The Contributions of Productivity, Price Changes and Firm Size to Profitability

Denis Lawrence
Meyrick and Associates

W. Erwin Diewert
University of British Columbia

and

Kevin J. Fox
University of New South Wales

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Abstract

Sources of profit change for Telstra, Australia's largest telecommunications firm, are examined. A new method allows for changes in a firm's profits to be broken down into separate effects due to productivity change, price changes and growth in the firm's size. This in turn allows us to calculate the distribution of the benefits of productivity improvements between consumers, labour and shareholders. The results show that around half the benefits from Telstra's productivity improvements from 1984 to 1994 were passed on to consumers in the form of real price reductions.

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Denis Lawrence	W. Erwin Diewert	Kevin J. Fox
Meyrick and Associates	Department of Economics	School of Economics
6 Kurundi Place	University of British Columbia	University of New South Wales
Hawker ACT 2614	Vancouver, B.C. V6T 1Z1	Sydney 2052
Australia	Canada	Australia
denis@meyrick.com.au	diewert@econ.ubc.ca	K.Fox@unsw.edu.au
Tel: 61-2-6278-3628	1-604-822-2544	61-2-9385-3320

1 Introduction

With the increasing pace of infrastructure reform in most countries there has been rapid productivity growth but considerable debate about who has benefited from reform: is it shareholders, consumers or employees? If the reform process is to provide ongoing and sustainable economic benefits then it is important that there be a reasonable distribution of benefits among these stakeholders. If all the benefits are passed on to users then infrastructure firms will have no incentive to invest further in their business and meet future infrastructure needs - or to commit the time and effort required to achieve further reforms. This will ultimately damage the economy's competitiveness and make consumers worse off in the long run. Conversely, if the infrastructure firm keeps all the benefits then users will be dissatisfied and pressures will mount for radical change. This may also make other firms which use infrastructure services less competitive and, thus, reduce economic growth.

The telecommunications industry is of particular interest due to the rapid pace of technological change, and because in most countries it is a regulated industry. It will be important for regulators to be aware of the distribution of the benefits from productivity improvements when setting price caps if reforms are to be sustainable. In this paper we use Australia's largest (and regulated) telecommunications provider, now known as "Telstra," to illustrate a method for quantifying the distribution of the benefits from productivity improvements that is relevant to all infrastructure industries. As well as helping assess the sustainability of reforms, the method also provides a basis for assessing the impact of external factors such as the entry of competitors and changes to labour laws.

Concurrent changes in output and input prices, productivity and firm size have made answering questions about the distribution of the benefits of infrastructure reform difficult. This paper applies a new index-number method to data for Telstra, 1984 to 1994, allowing changes in a firm's profit to be broken down into separate effects due to productivity change, price changes and growth in the firm's size. Profit is defined as the gross return to capital, which is the difference between the revenue from outputs produced and the cost of non-capital inputs. The gross return to capital has to cover the cost of depreciation and provide a residual return on the firm's assets. Changes over time in the value of a firm's gross return to capital can arise from three sources:

1. growth in the size of the enterprise — as the capital stock becomes larger, the same rate of return implies a larger dollar value return to capital;

2. improvements in productivity — more output is produced from a given quantity of inputs leading to more revenue and more profits; and

3. price changes — if output prices increase by less than input prices then the firm's gross return to capital will fall (with the benefit going to the firm's consumers and/or input suppliers, including workers).

Until now there has been no accurate way of separating and quantifying these influences. There have been attempts to approximate the contribution of price changes by looking at what the gross return to capital would have been this year using last year's prices applied to this year's quantities. However, this simple approach still confuses the contributions of growth and relative price changes and will be less accurate the longer the time period considered due to flaws in the assumed indexing procedure.

This paper makes two theoretical contributions. The first is the recognition that a "capital productivity growth" concept is a natural one to use in the context of measuring how the benefits of productivity improvements are distributed to various stakeholders. The second contribution is the demonstration that deflating the Diewert and Morrison (1986; 666-667) decomposition of value change into contributing components leads to effects that can be given welfare interpretations that are comparable across time.

Thus, our approach allows us to consider the separate contributions of productivity, output and (real) input price changes and changes in firm size to the changes in (real) profit. This in turn allows us to calculate the distribution of the benefits of productivity improvements between consumers, labour and shareholders. The results and methodology will be of interest to consumers, utilities, shareholders and regulators, and could form the basis of a new approach to utility regulation.

2 Methodology

Let π^t denote the profit of a firm in period t. Then we can define an index of the growth in the profit of the firm, between periods t and $t-1$, as follows:

$$G^t \equiv \pi^t/\pi^{t-1}, \tag{1}$$

which is one plus the growth rate of profits.[1]

An index of productivity growth between periods $t-1$ and t can be defined (residually) as an output index divided by an input index (i.e., output growth divided by input growth), as follows:

$$R^t \equiv \frac{G^t/P^t}{K^t}, \tag{2}$$

where P^t is a price index for the outputs, G^t/P^t is an implicit output quantity index (value growth divided by price growth), and K^t is an input quantity index. Consequently, productivity growth in (2) is the growth in the output quantity index that cannot be explained by growth in input utilization. By rearranging equation (2), we obtain:

$$G^t = R^t \cdot P^t \cdot K^t \tag{3}$$

where the ratio of profits can be decomposed into contributions from productivity (R^t), price (P^t) and input (K^t) growth.

[1] This could be net or gross operating surplus. We will use gross operating surplus as our definition of "profit" in our empirical application; see equation (8)

Any index number formula can be used for constructing the price and input indexes for use in (3). However, the Törnqvist (1936) index has several advantages that suggest its use in this context. Let $p^t \gg 0_N$ denote a price vector for period t prices, so that $p^t = (p_1^t, \ldots, p_N^t)$, where there are N net outputs, or "netputs", denoted by $y^t = (y_1^t, \ldots, y_N^t)$, and where $y_n^t > 0$ implies that the nth good is an output, while $y_n^t < 0$ implies that the good is an intermediate input.[2] Similarly, let $r^t \gg 0_N$ be the price vector for period t "primary" input prices, so that $r^t = (r_1^t, \ldots, r_M^t)$, where there are M primary inputs denoted by $k^t = (k_1^t, \ldots, k_M^t)$.

We can then define P^t and K^t in (3), respectively, as

$$P^t \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^{t-1} + s_n^t)\ln(p_n^t/p_n^{t-1})\right], \tag{4}$$

which is a Törnqvist price index, where $s_n^t = (p_n^t y_n^t)/(p^t \cdot y^t)$ is the profit share of netput n ($s_n^t < 0$ if good n is an input), using the notation $p^t \cdot y^t = \sum p_n^t y_n^t$, and

$$K^t \equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}(\sigma_m^{t-1} + \sigma_m^t)\ln(k_m^t/k_m^{t-1})\right], \tag{5}$$

which is a Törnqvist quantity index, where $\sigma_m^t = (r_m^t k_m^t)/(p^t \cdot y^t)$ is the profit share of fixed input m.

By noting that the Törnqvist index formula has the form of a (weighted) geometric mean, we can write the aggregate price index as a product of individual price sub-indexes:

$$P^t = \prod_{n=1}^{N} P_n^t. \tag{6}$$

P_n^t is defined as the nth term in (4), and gives the contribution of the price changes of the nth good to the aggregate price index. Similarly, the primary-input index in (5) can be

[2]The notation $p^t \gg 0_N$ means each element of p is positive, while $p^t > 0_N$ means $p^t \geq 0_N$ but $p \neq 0_N$.

written as:

$$K^t = \prod_{m=1}^{M} K_m^t. \tag{7}$$

K_m^t is defined as the mth term in (5), and gives the contribution of the change in the mth component of the primary inputs to the aggregate primary input index. Together, equations (3), (6) and (7) represent a detailed decomposition of nominal profit growth between $t-1$ and t.[3]

Note that by taking intermediate goods (including labour) as negative outputs, we are using a value-added (or gross-operating-surplus) type approach to output and productivity measurement, rather than a gross output approach; for a comparison of these two legitimate approaches, see Balk (2003).[4] In the following section, we will use both approaches for calculating productivity growth. The gross output productivity growth measure will be referred to as Total Factor Productivity (TFP) growth, while our gross operating surplus type approach will be referred to as Capital Total Factor Productivity (KTFP) growth, or simply, productivity growth. Since the input base for KTFP growth is very much smaller than the input base for TFP growth, KTFPG will be very much greater than TFP growth.

Thus far, we have not considered any economic theory behind this decomposition of a profit ratio. The choice of the Törnqvist index over other index numbers has been motivated above by the ability to decompose it easily as the product of sub-indexes, as in equations (6) and (7). The use of the Törnqvist index in (3) can be further justified by the axiomatic (or "test") approach to index numbers (Diewert, 2004).[5] In addition, it can be shown that the

[3]Similar decompositions have been employed in different contexts. For example, Diewert and Morrison (1986) and Fox and Kohli (1998) used this approach to decompose the growth in domestic product in the context of an open trading economy.

[4]This gross-operating-surplus approach is consistent with national income accounting conventions. Gross operating surplus is equal to the value of outputs less the value of intermediate inputs less the value of labour input. Here we include labour as an intermediate input rather than a primary input, as firms can typically adjust their labour input even in the short run.

[5]The usual axiomatic approach to index number theory regards the price and quantity vectors pertaining to two situtations to be compared as being completely exogenous vectors, whereas the economic approach to index number theory regards the two price vectors as being exogenous but the two quantity vectors are regarded as being determined endogenously as the solution to some sort of economic optimization problem.

Törnqvist index closely approximates the Fisher Ideal index, which has a slightly stronger justification from the axiomatic approach. This is a result in numerical analysis and does not depend on assumptions of optimising behaviour (Diewert, 1978). Hence, there are strong reasons for the choice of the Törnqvist index over many other index-number formulae, and therefore a justification exists from the axiomatic approach to index numbers for the profit decomposition represented by equations (3), (6) and (7). The appendix shows that it is possible to provide the proposed decomposition with an additional justification by drawing on the literature on the economic approach to index numbers.

In the empirical context considered in this paper, we define "profit" as the gross operating surplus, so that

$$\pi^t = p^t \cdot y^t = r^t k^t. \tag{8}$$

That is, r^t is defined as the *ex post* return on the fixed factor of production, so that $r^t = p^t \cdot y^t / k^t$. Note that no assumptions about competitive optimizing behaviour have been made here. We have simply defined profits to be the *ex post* return on capital.

Consider the case, as in our empirical application below, where there is only one primary input aggregate, which we will call "capital".[6] Then r^t and k^t are scalars, and the period t gross rate of return to capital is $r^t = \pi^t / k^t$. This is clearly a price for capital, being its value divided by its quantity, and so represents the (dollar) return to a unit of capital input. With only one primary input, its share of profit is one so that equation (5) reduces to

$$K^t = k^t / k^{t-1} \tag{9}$$

[6]Note that this is different from a national-accounting-type context, where labour is also treated as a primary input. It may be reasonable to make this assumption for a country, but for a firm which can easily vary its labour input in the short run, it seems more reasonable to treat labour as an intermediate good. Substitution between intermediate inputs and capital is still possible in the "long run," and we will be using annual data where we observe changes in capital and the intermediate inputs in the same period. This particular assumption can be viewed as just being clear about the short-run variable inputs that are available to decision-makers in the firm each (arbitrarily short) period.

In practice, inflation will increase nominal profit growth over time. In the presence of inflation, it is important to conduct the analysis in terms of real price changes to estimate the full extent of benefits passed on to consumers and input suppliers. This is because consumers and input suppliers benefit from the extent to which their price changes diverge from the rate of inflation, not to the extent of their nominal price changes.

As we wish to consider changes in profit which only relate to industry changes in prices, productivity and inputs, we remove the effects of general inflation by dividing profit in each period by the level of the consumer price index (cpi^t), so that the decomposition equation that we use is as follows:

$$G^{t*} = \frac{\pi^t/cpi^t}{\pi^{t-1}/cpi^{t-1}} = R^t \cdot P^{t*} \cdot K^t \tag{10}$$

using (3) and (4), where

$$\begin{aligned} P^{t*} &\equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^{t-1} + s_n^t) \ln(p_n^t/cpi^t)/\ln(p_n^{t-1}/cpi^{t-1})\right], \\ &= \prod_{n=1}^{N} P_n^{t*} \end{aligned} \tag{11}$$

where P_n^{t*} is the nth term in the first line of (11). Note that P^{t*} is also equal to $P^t/(cpi^t/cpi^{t-1})$. By dividing the period t prices p^t by the period t CPI, cpi^t, we can give welfare interpretations to price change contribution terms P_n^{t*} defined in (11).[7] If n is an output and P_n^{t*} is negative, this means that the purchaser of output n gets a benefit from his or her purchases of commodity n going from period $t-1$ to t in terms of paying a lower real price. If n is an intermediate input and P_n^{t*} is positive, this means that the supplier of intermediate input n

[7] Alternative deflators to the consumer price index (CPI) could be considered. However, using a deflator for e.g., telecommunications services and equipment in the current context would remove much or all of the price variability in which we are interested (as it would closely reflect the price movements in the industry, rather than just the general trend of overall inflation in the economy). Thus, we use the CPI as we want to capture contributions to profits from relative, or “real”, price changes; that is, the change in industry prices relative to overall economy-wide price changes measured by the CPI.

gets a benefit from his or her supplies of commodity n to the enterprise going from period $t-1$ to t in terms of receiving a higher real price. If n is a type of labour service that is supplied to the firm and P_n^{t*} is positive, this means that the real wages received by this type of worker have increased going from period $t-1$ to t. These benefits are made comparable over time by dividing by the natural numeraire price, the Consumer Price Index.

3 Growth, Productivity and Price Changes

In this and the following section we illustrate the application of the methodology using a database on Australia's largest telecommunications company, Telstra, published in Appendix 3 of Bureau of Industry Economics (1995). The database covers the years 1980 to 1994 although in this paper we limit coverage to the 11 years from 1984 to 1994. It contains data on the values and quantities of seven outputs (telephone calls, telephone services in operation, telephone connections, telegrams/faxpost, telex services in operation, telex calls and other network services) and three inputs (labour, capital and other inputs).

The 11 year time period covered by this study was one of considerable change and reform for Telstra which went from being a government owned monopoly to facing its first competition from Optus in 1992 and from Vodafone in 1993. While Telstra remained in government ownership throughout this period there was considerable structural reform and downsizing of the organisation. The former Telecom Australia, which handled domestic telecommunications, was merged with the Overseas Telecommunications Commission to form the full service carrier Telstra, and labour numbers fell by around 25 per cent from 87,000 in 1986 to 66,000 in 1994.

While it is possible to calculate an average implied labour price from the available data on compensation of employees and number of workers, there is no available price data for materials and services. Hence, the corresponding price index for these inputs was approximated by the CPI.

Estimating the economic quantity and user cost of the capital stock of a large, capital intensive, network based enterprise like Telstra is always problematic.[8] In the current database, the Bureau of Industry Economics (BIE) estimated the quantity of the capital stock by using the perpetual inventory method to update and backdate a 1986 estimate of the market value of Telstra's capital stock.[9] Telstra's estimated capital stock actually decreased by 5 percent between 1984 and 1994 as a result of structural reform and technical change. No adjustments were made for quality change, so that capital-embodied productivity growth is captured by the productivity measures considered.

While the BIE calculated an explicit annual user cost of capital, in this study the annual cost of using capital inputs is taken to be the gross return to capital (the difference between the revenue from outputs produced and the cost of non-capital inputs such as labour, materials and services). The gross return to capital has to cover the cost of depreciation and provide a residual return on the firm's assets.

FIGURE 1 HERE

TABLE 1 HERE

Telstra's total factor productivity (TFP) measures the efficiency with which Telstra converts inputs into outputs. It differs from the productivity concept of equation (2) in that it is measured as a direct (rather than "implicit") index of total output quantity formed from the seven output components relative to a total input quantity index formed from the three input components (labour, capital and other inputs). A (chained) Törnqvist index was used for calculating both the input and output indexes. This approach is a gross-output approach to measuring productivity, rather than a value-added-type approach as used in our profit decomposition, as noted earlier (Balk, 2003).

From figure 1 and table 1, we see that Telstra's TFP increased by 92 percent between

[8]See e.g. Griliches (1963), Jorgenson (1996), and Diewert and Lawrence (2000) for more on the general problems relating to the measurement of capital.

[9]The Bureau of Industry Economics was absorbed by Industry Commission in 1996 to form the Productivity Commission.

1984 and 1994 and by 47 percent between 1990 and 1994. This means that in 1994 a typical unit of Telstra's input was able to produce 47 per cent more output than it was just 5 years earlier in 1990 and 92 per cent more than it could have a decade earlier. This is a truly dramatic rate of productivity growth. While high, these productivity growth rates are similar to those found in telecommunications TFP studies in other countries for similar periods (see Boles de Boer and Evans 1996, and CRTC 1997). [10]

In terms of trend growth rates, Telstra's TFP increased by around 5 percent per annum over the 11 year period although it increased by 9.8 per cent annually for the last five years. This is substantially higher than the productivity growth for the economy as a whole and resulted from the combined effects of technological change and substantial restructuring and downsizing within Telstra. If all the benefits of this exceptionally high level of productivity growth had been retained by Telstra it would have led to a large increase in Telstra's gross return to capital. However, the effects of technological change, increasing competition and more stringent regulation put significant downward pressure on Telstra's output prices in the latter years.

FIGURE 2 HERE

We present changes in Telstra's average nominal output and input prices in figure 2 and table 1. The estimate of the overall price Telstra received for its output increased by 34 percent between 1984 and 1991 but then declined substantially. Over the same 11 year period, the consumer price index increased by 70 per cent. This means that our estimate of the average real price of Telstra's output — the overall price it charges to telecommunications consumers relative to the rate of inflation — declined by 76 per cent over the 11 year period. At the same time, however, the estimates of Telstra's nominal input prices outpaced inflation. Telstra's total inputs price index increased roughly 38 per cent more than the consumer price

[10]It is generally thought that output is not well measured in service industries, such as telecommunications, so it is possible that productivity growth is underestimated here. On the other hand, no adjustment has been made for changes in the quality of capital, and the estimated productivity growth includes capital-embodied technological change.

index.

If Telstra had passed on the full extent of its average input price increases to consumers then, all else unchanged, its gross return to capital would clearly have been much higher over the decade.

Changes in real prices are important because they provide a more accurate guide to the extent different groups benefit from price changes. In a time of inflation, consumers benefit from price changes that are below the rate of inflation, i.e. where the real price of the product they are purchasing has fallen. Conversely, labour only benefits from wage increases to the extent that those increases exceed the rate of inflation, i.e. when real wages have increased, not to the extent of their nominal wage increase. Labour also only benefits to the extent that the real wage increase applies to a standardised unit of labour abstracting from increases in skill levels and qualifications over time. The average real price of Telstra's output fell steadily over the decade.

The estimated real labour price also remained relatively constant between 1984 and 1991 but by 1994 it was 24 percent higher than it was a decade earlier. However, with the information available we have been unable to adjust for either the skill increases that occurred with technological change or the compositional changes that occurred with downsizing. Consequently, our estimates of real wage increases probably overstate the benefits going to labour.[11]

4 Sources of Change in Gross Return to Capital

It is clear from the preceding section that, other things being equal, the size of Telstra's real gross return to capital will have:

1. decreased somewhat from the reduction in the amount of capital used by Telstra;

[11] Such data problems are inherent in any productivity study, as we are always constrained by the available data. It is possible that there are considerable measurement problems besides those noted in this paper; see e.g. Jorgenson and Griliches (1972), Griliches (1994), and Diewert and Fox (1999, 2001).

2. increased substantially from Telstra's high rate of productivity growth;
3. decreased substantially from decreases in Telstra's average real output prices; and
4. decreased from increases in the average real price Telstra pays for its labour (although part of this reflects increasing skill levels and compositional change within the Telstra workforce).

Since we deal with the actual quantity of capital, labour and materials and services each period, there will be an approximate one-to-one correspondence between the changes in the gross return to capital we report for each of the scenarios and pre-tax profits. This is because none of the scenarios involve changes to the quantity of inputs and hence depreciation always remains the same. Changes to output quantities and prices (and labour prices) are then directly translated into changes in the gross return to capital and, because depreciation is unchanged, (approximately) into pre-tax profits.

In the remainder of the paper we use the term "productivity" to refer to the "capital total factor productivity' concept outlined below equation (7), and denoted "Prod" in figures 3 and 4 below. As can be seen from (3) and (6), this allows for the identification of the impacts of the changes in intermediate goods prices on profit growth. However, given that the price of "other inputs" (materials and services) was taken as the CPI, the use of equation (11) as the relevant price index leads to the prices of this aggregate making no contribution to the growth in the real return to gross capital. Hence, of the intermediate inputs, only the contributions from labour price changes are reported.

TABLE 2 HERE

Looking first at the 11 year period up to 1994, we present year-to-year percentage changes in the real gross return to capital in table 2 along with the change which would have occurred from each of the four sources in isolation. In other words, the third column of table 2 shows the percentage change in the real gross return to capital which would have occurred from year to year solely from changes in our estimates of the size of Telstra's capital stock, having controlled for productivity, real output and labour prices. While all contributions happen simultaneously, the estimates thus have the interpretation of being contributions to the real gross return to capital conditional on the level of other variables. Similarly, the fourth column shows the year to year percentage change in real gross return to capital attributable to productivity change, the fifth column shows the percentage change in the real gross return to capital attributable solely to changes in real output, and the last column shows the percentage change in the real gross return to capital attributable solely to changes in real labour prices.[12]

Over the 11 year period the real gross return to capital increased by an average 7.2 per cent per annum. *Ex post*, if there had been no productivity change and no change in real output and labour prices but the same growth in the size of the capital stock occurred then the real gross return to capital would have decreased by an average 0.5 per cent per annum.[13] This means the actual increase in real gross returns to capital has outpaced the growth in the size of the capital stock on average.

If all the benefits from productivity growth had been retained by Telstra and there had been no growth in the capital stock and no change in real output and labour prices then the real gross return to capital would have increased on average by a massive 19.8 per cent per annum. In the absence of growth in the capital stock, productivity changes and real labour price changes, then real gross returns would have been reduced annually by 8 per cent on average given the actual pattern of real output price changes. Finally, real labour price changes in the absence of any other changes reduced real gross returns to capital by an average of 1.7 per cent annually.

[12]While it may be of interest in some contexts to model interactions between the determinants of profit, such as capital and productivity (see e.g. Lucas, 1978, Jovancic, 1982), here we are conducting an *ex post* analysis on the observed data.

[13]Of course, if there had actually been no productivity change, then Telstra's investment decisions would have been different from those observed, for example. Our analysis is an *ex post* analysis of the observed data, so that by assuming "no change" of the other components, we are isolating contributions from each source in turn.

FIGURE 3 HERE

The cumulative impact of growth, productivity and real price changes on real gross returns to capital is shown in figure 3. Here we take the real gross return to capital in 1984 as the base and look at the cumulative effect of the actual annual changes in each of the three sources of change and also look at the progressive impact of the sources of change on the real return to capital. The dashed line near the bottom of the figure shows what would have happened to the real gross return to capital over the 11 years if there had been no productivity change and no changes in real labour and output prices — by 1994 the annual real return to capital for that year would have been 5 per cent lower.

The large dashed line at the top of the figure shows what would have happened to the real gross return to capital over the 11 years if there had been both the observed levels of growth and productivity change but no change in either real labour or average real output prices — by 1994 the annual real gross return to capital for that year would have been 430 per cent higher. The small dashed line near the top of the figure shows what would have happened to the real gross return with growth, productivity and real labour price changes but no change in the real output price. Finally, the solid line near the bottom of the figure shows the cumulative effect of all four contributors to changes in the real gross return to capital. This line coincides with the actual observed change in Telstra's real gross return over the period.

The gap between the "Growth" and "Growth + Prod" lines indicates the size of the potential contribution to Telstra's real gross return to capital from productivity improvements from 1984 onwards. The gap between the top two lines shows the extent to which the benefits from Telstra's high productivity growth has been passed on to its labour force in the form of higher real wages (although this probably overstates the benefits to labour as it ignores skill and compositional changes). For the first 8 years of the decade this gap was small but negative indicating that real wages fell behind cumulative inflation in that period.

This was reversed in the last 3 years when the gap became positive and relatively wide. The large gap between the second top (small dashed) line and the solid line near the bottom of the figure indicates the size of the benefit Telstra has passed on to its consumers over the period in the form of lower real prices. Finally, the gap between the solid line and the small dashed line at the bottom of the graph indicates the extent to which Telstra's owners (in this case the government) have benefited from Telstra's high productivity growth. With the exception of 1985, this gap was positive throughout the decade.

To illustrate how this information can be converted into dollar values, we now look at the contributors to changes in Telstra's real gross return to capital between 1990 and 1994. This is the period of major interest given the acceleration of regulatory reforms around 1990 and the introduction of competition in 1992. Over this 5-year period the average annual change in Telstra's real gross return to capital was 6.5 per cent. The change due to productivity improvement alone would have been on average 30 per cent per annum while the change due to growth alone would have been an average of -1.2 per cent per annum. Changes in the real price paid for labour alone decreased real returns by 6 per cent per annum on average while changes in the real price of Telstra's outputs alone reduced real returns by an average of 11.6 per cent per annum.

FIGURE 4 HERE

In figure 4 we present the cumulative effect of these contributions to changes in the real gross return to capital. In 1994 the actual annual real gross return to capital was 24 per cent higher than it was in 1990. Growth in the real capital stock on its own, all else unchanged, would have again led to the 1994 return to capital being 5 per cent lower than it was in 1990. The combined effect of growth and productivity improvements would have led to the 1994 real gross return to capital being 163 per cent higher than it was in 1990. These effects combined with changes in the real price of Telstra's labour would have led to real gross returns being 103 per cent higher in 1994 than in 1990. Adding the impact of real output price reductions accounts for the gap between this figure and the increase actually observed of 24 per cent, indicating that a large part of the Telstra "productivity dividend" has been passed on to consumers in the form of lower real prices.

TABLE 3 HERE

In 1990 Telstra's real gross return to capital was around $4.4 billion (expressed in 1994 prices). Table 3 shows how this changed over the subsequent 4 years. By 1994 the gross return to capital was around $5.5 billion. In the absence of other changes, growth in the size of the capital stock would have taken this figure down to around $4.2 billion. Growth plus productivity improvements would have taken it to $11.7 billion in the absence of real price changes while growth, productivity improvements and real labour price changes would have taken it to $9 billion.

The total productivity dividend in 1994 for productivity change since 1990 was, thus, around $7.5 billion. The distribution of this was a benefit of around $3.5 billion passed on to consumers, a benefit of around $2.7 billion passed on to Telstra's labour (although, as noted above, this probably overstates the benefit to labour as skill and compositional changes are ignored) and a benefit of around $1.3 billion passed on to Telstra's owners in the form of an increased rate of return. This means around 47 per cent of the benefit from cumulative productivity improvements over this 5 year period was passed on to consumers in 1994. Another way of looking at this result is that, in 1994, if Telstra had not passed a large proportion of the benefits of productivity improvement over the 5 years on to consumers, then all else being equal its pre-tax profit would have been $3.5 billion higher.

5 Conclusion

A new economic method for decomposing changes in a firm's real gross return to capital into the contributions from changes in productivity, prices, and firm size has been developed in this paper and applied to a publicly available database on Telstra, Australia's largest telecommunications company.

The results show that around half of the benefits from Telstra's productivity improvements over the decade from 1984 to 1994 were passed on to consumers in the form of real price reductions. This benefit to consumers amounted to $3.5 billion in 1994 prices. Around 30 per cent was passed on to labour while the remaining 20 per cent was passed on to Telstra's owner (the government as it then was) in the form of higher returns.

As well as providing the first rigorous means of quantifying the distribution of benefits from productivity and real price changes, the methodology could also play an important role in the regulation of infrastructure utilities. By rigorously quantifying the distribution of gains it provides regulators with a better source of information on how to treat the various stakeholders — consumers, employees and owners — in future periods.

For infrastructure reform to be sustainable it is necessary for there to be a reasonable distribution of benefits among stakeholders. If one group - be it consumers or owners - capture all the benefits then the reform process will likely fail to the long term detriment of economic growth and consumer welfare. Thus, if one stakeholder group has extracted all the benefits from reform there may be a case for the regulator ensuring other groups also receive some of the benefit going forward. For instance, if firms are to have sufficient incentive to invest in new technology and capacity, the regulator cannot hand all the benefit of productivity improvements to users by imposing overly zealous price caps.

Like any empirical study, a number of assumptions have to be made to operationalise the analysis. One remaining area of weakness, particularly in a rapidly changing area like telecommunications, concerns the introduction of new products and technologies. The illustrative case study assumed that the type and quality of both outputs and inputs remains constant over time. Consequently, the case study underestimated the extent of consumer benefit since no allowance was made for the increased utility associated with an increase in the consumer's choice set. Conversely, the extent of benefits flowing to labour was likely to be overestimated as no allowance was made for increases in average skill levels associated with technological change and downsizing. Both these topics should be the focus of future work.

Appendix

Here we provide a justification from economic theory for the profit decomposition method that was presented in the methodology section. Note that this is an optional justification, in that the method was justified above solely from accounting algebra and the axiomatic approach to index numbers.

In using an economic justification, an important issue that needs to be considered is the exogeneity of prices. For infrastructure firms, the regulator typically sets output prices so that price taking behaviour is an acceptable approximation to what would prevail under deregulation. That is, whether the prices are determined by a perfectly competitive market or by a regulator, the effect is the same in that prices are taken as exogenously given by the firm(s). For inputs, we assume that the prices are exogenously determined in a competitive market. Also, the quantity of capital available to the firm at time t, k^t, is taken as exogenously given ("quasi-fixed") in every period.

Consider a general representation of a restricted profit function for a firm, π^t, as follows:

$$\pi(p^t, k^t, t) = \max_{y^t} \left\{ p^t \cdot y^t : (y^t, k^t, t) \in S^t \right\} \tag{12}$$

where S^t is the production possibility set for the firm. Hence, profit is maximized by the choice of y^t, subject to the constraint that k^t is exogenously given in each period (Samuelson, 1953-4; Gorman, 1968). The conditions which define a restricted profit function with constant returns to scale are that it is (i) a nonnegative function, (ii) positive homogeneous of degree one in p^t, (iii) convex and continuous in p^t for every fixed k^t, (iv) positive homogeneous of degree one in k^t, (v) nondecreasing in k^t for every fixed p^t, and (vi) concave and continuous in k^t for every fixed p^t.

We consider the case where the log of $\pi(\cdot)$ in (12) has the translog form (Christensen, Jorgenson and Lau, 1973; Diewert, 1974; Russell and Boyce, 1974), such that for each period

t

$$\ln \pi(p^t, k^t, t) \equiv \alpha_0^t + \sum_{i=1}^{N} \alpha_i^t \ln p_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_{ij} \ln p_i^t \ln p_j^t + \ln k^t, \tag{13}$$

where $\alpha_{ij} = \alpha_{ji}$, for $i, j = 1, \ldots, N$, and the following restrictions hold so that the functional form in (13) exhibits constant returns to scale: $\sum \alpha_i^t = 1$ and $\sum \alpha_{ij} = 0$. Note that only the "second-order" coefficients in (13) are restricted to be constant across time. This translog profit function is "flexible" in the sense that it can approximate an arbitrary, twice continuously differentiable function to the second order (Diewert, 1974; p. 113).

Diewert and Morrison (1986) exploited the translog identity of Caves, Christensen and Diewert (1982) to prove a relationship between the translog functional form and the Törnqvist index formula and which they use for decomposing the growth in domestic product for a trading economy. In the current context we have the following theorem.

Theorem 1 *If the functional form for a firm's profit function, π, is translog as defined by (13) in periods $t-1$ and t, firms are price takers and there is profit maximising behaviour in both periods, then a theoretical productivity index of the form.*

$$R^t \equiv \left[\frac{\pi(p^{t-1}, k^{t-1}, t)}{\pi(p^{t-1}, k^{t-1}, t-1)} \frac{\pi(p^t, k^t, t)}{\pi(p^t, k^t, t-1)} \right]^{1/2} \tag{14}$$

can be written as

$$R^t = \frac{G^t / P^t}{K^t}$$

as in equation (2), where P^t and K^t have the Törnqvist form of equations (4) and (9), respectively.

Note that first ratio in the brackets of the theoretical productivity index in (14) is an index of productivity difference using period $t-1$ reference netput prices and capital quantities, and the second ratio is a competing index of productivity change which uses t reference netput prices and input quantities. In each case, the only thing changing in going from the denominator to the numerator is technology. In this way, technological change (which is equal to "productivity change" in this context) is captured by both ratios. Because it is unclear which of these two possible theoretical indexes is preferred, a geometric mean of the two is used in (14).

Proof of the Theorem: If producers are price-taking profit maximisers, then from Hotelling's Lemma,

$$y^t = \nabla_p \pi^t(p^t, k^t, t) \tag{15}$$

using vector notation, where ∇_p denotes the vector of first order derivatives with respect to each element of the price vector p^t. Then,

$$\begin{aligned} R^t &= \left[\frac{\pi(p^{t-1}, k^{t-1}, t)/k^{t-1}}{\pi(p^{t-1}, k^{t-1}, t-1)/k^{t-1}} \frac{\pi(p^t, k^t, t)/k^t}{\pi(p^t, k^t, t-1)/k^t}\right]^{1/2} \\ &= \frac{\pi(p^t, k^t, t)/k^t}{\pi^{t-1}(p^{t-1}, k^{t-1}, t-1)/k^{t-1})} \left[\frac{\pi(p^{t-1}, k^{t-1}, t)/k^{t-1}}{\pi(p^t, k^t, t-1)/k^t} \frac{\pi(p^{t-1}, k^{t-1}, t-1)/k^{t-1}}{\pi(p^t, k^t, t-1)/k^t}\right]^{1/2} \\ &= \frac{p^t \cdot y^t}{p^{t-1} \cdot y^{t-1}} \exp\left\{\frac{1}{2}\left[\nabla_{\ln p} \ln \frac{\pi(p^t, k^t, t)}{k^t} + \nabla_{\ln p} \ln \frac{\pi(p^{t-1}, k^{t-1}, t-1)}{k^{t-1}}\right] \ln\left(\frac{p^{t-1}}{p^t}\right)\right\} \frac{k^{t-1}}{k^t} \end{aligned} \tag{16}$$

where we have used the translog identity, $\pi(p^t, k^t, t) = p^t \cdot y^t$, and the notation $p^t \cdot y^t = \sum p_i^t y_i^t$. Using (15) to re-express this last line of (16) yields

$$R^t = \frac{p^t \cdot y^t}{p^{t-1} \cdot y^{t-1}} \exp\left\{\frac{1}{2}\sum_{i=1}^{N}\left[\frac{(p_i^t y_i^t)/k^t}{p^t \cdot y^t/k^t} + \frac{(p_i^{t-1} y_i^{t-1})/k^{t-1}}{p^{t-1} \cdot y^{t-1}/k^{t-1}}\right] \ln\left(\frac{p_i^{t-1}}{p_i^t}\right)\right\} \frac{k^{t-1}}{k^t}$$

which can easily be simplified to prove the theorem.

As shown by Diewert and Morrison (1986), similar theorems can be proven to provide a theoretical link between price and quantity and economic theory. In fact, every sub-index of equations (6) and (7) can be similarly derived from theoretical price and quantity indexes which are functions of profit functions. This provides a firm micro-theoretic foundation for every component of the decomposition of profit growth represented by equations (3), (6) and (7).

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Table 1: **Telstra's TFP, average nominal output and input price indexes, 1984 to 1994**

Year Ending 30 June	*Capital quantity*	*Total Factor Productivity*	*Total Output Price*	*Consumer Price Index*	*Total Inputs Price*	*Labour Input Price*
1984	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.977	0.989	1.051	1.043	1.040	1.070
1986	0.977	1.109	1.097	1.130	1.217	1.128
1987	0.991	1.144	1.131	1.236	1.295	1.194
1988	0.981	1.216	1.257	1.326	1.528	1.300
1989	0.983	1.285	1.324	1.424	1.702	1.404
1990	1.001	1.310	1.326	1.538	1.738	1.485
1991	1.013	1.384	1.347	1.619	1.866	1.566
1992	1.015	1.460	1.306	1.650	1.907	2.054
1993	0.987	1.714	1.258	1.667	2.159	1.953
1994	0.952	1.920	1.213	1.697	2.330	2.106

Source: Estimates based on BIE (1995) database

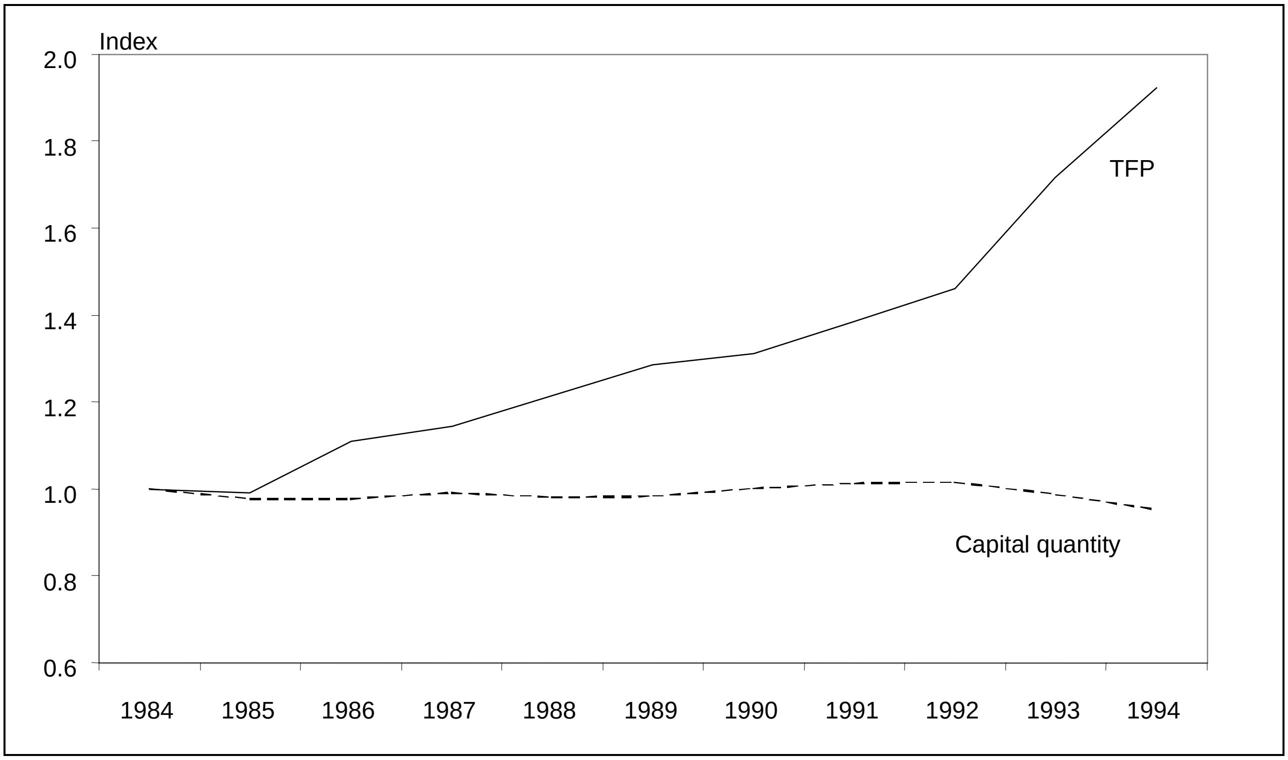
Table 2: **Contributors to Telstra's annual change in real gross return to capital, 1985 to 1994**

Year	*Change in real gross*	*Change in real return to capital solely due to:*			
ending	*return to capital*	*Growth*	*Total capital productivity*	*Real output price*	*Real labour price*
30 June	*%*	*%*	*%*	*%*	*%*
1985	-7.24	-2.34	-2.86	2.15	-4.28
1986	27.72	0.03	37.03	-9.97	3.50
1987	-2.53	1.48	8.36	-13.80	2.83
1988	24.96	-1.04	16.62	9.09	-0.75
1989	10.04	0.20	14.08	-4.29	0.58
1990	-6.78	1.83	4.98	-16.96	5.01
1991	8.12	1.21	15.02	-8.62	1.64
1992	-15.12	0.23	15.98	-12.85	-16.22
1993	25.36	-2.75	56.69	-12.44	-6.05
1994	7.49	-3.59	32.37	-12.69	-3.53
Average	7.20	-0.48	19.83	-8.04	-1.73

Table 3: **Telstra's real gross return to capital and cumulative productivity dividend, 1990 to 1994**

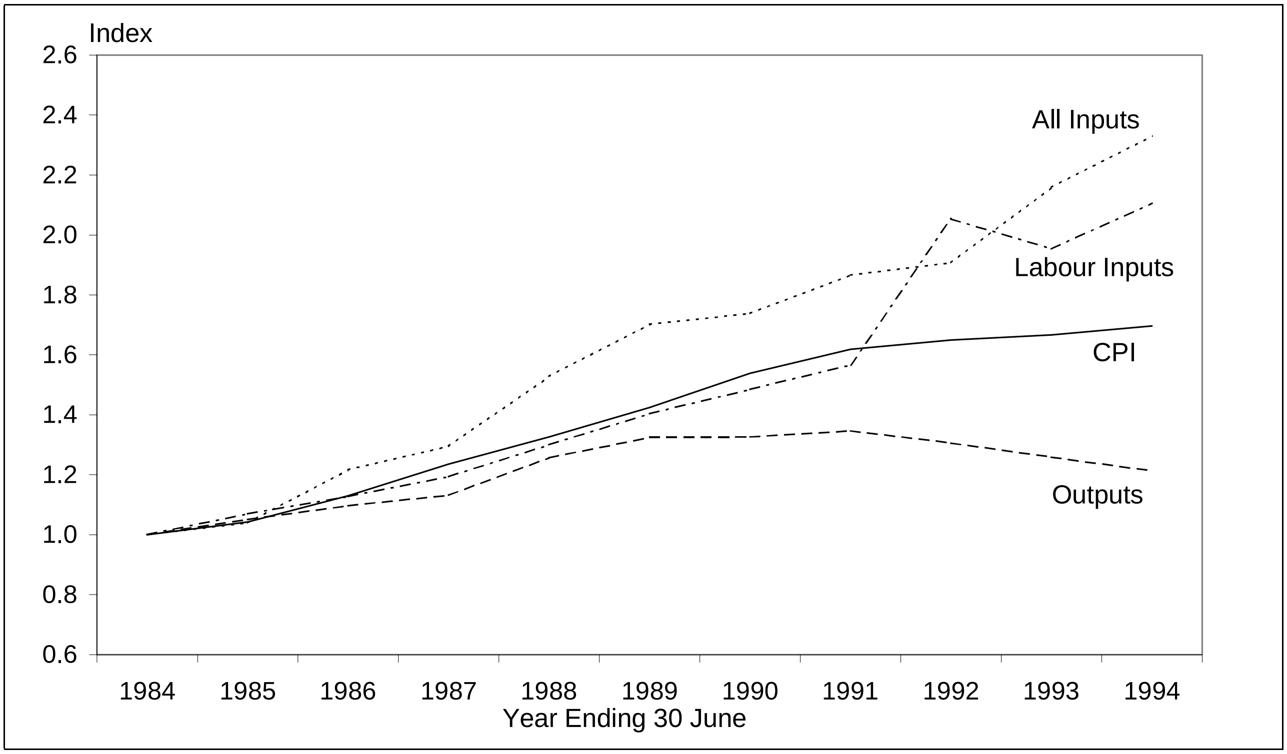
Year ending 30 June	*Cumulative real return due to:*				*Productivity dividend*			
	Growth	*Growth plus TFP*	*(2) plus real price labour*	*(3) plus real price output*	*Total*	*To labour*	*To consumers*	*To Telstra owners*
	(1)	*(2)*	*(3)*	*(4)*	*(5)= (2)-(1)*	*(6)= (2)-(3)*	*(7)= (3)-(4)*	*(8)= (4)-(1)*
	$1994m	*$1994m*	*$1994m*	*$1994m*	*$1994m*	*$1994m*	*$1994m*	*$1994m*
1990	4,439	4,439	4,439	4,439				
1991	4,492	5,167	5,252	4,799	675	-85	453	307
1992	4,503	6,007	5,115	4,073	1,504	892	1,041	-429
1993	4,379	9,153	7,322	5,106	4,774	1,830	2,216	727
1994	4,222	11,680	9,014	5,489	7,458	2,666	3,525	1,267

Figure 1: **Telstra's Total Factor Productivity and Capital Quantity, 1984–1994**



Source: Estimates based on BIE (1995) database

Figure 2: **Telstra's average nominal output and input prices, 1984 to 1994**



Source: Estimates based on BIE (1995) database.

Figure 3: **Cumulative contribution to changes in Telstra's real gross return to capital, 1984 to 1994**

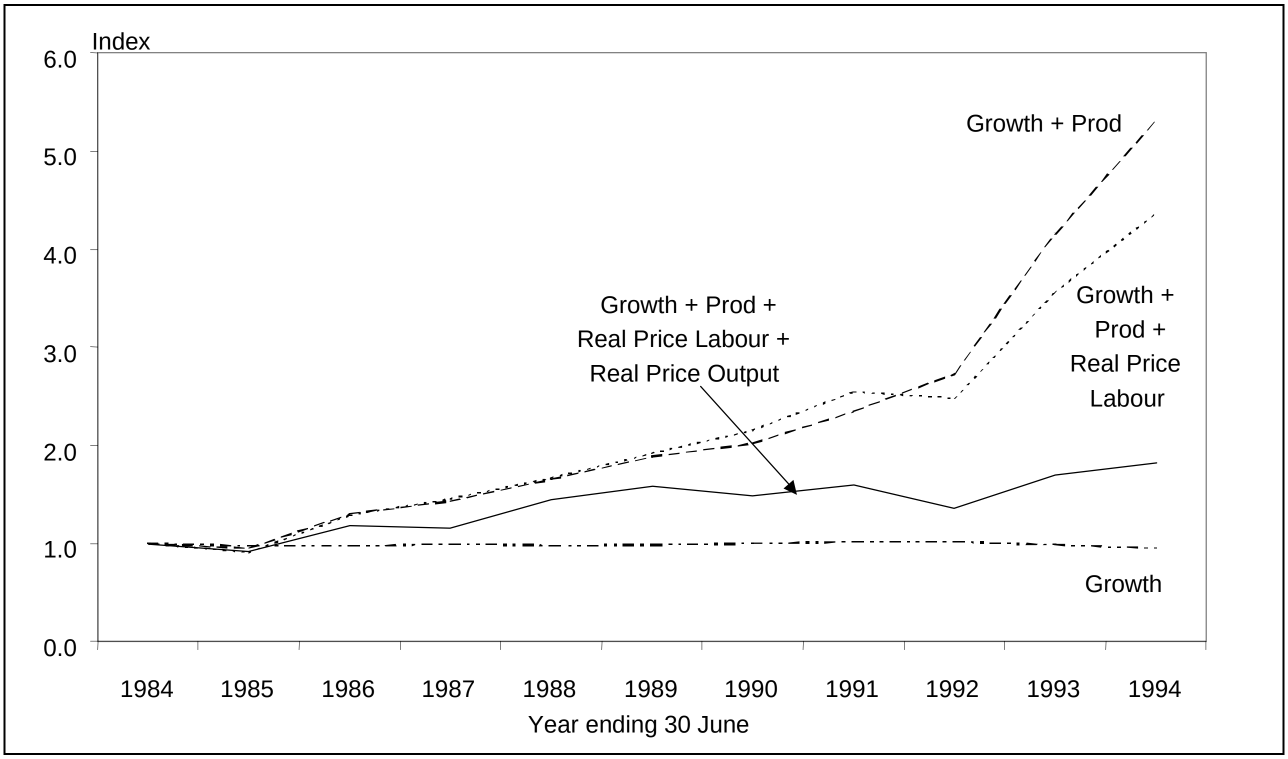


Figure 4: **Changes in real return to capital and the distribution of Telstra's cumulative productivity dividend, 1990 to 1994**