Progress and Challenges in the Measurement of Productivity

by

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Prepared for the UNIDO and IDE
Conference on Productivity and Growth in Africa and Asia
October 9-11, 2007

PRELIMINARY DRAFT

Abstract

This paper reviews some recent international progress in the measurement of productivity, and highlights some of the many remaining challenges. An overview of the methodology used by the Australian Bureau of Statistics is given as an example of international ``best practice".

Key words: Productivity measurement, industry dynamics, index numbers.
JEL classification: C43, D24, E23

[*] The author gratefully acknowledges the financial support of the Australian Research Council (DP0559033), and helpful comments from Don Brunker, Paul Roberts and Ian Bobbin from the Australian Bureau of Statistics. The views expressed in this paper are those of the author, and do not (necessarily) represent those of the Australian Research Council nor the Australia Bureau of Statistics.

``Econometricians have an ambivalent attitude towards economic data. At one level, the ``data" are the world that we want to explain, the basic facts that economists purport to elucidate. At the other level, they are the source of all our troubles."

Zvi Griliches (1985)

``What gets measured gets reported and worried about; what goes unmeasured gets ignored. When you collect and make readily available good statistics, you inform the public, provide ammunition for activists and oppositions, equip bureaucrats with the data they need to develop good policy, make it possible to set targets and give governments early feedback on the success or failure of those policies."

Ross Gittins (Sydney Morning Herald, 4 July 2007)

1. Introduction

Productivity growth has long been of interest to economists and policy makers as a primary source of economic growth and welfare change. It can lead to improvements in living standards in many ways: more output for the same inputs means that there are more goods (in aggregate) to consume; one can work less and produce same amount of goods meaning more time for leisure; and less natural resources are required to produce the same amount of output, meaning preservation of the environment.

Additionally, it is one way of assessing ``performance" relative to other countries and over time. For example, the recent push in New Zealand for there to be official productivity statistics was largely motivated by a desire to know whether the micro-economic reforms of the 1980s had any productivity growth payoff, both over time and relative to other countries.

In this paper, a description of productivity measurement by the Australian Bureau of Statistics (ABS) is given as an example of the sort of careful and thoughtful effort that is going into productivity measurement by leading statistical agencies.[1] Similar approaches to that used by the ABS are used by other statistical agencies, such as Statistics New Zealand, Statistics Canada and the U.S. Bureau of Labor Statistics.

A comparison of the ABS productivity growth estimates with an alternative productivity series is provided to show how two very careful and sensible approaches can lead to quite different results.

Some remaining, and possibly expanding, problems in productivity measurement are also reviewed. It may be surprising to data users that there are so many remaining problems after so much effort has been put into improving measurement in many countries and through international efforts.

Griliches (1994) proposed the following reasons why the data are perhaps not as good as we might hope:

• The measurement problems are really hard.

• Economists typically have little influence on government, especially concerning data collection.

• Statistical agencies are underfunded and the problems are getting harder.

• We do not put enough emphasis on the value of data and data collection in our training of graduate students and in the reward structure of our profession. ``It is the preparation skill of the econometric chef that catches the professional eye, not the quality of the raw materials in the meal, or the effort that went into procuring them."

These problems are not going to be overcome any time soon, yet productivity numbers are required by policy makers in many countries. This paper attempts to give an indication of where we are at internationally in the measurement of productivity growth.

The rest of the paper is structured as follows. The next section gives a brief overview of some of the international efforts in constructing productivity databases. Section 3 introduces the main index numbers which are used by various statistical agencies in constructing productivity growth aggregates. Section 4 gives an overview of the methods

[1] The ABS has had a particularly active productivity measurement program in the last few years, with estimates of ``market sector" productivity growth available, along with newly released industry-level

used by the Australian Bureau of Statistics in constructing its productivity database. This provides a good example of the sort of requirements (both in terms of data and effort) needed for the construction of a sensible productivity database. Productivity data for Australia are presented, along with the results from an alternative database. Section 5 gives a brief overview of some of the remaining, and developing, challenges in productivity measurement and its analysis. Section 6 concludes.

2. Some Progress: A brief overview

Partial productivity estimates are produced for many countries. These are typically in the form of Gross Domestic Product divided by some (basic) measure of labour, giving a measure of labour productivity. However, these are very basic measures of productivity which ignore the fact that inputs other than labour are used; substitution from the use of labour to the use of machines may not increase output, but will increase labour productivity. Hence, in what follows we consider international efforts in constructing more complete productivity measures. Multifactor productivity tries to take into account the fact that there are more inputs going into production than simply labour.[2]

Countries that produce official (multifactor) productivity growth estimates for parts of their economies (usually manufacturing or the ``market sector'') include Canada, the U.S., Australian and New Zealand. It is perhaps not surprising that these are relatively affluent countries, as a considerable investment of resources is required to establish and maintain productivity statistics. Even for wealthy countries, one of the key barriers to introducing productivity statistics is the lack of human capital; like any field, the knowledge can be quite specialised. The OECD Productivity Manual, OECD (2001), sets out a guide for ``best practice'' in productivity measurement by statistical agencies, substantially lowering the barriers for countries to start producing their own productivity estimates. So, with international examples to draw from, plus the Productivity Manual, it is becoming easier

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estimates, using both ``gross output'' and ``value added'' frameworks.

[2] Academics often use the term ``total factor productivity'', but statistical agencies seem to prefer ``multifactor productivity'', possibly because it indicates that not all factors of production are necessarily included in the input aggregate.

(in some ways) for countries to start producing productivity accounts.

While it is valuable to have aggregate productivity statistics, they can mask where productivity gains are being achieved. Hence, the U.S. Bureau of Labor Statistics reports productivity statistics for the aggregate manufacturing sector and individual industries within this sector. The Australian Bureau of Statistics has just released experimental estimates of industry multifactor productivity (for the industries within the ``market sector''), and Statistics New Zealand is about to release a similar database.

In Europe, there is a major push for the development of comparable productivity statistics through the ``EU KLEMS'' project run by the Groningen Growth and Development Centre at the University of Groningen (www.euklems.net). This project aims to create a database which measures not only productivity growth, but economic growth, employment creation, capital formation and technological change at the industry level for all European Union member states from 1970 onwards. Other non-EU countries (e.g. Australia) are collaborating with this project by developing EU KLEMS-consistent databases, thus further facilitating international comparability of key measures of economic performance.

Concerning the treatment of data, much progress has been made internationally on the measurement of capital goods (using a ``user cost of capital'' approach), and in taking into account changes in the quality of assets and consumer goods. However, as we make progress, there are always new (and sometime unexpected) challenges. Before turning to some of these, the actual practice of productivity measurement is examined, beginning with a description of the basics and then the example of productivity measurement by the Australian Bureau of Statistics.

3. Productivity Measurement Using Index Numbers

While economists and statistical agencies typically motivate the calculation of productivity growth using economic theory (usually a ``growth accounting'' framework), the basics can be explained and interpreted without recourse to such theory.

We wish to know if outputs are growing faster than inputs. If so, then there is output growth which cannot be simply explained by an increase in input utilisation. Thus, if we divide a measure of output growth by a measure of input growth, we have productivity growth (sometimes known as an ``index of our ignorance"). This is the standard way that statistical agencies calculate productivity.[3]

In an economy with many outputs and inputs, the implementation of this approach requires the construction of aggregate measures of output growth and input growth. This is achieved using index numbers.

Index number theory is based on decomposing a value ratio into price change and quantity change components:

$$\frac{p^1 \cdot q^1}{p^0 \cdot q^0} = P(p^0, p^1, q^0, q^1)Q(p^0, p^1, q^0, q^1), \tag{1}$$

where p^t and q^t are vectors of prices and quantities, respectively, $p^t \cdot q^t \equiv \sum_{n=1}^{N} p_n^t q_n^t$, for periods $t = 0,1$ and there are $n = 1,\ldots,N$ goods. $P(p^0, p^1, q^0, q^1)$ and $Q(p^0, p^1, q^0, q^1)$ are thus indexes of price and quantity change that, multiplied together, give value change.

Commonly used index number formulae for the price and quantity indexes are the Laspeyres (1871) index, the Paashce (1874) index, the Fisher (1922) index and the Törnqvist (1936) index.

The Laspeyres quantity index between periods 0 and 1 is defined as

$$Q_L(p^0, p^1, q^0, q^1) \equiv \frac{p^0 \cdot q^1}{p^0 \cdot q^0}. \tag{2}$$

This index weights period 0 and period 1 quantities by period 0 prices. This is the most commonly used formula by statistical agencies in constructing aggregates such as real gross domestic product (GDP) and the consumer price index (CPI). The Paasche quantity index between periods 0 and 1 is defined as

$$Q_P(p^0, p^1, q^0, q^1) \equiv \frac{p^1 \cdot q^1}{p^1 \cdot q^0}. \tag{3}$$

Note that the only difference between the Laspeyres and Paasche quantity indexes is

[3] An alternative approach is based on the econometric estimation of functional forms which represent the available technology. This approach is not typically used by statistical agencies, so is not considered here; see

which period's prices are used as weights. The Paasche index is not widely used by statistical agencies in constructing quantities indexes.[4]

An alternative to using either the Laspeyres or Paasche indexes is the Fisher index, which is the geometric mean of the two:

$$Q_F(p^0, p^1, q^0, q^1) \equiv [Q_L Q_P]^{1/2} \tag{4}$$

This obviously avoids the choice between using period 0 or period 1 prices as weights. In addition, this index has some very nice properties; see e.g. Diewert (1992). Hence, it is a popular choice among academic economists, and is used by the U.S. Bureau of Economic Analysis in constructing real GDP. It is also common in productivity studies, and is used by e.g. Statistics Canada for this purpose.

Another popular choice is the Törnqvist index, which has properties which are in many ways similar to the Fisher index, and which will approximate the Fisher index very closely in most empirical applications. The Törnqvist quantity index between periods 0 and 1 is defined as

$$Q_T(p^0, p^1, q^0, q^1) \equiv \prod_{n=1}^{N} \left(\frac{q_n^1}{q_n^0} \right)^{1/2(s_n^1 + s_n^0)} \tag{5}$$

where $s_n^0 = p_n^0 q_n^0 / p^0 \cdot q^0$, the period 0 value share. This is used by the U.S. Bureau of Labor Statistics in calculating output and input aggregates in its manufacturing productivity database, and both the Australian Bureau of Statistics and Statistics New Zealand in calculating the input aggregate in their respective productivity databases.

4. Productivity Measurement in Australia

The Australian Bureau of Statistics (ABS) produces multifactor productivity estimates for the market sector on an annual basis. They also publish an index of labour productivity. The output concept used is gross value added in chain volume (quantity) terms, calculated

e.g. Fox (1996) for a comparison of productivity estimates from the alternative approaches.

[4] However, the Paasche price index (which reverses the role of prices and quantities compared with the quantity index) is commonly used in constructing the GDP deflator; if real GDP (quantity index) is constructed using a Laspreyres index, then the deflator (price index) should be constructed using the Paasche index to satisfy (1).

using the Laspeyres index number formula.[5] So, labour productivity is real value added divided by hours worked, and multifactor productivity (MFP) is real value added divided by an index of labour *and* capital inputs.

They also publish quarterly estimates of GDP per hour worked for the market sector and for the whole economy.[6]

In addition, capital productivity (real value added per unit of capital) is reported, where the capital variable is the flow of capital services. This is calculated by weighting chain volume measures of the productive capital stock of different asset types together using their rental prices as weights. There are capital input measures for up to 14 asset types for the corporate and unincorporated sectors for each of the 12 industry Australia-New Zealand Standard Industrial Classification (ANZSIC) divisions that comprise the ``market sector". For each capital input there is a rental value that is used to weight the volume indicators of the flow of capital services in constructing the aggregate capital services index.

To construct an aggregate input index, this aggregate chain volume measure of capital services is combined with a measure of hours worked using a Törnqvist index, using estimates of shares of capital and labour income as weights.

MFP for the market sector is then calculated by dividing the chain volume measure of gross value added (a Laspeyres output quantity index) by the chain volume input aggregate (a Törnqvist input quantity index).

4.1 Some Specifics

This section draws on Australian National Accounts: Concepts, Sources and Methods (2000) (Cat. no. 5216.0).

4.1.1 Definition of the Market Sector

While labour productivity estimates are calculated for the economy as a whole, MFP

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[5] Value added is defined to be output less intermediate inputs (materials, energy, business services, and so forth). For more details, see Australian System of National Accounts (Cat. no. 5204.0).

[6] See Australian National Accounts: National Income, Expenditure and Product (Cat. no. 5206.0).

and capital productivity are only calculated for the ``market sector''.

The market sector is comprised of the following industries:

- Agriculture, forestry, and fishing;
- Mining; Manufacturing;
- Electricity, gas and water; Construction;
- Wholesale trade;
- Retail trade;
- Accommodation, cafes and restaurants; Transport and storage;
- Communication services;
- Finance and insurance; and
- Cultural and recreational services.

The excluded industries are:

- Property and business services;
- Government administration and defence;
- Education; Health and community services;
- Personal and other services; and
- the special industry Ownership of dwellings.

For these excluded industries, estimates of real value added are derived using input data as measures of output. By definition, productivity growth for these sectors is then zero, making productivity analysis meaningless.

Note that the market sector includes all institutional sectors, including general government. As government activity is (generally) not marketed, it could be argued that it should be netted out from each industry. The ABS, however, leaves it in due to ``the difficulty of excluding general government components from outputs and inputs''. General government only comprises a very small percentage of most market sector industries, so this is unlikely to be of major concern.

4.1.2 Measurement of Capital

The estimation of capital input is perhaps the most difficult area in constructing MFP estimates.[7] A major problem with the estimation of capital services is the uncertain quality of the data used in their construction; specifically, mean asset lives and asset life distributions. A brief overview is provided here on the ABS approach to constructing capital service flows for productivity analysis.

The capital services produced by an asset over its life are directly proportional to the productive capital value of the asset. Therefore, an aggregate index of capital services can be produced by weighting together volume indexes of the productive capital stock of different assets, where rental prices are used as weights.

The ABS considers the following asset types in producing estimates of the productive capital stock:

- six types of machinery and equipment: computers and computer peripherals; electronic and electrical machinery and communications equipment; industrial machinery and equipment; road vehicles; other transport equipment; and other equipment;
- buildings and structures other than dwellings;
- livestock;
- artistic originals;
- mineral exploration;
- computer software;
- inventories; and
- land.

Note that in order to calculate capital stocks from the components of ``gross fixed capital formation" (all of the above components excluding inventories and land), age-efficiency profiles are needed; the method used by the ABS is based on the assumption of hyperbolic efficiency decline (as is also assumed by the BLS and Statistics New Zealand). Volume estimates for the inventory items are obtained for all the market sector industries other than Communications, Finance and insurance; and Cultural and recreational services.

Livestock can be thought of as either a producing asset or an inventory stock. The stock used for ongoing production, such as dairy cattle and the breeding stock, has a finite life and will hence depreciate; as such, it can be treated like other capital assets (although it has the unusual feature of being able to reproduce itself). However, livestock raised for slaughter are treated as inventory.

The stock of agricultural land is treated as a non-depreciable asset; its quantity remains constant over time.

For non-agricultural land, the treatment is somewhat different. There can be changes in the capital services provided by land due to changes in the value of buildings on the land. Hence, estimates for each industry are calculated by taking the balance sheet value for the reference year as a benchmark and making the assumption that the growth rate is half that of the productive capital stock of non-dwelling construction.

The aggregate index of capital services is compiled in the form of a Törnqvist index. The growth rates of productive capital stocks of each asset type are weighted together using estimates of the rental prices. We generally do not observe rental prices, as for most types of capital the owner is also the user. The problem of how to estimate rental prices is considered below.

4.1.3 Rental Prices for Capital

Rental prices are used to form the weights applied in aggregating the estimates of productive capital stock of each asset type to form a Törnqvist index of industry capital services. The ABS uses a user cost of capital approach to estimate these (unobserved) rental prices.

In its most basic form, the user cost of capital has three components: depreciation, a rate of return reflecting financing costs, and a capital gain (or loss) component. In a more complete specification, it also includes a corporate income tax component, tax depreciation allowances, investment credits and indirect taxes. The user cost equation used by the ABS is as follows:

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[7] This helps explain the popularity of labour productivity estimates.

$$UC_{ijt} \equiv T_{ijt}(r_{it} p_{ijt} + d_{ijt} p_{ijt} - p_{ijt} + p_{ij(t-1)}) + p_{ijt} x_{it},$$

where

$i =$ industry

$j =$ asset type

$t =$ discrete time period

$T =$ income tax parameter

$r =$ rate of return

$p =$ price for new capital goods

$d =$ depreciation rate

$x =$ effective average non-income tax rate on production.

While increasing practical complexities, the inclusion of the tax parameters (T_{ijt}) partially removes distortions to the rental price due to different tax allowances for different capital items and industries over time.[8]

A key variable for the calculation of the user cost of an asset is the rate of return, r. The ABS uses both endogenous and exogenous rates of return. The endogenous rate of return is the internal rate of return for the industry. This imposes the same rate of return for all asset types within an industry; capital rent is defined as the sum across all assets of their rental price multiplied by the real productive capital stock and the rate of return is then solved for after equating this to the non-labour income (Bureau of Labor Statistics 1983, Hall and Jorgenson 1967). This can be considered as an *ex post* approach, as the rate of return is calculated after the result of the investment decision is known.[9]

Another approach to calculating rates of return is to use an exogenous rate of return such as the interest rate on government bonds. This can be considered an *ex ante* approach, as the exogenous rate of return can be interpreted as the expected return on an investment decision.

The ABS uses both endogenous and exogenous rates of return when estimating capital services estimates, depending on the circumstances. A problem that can occur in

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[8]Measurement of these parameters can be quite complex; even a brief description of the ABS approach is beyond the scope of this paper.

[9]There are a number of decisions that need to be made in the seemingly simple calculation of endogenous rates of return, such as whether the productive capital stock should be used (as currently), or the net capital

calculating the rental prices is that they can be negative for some assets in some years. To try to mitigate this problem, the ABS applies a ``floor" to the rate of return equal to 4% plus the consumer price index (CPI), i.e. an exogenous rate. Only if the calculated endogenous rate is greater than or equal to this floor is the endogenous rate used. However, applying this floor does not guarantee that negative user costs will not be found.

When user costs are negative, the ABS sets the rental price to a very small positive number.[10]

4.1.4 Measurement of Labour

Labour input is measured by constructing indexes of hours worked. The total hours worked in any period is calculated as the product of the number of employed workers and average hours worked. An index of hours worked is preferable as a measure of labour input than simply the number of employed workers, as hours worked captures changes in overtime worked, standard weekly hours, leave taken, and changes in the proportion of part-time employees.[11]

Due to limitations in the hours worked data, the hours worked series is reported only in index form. One advantage of this is that over- (or under-) reporting of hours worked is less important if the data is in index form than if it is in levels form; often we only care about the changes in the series, and therefore the index form is entirely adequate.

The employment estimates used to derive hours worked comprise all labour engaged in the production of goods and services:

- civilian wage and salary earners;
- employers;
- self-employed persons;
- persons working one hour or more without pay in a family business or on a farm;

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stock. The ABS is considering changing its approach; see ABS (2007, p. 107)

[10]This practice has also been adopted by Statistics New Zealand.

[11]Changes in the quality of labour are not taken into account in the headline hours worked series. Thus, productivity growth estimates capture changes in labour force quality. To obtain a measure of productivity that excluded the effect of changing skill levels, it would be necessary to adjust hours worked for changes in the quality of the labour force. The ABS does publish an experimental quality-adjusted labour input series; see ABS Research Paper (1351.0.55.010): *Quality-adjusted Labour Inputs*, 2005.

and

- members of the Australian defence forces.

The annual figures are simple arithmetic averages of observations on employment levels during the year.

Total average hours worked are reported for each month, from the Labour Force Survey (LFS). However, estimates are available only for the mid-month of each quarter for individual industries and the market sector. The average hours worked series relate to a fortnight in the first half of the month. There are several problems with the series, including the following.

- The design of the LFS means that the two week reference period is representative of only one week of each month. Thus, there are only 12 weeks of the year where total hours worked are actually observed.
- Hours worked reported in the reference period may not be representative of the quarter due to holidays. Consider the following. In Australia, many people take leave in January (which is summer). The average hours worked recorded in February is then likely to overstate the average level of hours worked for the quarter. This is the main reason that the ABS presents the hours worked estimates in index form.
- Hours worked in the reference period may reflect the changing incidence of public holidays. ``Calendar corrections" do not entirely remove this problem. Therefore, only the estimates of average hours worked in the mid-month of each quarter are used to derive the estimates of hours worked for ``all industries".
- Details of the hours worked by members of the Australian defence forces are not available from the Household Labour Force Survey. The average weekly hours worked of civilian employees is used to proxy their hours worked per week.

4.1.5 Capital and Labour Income shares

For the market sector, Total income = Gross Operating Surplus of corporations and general government + Gross mixed income + Compensation of employees + Taxes less subsidies on production and imports.

Gross mixed income and Taxes less subsidies on production and imports include both capital and labour components, and these are split in order to obtain capital and labour shares.

Thus, Total income = Gross Operating Surplus + Proprietors' capital income + Net taxes on production (capital) + Compensation of employees + Proprietors' labour income + Net taxes on production (labour).

Capital's income share = (Gross Operating Surplus + Proprietors' capital income + Net taxes on production (capital))/(Total Income).

Labour's income share = (Compensation of employees + Proprietors' labour income + Net taxes on production (labour))/(Total income).

These shares can then be used in the Törnqvist input quantity index to construct the aggregate input index.

Note that a procedure is needed to split gross mixed income (the national accounts aggregate) into labour and capital shares of income earned by unincorporated business in order to calculate the proprietors' capital income and the proprietors' labour income; see Australian National Accounts: Concepts, Sources and Methods (2000) (Cat. no. 5216.0)

In addition, capital and labour shares of net taxes on production and imports are required. The taxes on capital that can be separately identified are: land tax; local government authority rates; motor vehicle registrations; stamp duties; and miscellaneous taxes. The tax on labour is payroll tax.[12] There are some cases where a tax cannot be exclusively allocated to either labour or capital. In these cases, the ABS allocates the tax in proportion to labour and capital factor incomes.

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[12] Fringe benefits tax used to be classified as a tax on production, but now it is classified as an income tax. Historical revisions were implemented in 2005.

4.2 Productivity Estimates

The methods used to construct the ABS market sector productivity series have been presented above. Here we turn to looking at the numbers, but also look at estimates from an alternative productivity data set which was constructed for Australia. This is a recently constructed data set by Diewert and Lawrence (2005), which will be referred to as the DL database.

The DL database was largely built on the ABS productivity database which covered the value, price and quantity information on 12 of 17 major industrial sectors of Australian economy. From the available data on 12 major industries, the ABS constructs its ``market sector" multifactor productivity (MFP) estimates for more than 40 years, starting from 1965. The DL productivity database is different from the ABS database in the following respects:

- The DL productivity database includes not only 12 of Australia's major industrial sectors in the ABS productivity database, it also accounts for 4 additional sectors (i.e. Health, Education, Business and property services, Personal services). The major industrial sector of Australia's economy that is not included in DL database is Government administration and defence. The DL database consists of information on value, price and quantity of 16 out of Australia's 17 major industrial sectors, referred to as the ``expanded market sector", for 45 annual observations from 1959-1960 to 2003-2004.
- Output measure was derived from final consumption components instead of sectoral gross value added.
- Inputs and outputs were constructed in terms of producer prices after relevant taxes and/or subsidies have been accounted for, as opposed to the ABS's consumer prices approach.
- ``Jorgenson" geometric depreciation methodology was employed in building capital and inventory input series. The ABS is currently following the US Bureau of Labor Statistics methodology (hyperbolic efficiency decline) for forming stocks and flows which the authors argued to be less consistent.

In addition, the ABS uses the Laspeyres index formula for its output aggregate and a

Törnqvist index for its input aggregate, whereas the DL database uses the Fisher Ideal index throughout.

Table 1: Multifactor Productivity Growth, ABS versus DL

	ABS		DL	
	Mean	s.d.	Mean	s.d.
1966-2004	1.012	0.022	1.015	0.028
1966-1985	1.013	0.028	1.017	0.035
1986-2004	1.011	0.014	1.013	0.018

NB: A mean value greater than one implies positive MFP growth, while a value less than one implies negative TFP growth. The mean value less one times a hundred gives the average percentage growth in MFP. ``s.d.'' denotes standard deviation. ABS refers to the official productivity growth series reported by the Australian Bureau of Statistics, while DL refers to productivity growth from the Diewert and Lawrence (2005) database for Australia.

Productivity growth for Australia from the ABS database, 1966-2004, is plotted in Figure 1, while summary statistics are reported in Table 1. The DL database productivity growth series, 1961-2004, is plotted in Figure 2, with the summary statistics reported in Table 1 alongside the ABS data results. The sample size of the DL database is restricted in this table for comparability purposes, so that it starts from 1966. The means for each sample period considered suggest that the databases are quite comparable, with slightly higher productivity growth in each of the subperiods (1966-1985 and 1986 to 2004) for the DL database, and therefore higher productivity growth over the entire sample (1.5% versus 1.2%).

However, a comparison of figures 1 and 2 (and the standard deviations from Table 1) reveal that there was considerably higher variation in the DL productivity series, especially early in the sample. The volatility of the DL productivity series in Figure 2 results from there being little relationship between input growth and output growth. This is somewhat of a concern, given that one would expect to see some long-run relationship between input growth and output growth. However, it probably reflects the broader coverage of the DL database compared with the ABS database, to include some sectors where measurement is more difficult. It seems there is simply a lot of noise in the measured data for several industries which have been included, particularly early in the sample.[13]

The productivity numbers in this section show that two alternative, entirely sensible, approaches to productivity measurement can lead to quite different results.

5. Some Challenges

``Why don't we know more after all these years? Our data have always been less than perfect. What is it about the recent situation that has made matters worse? The brief answer is that the economy has changed and that our data-collection efforts have not kept pace with it. ``Real" national income accounts were designed in an earlier era, when the economy was simpler..." Griliches (1994)

While considerable progress has been made in constructing aggregate, market sector, manufacturing and industry multifactor productivity growth data bases in industrialised countries, many challenges remain. One obvious problem is that while there is general agreement on many of the basic principles of productivity measurement, different countries make different choices in the design and implementation of their productivity database. For example, Statistics Canada (2001, Appendix 1) explains the differences between the Canadian approach and the approach used by the U.S. Bureau of Labor Statistics. Statistics New Zealand paid close attention to ABS practice in constructing its productivity database, but still made different choices in many small (subtle) ways. Differences between countries could be as obvious as the use of different index number formulae and industry coverage, but could also be more subtle (such as the treatment of negative user costs). This will affect the ability to compare productivity growth rates across countries; the ability to make such comparisons may be of particular interest to developing countries, so it would be useful to have a standard convention for productivity measurement.

Unfortunately, such a convention does not exist (despite the fine efforts of the OECD), and is unlikely to exist any time soon as different countries try to improve their

[13] Fox and Nguyen (2007) provide more analysis on the differences between the data sets.

productivity statistics using alternative methodologies and introduce improvements with different timing. For example, countries take different approaches to the quality adjustment of outputs, and many industrialised countries are working on capitalising investments in research and development (R&D), while it is likely to be a long time before this practice is widespread.

The international comparability of productivity growth rates is addressed again later, in section 5.5. But first, problems with the measurement of service sector outputs, changing quality of goods, the classification of consumption expenditures and business expenses, and the environment are considered.

5.1 Service Sector Outputs

The growth in the service sector over the last sixty years has been quite dramatic in most industrialised countries. There is increasing evidence to suggest that the services sector is becoming the primary source of aggregate productivity growth. For example, Bosworth and Triplett (2007) find that over the period 1995--2005, MFP growth ``substantially exceeded productivity accelerations in the goods sector'' in the U.S. It is very difficult to measure the outputs of many service sectors, so we may still be understating the role that service sector productivity has in driving economic growth and welfare.

Diewert (2005) noted the following general categories of service products where there are substantial measurement difficulties.

- Unique products; how to construct indexes over time if the product is only observed once? Such products are perhaps becoming more common.
- Complex products; e.g. telephone service plans.
- Tied products; how to separate the prices and hence quantities of the bundled products?
- Marketing and advertising products; is there an economic paradigm for products which aim to influence consumers or inform them consumers about their tastes?
- Financial products; it is not yet entirely resolved how to determine the real price of monetary deposits.

• Uncertain products; what is the correct pricing concept for gambling and insurance expenditures?

With the huge expansion in the service sector in industrialized countries over the last sixty years, it seems imperative that increasing effort goes into solving these problems --- they will be equally confronted by developing countries.

5.2 New Goods and Quality Adjustment

The rapid increase in the quality of computers and many other capital goods has led to the practice in some countries of adjusting price indexes in order to take into account quality improvements using hedonic regression techniques (Court, 1939; Griliches, 1961, 1994; Silver, 2004; Triplett, 2004).[14] This, in turn, has led to substantial declines in investment deflators, relative to the unadjusted price indexes. The lower deflators lead to higher real investment, and hence higher output levels. The more accelerated the fall in prices, the higher the rates of real GDP growth. This can, in turn, impact on productivity growth estimates (Jorgenson and Stiroh, 2000; Nordhaus, 2000; Gordon, 2000). As not all countries have adopted such methods (e.g., the U.S., Canada, Australia and New Zealand have, Germany has recently and the U.K. has not), there is the possibility that relative real GDP growth rates are being distorted.[15] In addition, not all countries make adjustments in the same way, to the same commodities groups, and they did not all start making adjustments at the same time; for a review of different methods employed in the construction of national accounts by different countries, see e.g. Bover and Izquierdo (2003).

The country which seems to make the most hedonic adjustments is the U.S. Landefeld and Grimm (2000) reported that 18% of GDP final expenditures are deflated using indexes that are calculated with hedonic methods, and this figure is now probably higher. Even

[14]This section draws on Diewert and Fox (2005).

[15]Schreyer (2002, p. 1, footnote 1) notes that this issue has received widespread attention: ``America's hedonism leaves Germany cold," *Financial Times*, 4 September 2000; ``Apples and Oranges," *Lehman Brothers Global Weekly Economic Monitor*," September 2000; *Monthly Report of the Bundesbank*, August 2000; ``The New Economy has arrived in Germany---but no one has noticed yet," *Deutsche Bank Global Market Research*, 8 September 2000; Wadhwani, Sushil, ``Monetary Challenges in a New Economy," speech delivered to the HSBC Global Investment Seminar, October 2000.

with unprecedentedly steep declines for some hedonic price indexes, there is some empirical support for these indexes using matched-model indexes from high-frequency data (Aizcorbe, Corrado and Doms, 2000). Moulton (2001) notes the commitment of U.S. statistical agencies to increase the use of hedonic methods, as there is a view that much quality change is still being missed by statistical agencies. However, this view is not shared by all countries, and there has been much interest in the role of statistical agency methodology in driving the U.S.--Europe output growth and productivity gap of the late 1990s.[16]

Obviously, these problems of different national accounts methodologies will not matter for international comparisons if they do not affect the comparisons. Wyckoff (1995) examines labour productivity in the computer and software equipment sector across OECD countries, applying the hedonically adjusted U.S. price deflator for this sector to each country's nominal output figures. He finds that most of the differences in productivity in this sector between countries can be attributed to different methodologies in calculating the price deflator. Van Ark (2000) finds supporting evidence of this result for the 1990s for the European countries which still did not use hedonic price indexes.

So, for some sectors of the economy the choice of deflator will have significant effects on international comparisons. However, at the aggregate level, it is unclear whether the impact is significant. Pakko (2002, table 1, p. 4) reports that, on average, the contribution of equipment and software investment in the U.S. was 1.09% to GDP growth of 4.11% for the period 1995-2000, compared with a 0.12% contribution to 3.53% GDP growth in the 1950s. For New Zealand, which uses hedonic methods, the deflator for Plant, Manufacturing and Machinery fell by 29% over the period 1992--1999, while the GDP deflator rose 8.8% over same period. Plant, Machinery and Equipment has been growing as a percentage of real GDP: 5% in 1988, 9% in 1999. These observations indicate a large increase in the role of investment in determining GDP growth.

However, Scheuer (2003) estimates that ``the growth differential between Germany and the United States over the second half of the nineties is likely to have been just over 0.4 percentage points p.a. smaller if more harmonised methods had been used to deflate IT

[16]The treatment of some high technology goods as either investment or intermediate goods has also been of concern. For example, the share of total software expenditures recorded as investment differs greatly between

goods and to calculate software investment." Schreyer (2002), using a range of simulations, found similarly small impacts from the choice of deflator for international comparisons. Thus, it seems that different deflators can only explain part of the growth difference between countries, such as the 2.5% average between the U.S. and Germany for 1996--2002. However, it should be noted that such comparisons are fraught with difficulties, as results will depend on which country's deflator is chosen to apply across countries, the fact that different countries probably should have different deflators anyway, and that the choice of deflator is not the only difference in statistical techniques used across countries (e.g. there are also differences in terms of index number formula used). Therefore, the impact may be larger or smaller than current estimates but, other things equal, it is likely to be growing given the growing share of investment in high technology capital goods. This is mitigated in practice by an increasing trend for statistical agencies to embrace hedonic techniques.[17] However, even small differences can accumulate over time to be sizable.

5.3 Have Consumption Expenditures become Business Expenses?

Consumption expenditures are final ``goods" and hence appear as part of value added.[18] Business expenses are intermediate ``goods" and do not appear as a positive part of value added. The expansion of business expense accounts, and various fringe benefits, may have caused many consumption items to now be classified as intermediate goods. Entertainment expenses, as well as company gyms, daycare centers, cars, home loans and parts of business travel, are all former consumption expenditures which will not appear in final aggregate demand (Triplett, 1997; Diewert and Fox, 1998).[19]

OECD countries, such as 4% for the UK and 70% for Spain (Ahmad et al., 2003).

[17]Even Germany now uses hedonic methods. ``In May 2004 the German statistics agency, the Statistisches Bundesamt, extended the use of the hedonic method to IT products of the producer, import and export price indexes and also the wholesale price index....Prior to this, hedonic quality adjustment had only been applied by the German statistics agency to subsets of the consumer price index. Since June 2002 this has included a sub-index for personal computers and since May 2003 a sub-index for used cars based on hedonic methods....In early 2004 hedonic price measurements were also used to calculate a house price index as part of a European pilot study. Work is currently in progress on hedonic consumer price indexes for the subsets ``electrical household appliances" and ``consumer electronics". The intention is to implement these in our regular reporting by January 2005." (Linz, Behrmann, Becker, 2004).

[18]This and the following section draw on Diewert and Fox (2001).

[19]``Salary sacrifice" schemes are becoming an increasingly common way to avoid taxes in many countries.

A Japanese study (reported in the Asahi Shimbun, 1995) hinted at the extent that such a re-classification of consumption expenditures had taken place. An index of economic activity was found to be very highly correlated with blood sugar levels of Japanese businessmen. When there was a decline in the economic-activity index around 1990, blood sugar levels fell correspondingly. A possible reason for this remarkable correlation is that entertainment expense accounts expand with economic growth, and dietary habits change as a result. If Japanese businessmen consume more and richer food, (perhaps Western food), when they dine out than when they eat at home, then this could explain this correlation. Larger expense accounts means more entertaining of guests and more dining out, hence higher blood sugar levels. If this is indeed the reason behind the correlation, then this suggests that actual real value added is growing faster than measured during economic booms, and slower than measured during downturns --- cuts in expense accounts result in a re-classification of consumption back to final demand expenditures, which would contribute to measured output growth. This, in turn, has an obvious impact on productivity measurement.

5.4 The Environment

There are other examples of such misclassification of final demand expenditures as business intermediate expenditures. The impact of pollution control and environmental preservation regulations on productivity have been examined by, e.g., McConnell (1979, p. 44), Malkiel (1979, pp. 83--84), Nordhous (1982, p. 138), Mairesse (1982, p. 161), and Bailey and Gordon (1988, p. 362). These results are related to the much publicised arguments put forward primarily by Porter (1990), and Porter and van der Linde (1995) on the possibility of productivity-improving environmental regulation. It may be more appropriate for expenses that firms incur in preserving the environment to be treated as final demand expenditures, rather than as intermediate business expenses. At least, if these expenditures are to be classified as costs for firms, there should be appropriate measures of

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Under these schemes, employees may give up salary and be compensated in kind through, e.g., the use of a company car. The expansion of these schemes attracted the attention of the Australian Government recently: ``Salary packaging, elaborate tax schemes used by the wealthy and increasing numbers of multi-national companies, have been cited as some of the prime risks to the tax system. ... The Treasury did not give any indication of the numbers of people involved in these schemes, but the mention of salary sacrifice schemes indicates that they pose a significant threat to revenue," (Sydney Morning Herald, May 14 1998).

the ``output", i.e., the resulting improvement in the environment. Taking this into account would increase the productivity growth measures for the sectors subject to such regulation, and the economy as a whole.

5.5 A Problem with Cross-Country Growth Comparisons

``We must at least always ask ourselves what it is we are trying to measure, and then inquire how well it can in fact be measured. In overlooking these questions, we have developed some bad habits, in particular when it comes to comparing growth in different economies."

Nutter (1957, p. 61)

One of the main uses of productivity statistics is to compare growth rates across countries. In this context, productivity growth is regarded as a measure of relative economic performance. It is well-known that level comparisons of productivity between countries are fraught with difficulties. However, Fox (2005) noted that if economies are considerably different in terms of relative industry shares, then even such growth comparisons can lead to inappropriate interpretations and conclusions.

The ``problem" is as follows. One country may have higher productivity growth than another in every sector, yet have lower productivity growth overall. In this section, the reason this result arises is illustrated, and it is noted that the result contains information about the reasons for the relative aggregate performance of countries.

Consider the case, without loss of generality, where there are two countries A and B, and sectors 1 and 2 in each country. These sectors produce the same goods in each country. Now assume, for simplicity, that input growth is the same in both sectors in both countries. Hence, using a standard definition of total-factor productivity as output growth divided by input growth, output growth determines productivity growth.

Let Y_{ij}^{t} denote real value added in country i, $i = A,B$, sector j, $j = 1,2$, for period t, $t = 0,1$. Then consider the following case, where output growth (and hence productivity growth) is higher in each sector in country A than in country B. That is,

$$\frac{Y_{A1}^{1}}{Y_{A1}^{0}} > \frac{Y_{B1}^{1}}{Y_{B1}^{0}}, \tag{6}$$

and

$$\frac{Y_{A2}^{1}}{Y_{A2}^{0}} > \frac{Y_{B2}^{1}}{Y_{B2}^{0}}. \tag{7}$$

Then we can note the following paradox.

PARADOX *Although A has higher productivity growth in both sectors, it can have lower aggregate productivity growth than B. That is, the following is possible:*

$$\frac{Y_{A1}^{1} + Y_{A2}^{1}}{Y_{A1}^{0} + Y_{A2}^{0}} < \frac{Y_{B1}^{1} + Y_{B2}^{1}}{Y_{B1}^{0} + Y_{B2}^{0}}. \tag{8}$$

The aggregation of output across sectors by addition before using division to get growth rates should indicate an obvious potential for a troublesome result like this arising. However, the definition of productivity in (8) is consistent with the definition of productivity at the sectoral level. A simple re-expression of the first half of (8) suggests how this paradoxical result is possible, as follows:

$$\frac{Y_{A1}^{1} + Y_{A2}^{1}}{Y_{A1}^{0} + Y_{A2}^{0}} = \theta_{A1}^{0} \cdot \frac{Y_{A1}^{1}}{Y_{A1}^{0}} + \theta_{A2}^{0} \cdot \frac{Y_{A2}^{1}}{Y_{A2}^{0}}, \tag{9}$$

where θ_{Aj}^{0} is the share of industry j in total output for country A, or $\theta_{Aj}^{0} = Y_{Aj}^{0}/(Y_{A1}^{0} + Y_{A2}^{0})$, $j = 1,2$. Naturally, a similar expression to (9) exists for country B. It is clear then that the sector shares play a role in determining aggregate productivity, and that they also play a role therefore in determining relative productivity between countries A and B.

Let g_{ij} denote productivity growth between periods 0 and 1, country i, sector j. Then using (9), equation (8) becomes:

$$\theta_{A1}^{0} g_{A1} + \theta_{A2}^{0} g_{A2} < \theta_{B1}^{0} g_{B1} + \theta_{B2}^{0} g_{B2}, \tag{10}$$

or

$$\theta_{A1}^{0} g_{A1} - \theta_{B1}^{0} g_{B1} < \theta_{B2}^{0} g_{B2} - \theta_{A2}^{0} g_{A2}. \tag{11}$$

Hence, if country A has relatively more of its total output in the sector with lower growth, and country B has relatively more of its total output in the sector with higher growth, then the paradoxical result is possible. Another simplifying assumption, and a numerical example illustrate this, as follows.

Let the output (and productivity) growth in sector 1 be the same in both countries, and similarly for sector 2; $g_{A1} = g_{B1} = g_1$ and $g_{A2} = g_{B2} = g_2$. Then (11) becomes

$$(\theta_{A1}^{0} - \theta_{B1}^{0})g_1 < (\theta_{B2}^{0} - \theta_{A2}^{0})g_2. \tag{12}$$

If $\theta_{A1}^{0} = 0.9$, $\theta_{A2}^{0} = 0.1$, $\theta_{B1}^{0} = 0.8$ and $\theta_{B2}^{0} = 0.2$, then

$$(0.1)g_1 < (0.1)g_2 \Rightarrow 1 < g_2/g_1. \tag{13}$$

In the example above, productivity growth is higher in sector 2 than in sector 1, while productivity growth of each sector is the same in both countries, yet aggregate productivity growth is different because of the different shares. From this example, it is straightforward to see that the assumption of equal sectoral growth rates can be relaxed while the inequality in (11) still holds. That is, the inequality in the paradox holds because of A having a higher share of its economy than B in the sector with lower productivity growth.

Equation (9) can be interpreted as the well-known Laspeyres quantity index, with prices set equal to one in period 0. More generally, the Laspeyres index can be written as follows:

$$Q_L^{0,1} = \sum_{m=1}^{M} s_m^L \frac{q_m^1}{q_m^0}, \tag{14}$$

where $s_m^L = p_m^0 q_m^0 / \sum_m p_m^0 q_m^0$ is the value share in period 0, and q_m^t is the quantity for periods $t = 0,1$ of goods $m = 1,\ldots,M$. The well-known Paasche index can also be written in a similar form to the right-hand side of (9):

$$Q_P^{0,1} = \sum_{m=1}^{M} s_m^P \frac{q_m^1}{q_m^0}, \tag{15}$$

where $s_m^P = p_m^1 q_m^0 / \sum_m p_m^1 q_m^0$. If prices are constant and normalised to one, then the Paasche index is equal to the Laspeyres index in (9). In addition, consider the following expression for the Fisher index (geometric mean of the Paasche and Laspeyres indexes):

$$Q_F^{0,1} = [\sum_{m=1}^{M} s_m^L (q_m^1/q_m^0) \cdot \sum_{m=1}^{M} s_m^P (q_m^1/q_m^0)]^{1/2}. \tag{16}$$

Obviously, if prices are constant and normalised to one, then the Fisher index equals the Laspeyres and Paasche indexes, and would also have the form of (9). Therefore, (9) can also be thought of as a special case of aggregating using a Fisher index. Suppressing prices in aggregation as in (9) merely simplifies the illustration of the paradox, without affecting the generality of the observation. It should be obvious from (16) that as long as different countries have different weights (shares) for the sectors, then the paradoxical results are possible. What matters is the relative weight that the sector with lower growth gets in each country.

The extreme case noted in the paradox above (where the inequality is reversed in the aggregate case), does not have to occur for the above observations to be relevant. For example, a country may have much higher productivity growth than another in all sectors, yet in aggregate have only marginally higher productivity growth, for the reasons already noted.

What if input growth is not held constant across sectors and countries? It is unclear how to aggregate in this case. One approach is to use output shares to weight productivity growth rates. Input shares could similarly be used as weights, which is more natural as can be seen by a simple rearrangement of the resulting productivity measure.[20] However, as we can write an equation like (9) for inputs as well, we could also take a ratio of the output index to the corresponding input index. Hence the choice is somewhat arbitrary.

It is interesting to note that while the above discussion has been in terms of productivity, what has been shown through suppressing the role of inputs is that a country can have higher output growth in every industry yet have lower output growth overall. This implies that, for example, real Gross Domestic Product (GDP) growth rates are not really directly comparable across countries as each country has different shares that are used in the construction of the GDP index. This has nothing to do with the lack of ``chaining'' (updating the base) or the use of, e.g. the Laspeyres index rather than the Fisher index, only the use of different weights in different countries. Thus, even if two countries being compared used chained Fisher indexes in the construction of the GDP index (as the U.S.

[20] In this case we start with the definition of productivity level in each sector as output divided by input. Some simple algebra leads to the conclusion that the natural way to aggregate then is to sum each of the productivity level using real input shares, then to take the ratio of the different period productivity aggregates to get productivity growth. However, the approach of Färe and Zelenyuk (2003) and Zelenyuk (2003) naturally leads to the use of output shares in aggregation.

has since 1995), the problem would still exist.[21]

6. Conclusion

International efforts on productivity measurement have made a lot of progress over the last couple of decades. This makes it easier for developing countries to follow the lead of industrialised countries and international agencies in producing their own productivity statistics to inform policy. However, it is clear that many measurement problems remain, and that it is not a costless exercise to produce good productivity statistics.

A key problem faced by most countries, besides the lack of funding, is the lack of human capital with expertise in the field of measurement economics. This has been somewhat mitigated by initiatives such as the OECD Productivity Manual (2001) and the EU KLEMS project, by providing a consistent productivity measurement framework, lowering both the financial and human capital costs in producing productivity statistics.

Realistically, many countries are still a long way from being able to produce detailed productivity statistics that are anything more than very simple partial measures. Perhaps there are many more priorities for the use of scarce resources than producing productivity statistics. However, statistics inform policy, and the use (or misuse) of inappropriate statistics can be damaging to economic growth.

On a more positive note, it is clear that there is a commitment in many countries to continue to develop productivity databases at more disaggregated levels, and to address some of the outstanding problems in productivity measurement.

[21] It is worth laboring this point a little, as there seems to be a somewhat popular view that the use by the U.S. of a chained Fisher index to construct real GDP has solved all manner of aggregation and international comparison issues. Different countries will have different shares, and hence paradoxical results such as those illustrated above are possible. Chaining cannot help. Equation (16) has only two periods, whereas chaining can only be done when there are more than two periods, and always involves the direct comparison of two periods as in (16). Kohli (2003) highlights some other problems with the measurement of GDP, and international comparisons, that cannot be solved by the use of chaining and the use of the Fisher index

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Figure 1: Productivity Growth, ABS Data

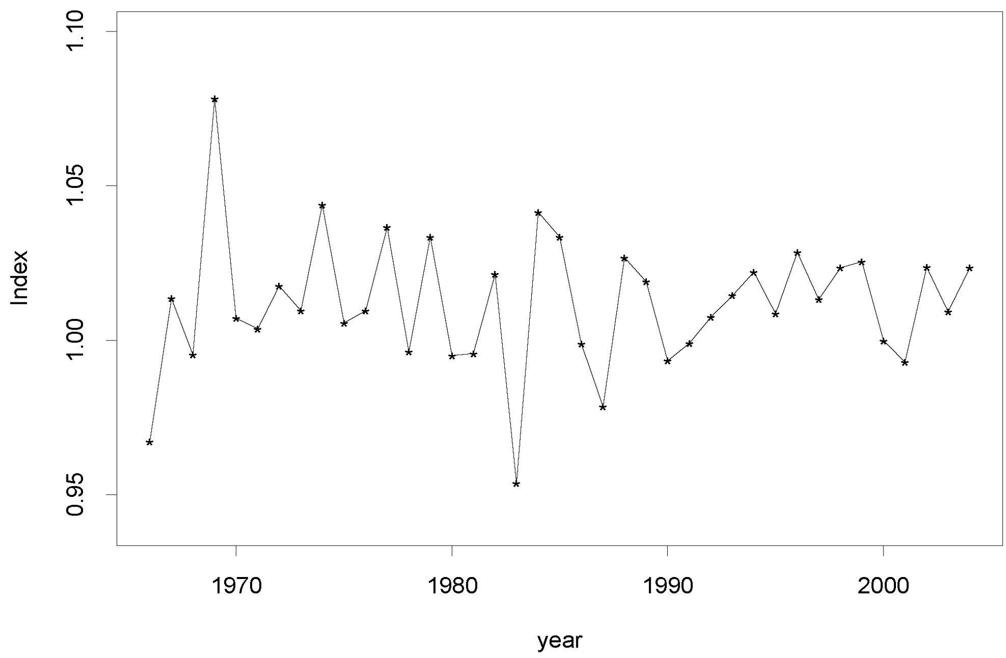

Figure 2: Productivity Growth, Diewert-Lawrence Data