) that were presented at this conference.

60 The general government sector in each economy cannot be expected to behave in an optimizing manner so that the usual assumptions underlining the growth accounting methodology will generally not hold for the nonmarket sectors in each economy.

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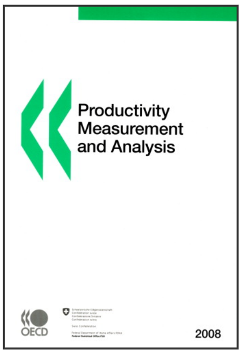

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