New South Wales
TREASURY

PROFIT COMPOSITION ANALYSIS: A TECHNIQUE FOR LINKING PRODUCTIVITY MEASUREMENT & FINANCIAL PERFORMANCE

Office of Financial Management

Research & Information Paper

TRP 99-5 **December 1999**

The views expressed in this paper are those of the authors and do not necessarily reflect those of either the NSW Treasury or the NSW Government.

PREFACE

The NSW Treasury has developed an economic model, called Profit Composition Analysis (PCA), for analysing the performance of regulated entities. PCA links the financial and economic dimensions of a firm's performance using the Shareholder/Economic Value Added measure of profit. The model separates a change in profit into its respective productivity and pricing sources. PCA can assist managers to understand the causes of profit change, and to develop productivity and pricing strategies for performance improvement.

The potential uses of the PCA technique are demonstrated with an evaluation of the impacts of regulated pricing determinations and productivity change on historic and projected financial performance using an illustrative example. The illustrative example is based on a successful pilot study of a NSW government business.

This Treasury Research & Information Paper has been prepared by Sang-Hee Han and Andrew Hughes. The paper is a revision of a Treasury Working Paper (TWP 99-4) on PCA that was presented to the 28th Conference of Economists at La Trobe University, 26-29 September 1999. The authors are grateful to Professor Knox Lovell (University of New South Wales), Dr D. S. Prasada Rao (University of New England), Mr Richard Cox (NSW Treasury) and Dr Suthathip Yaisawarng (Union College, USA) for their technical advice and comments on earlier versions of the document. The views expressed in this paper are those of the authors and do not necessarily reflect those of either the NSW Treasury or the NSW Government.

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Treasury ref: **TRP 99-5**
ISBN: **0 7313 3081 1**

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1. INTRODUCTION

The objective of this paper is to explain a performance measurement tool, called Profit Composition Analysis (PCA), which has been developed by NSW Treasury. This paper is targeted primarily at accounting and finance staff working in regulated enterprises, economic policy makers and industry regulators.

PCA links the financial and economic dimensions of a firm's performance using the Shareholder/ Economic Value Added[1] measure of profit. The model separates a change in profit into its respective productivity and pricing sources. PCA can assist managers to understand the causes of profit change, and to develop productivity and pricing strategies for performance improvement.

In competitive markets it is reasonable to assume that increases in profit are consistent with increases in productivity. Where competition is lacking, however, profits can be increased through raising output prices and without necessarily improving productivity. As government-owned businesses typically operate in markets where competition is lacking, it is useful to be able to understand the relationship between changes in their productivity, changes in prices and changes in profit levels. Such an understanding can help to inform regulatory decisions regarding prices where a major challenge is striking a balance between passing on productivity improvements to customers in the form of lower prices and to shareholders in the form of higher profits.

The potential uses of the PCA technique are demonstrated with an evaluation of the impacts of regulated pricing determinations and productivity performance on historic and projected financial performance using an illustrative example. The illustrative example is based on a successful pilot study of a NSW government business that was conducted in 1998-99.

This paper is organised as follows. Section 2 sets out the main elements of the PCA analytical framework and methodology. The uses of the technique are demonstrated using an illustrative example in Section 3. Practical application lessons from the pilot study are also presented in this section. Conclusions are presented in Section 4.

Appendix A provides a review of productivity measurement approaches to explain the context for PCA followed by a theoretical evaluation of the methodology. Appendix B contains the PCA index formula in nominal dollar value form. Appendix C extracts the underlying productivity and price 'drivers' from the PCA index formula.

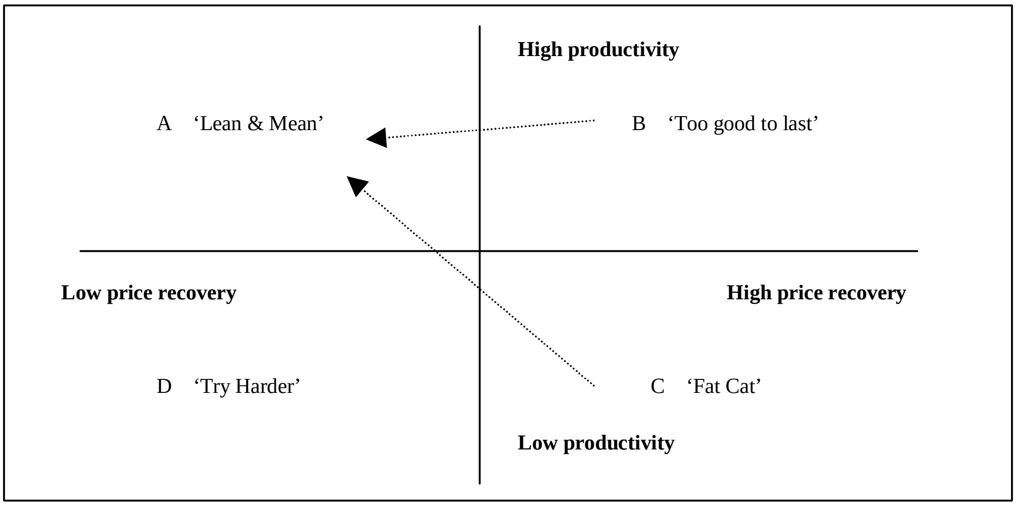
2. THE PROFIT COMPOSITION ANALYSIS APPROACH TO PERFORMANCE MEASUREMENT

2.1 Background

The Commonwealth and State/Territory governments have actively pursued micro-economic reform policies over the past 15 years to improve resource allocation and economic efficiency in the Australian economy. This has led to the restructuring of public monopolies in the utility, transport and communications sectors through the implementation of commercialisation policies, the introduction of competition and the establishment of independent price regulation for residual natural monopoly segments (where the introduction of competition is not feasible).

The conceptual framework presented in Pierce (1997) linking productivity, price recovery and profitability provided the starting point for the development of PCA. It is reproduced in Figure 2.1.

Figure 2.1: Productivity, Price Recovery and Profitability



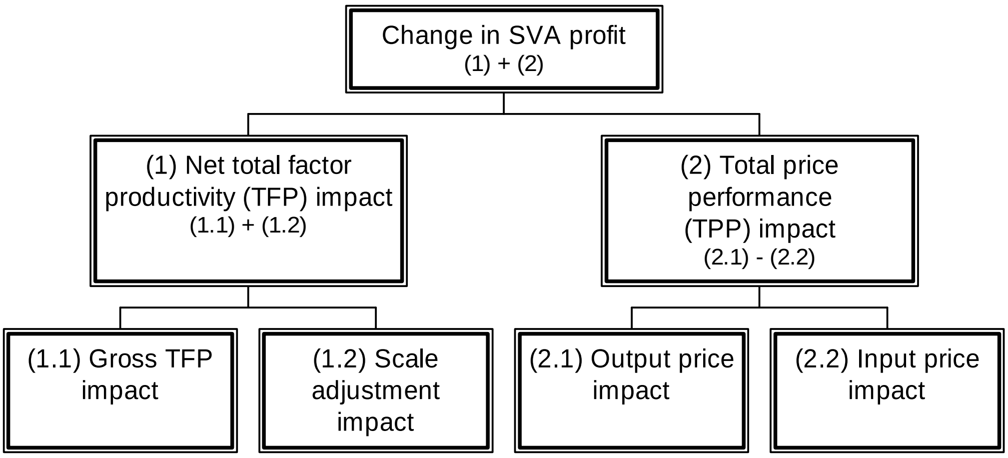
The framework shows four very different positions for a government business with corresponding differences in the appropriate reform path. In the new economic environment profitability derived from monopoly rents (Quadrants B and C) is no longer sustainable. Profitability will need to increasingly come from productivity improvements (Quadrant A). Quadrant A implies a greater distribution of productivity gains to consumers in the form of lower prices through both market and non-market (price regulation) mechanisms.

Sustained productivity improvements by government businesses offer significant macroeconomic benefits. At an economy wide level, they improve the competitiveness of downstream industries, help to restrain consumer price inflation and contribute to higher community living standards. In sum, information on productivity and efficiency is of strategic importance to ongoing cost containment for government businesses.

2.2 Analytical Framework

The main elements of the PCA framework[2] are presented in Figure 2.2.

Figure 2.2: PCA Analytical Framework



An SVA profit change[3] is dissected into two major parts: a net total factor productivity (TFP) impact and a total price performance (TPP) impact. The impacts are measured as nominal dollar value changes[4].

The net TFP impact measures the change in overall productivity between two periods in terms of the value of input quantity savings per unit of output, adjusted for any change in the scale or the scope of a firm's operations. An improvement in TFP performance, assuming no other changes, will increase a firm's profit.

The net TFP impact is equal to the sum of the gross TFP impact and scale adjustment impact. The gross TFP impact[5] measures productivity change as the difference between the aggregate input/output ratio over two periods of production. The scale adjustment impact[6] captures the value of changes in the scale of operations evaluated at the base period production technology.

The TPP impact[7] measures whether a firm's output prices are recovering input prices and contributing to increases in profit. It can be viewed as the impact of changes in a firm's 'terms of trade'; the price the firm gets for its outputs relative to what it must pay for its inputs. More formally, it is equal to the difference between the output price impact and the input price impact. An overall increase in output prices, assuming no other changes, will increase a firm's profit. Conversely, an overall increase in input prices, assuming no other changes, will reduce a firm's profit.

A cost impact[8] can be simply calculated using the PCA framework. It is the difference between the net TFP impact and the input price impact; that is, (1) - (2.2). A positive cost impact indicates that the cost-saving effects of productivity growth offset the cost-increasing effects of higher input prices. The converse is true for a negative cost impact.

It is important to consider the relationship of a firm's capital expenditure and the PCA framework. The nature of a firm's capital expenditure determines the split between input price and quantity effects. If the capital expenditure is directed at expanding the physical capacity of the firm's capital stock then the capital input *quantity* will increase. This will, in turn, show up as a reduction in TFP assuming no other changes. Alternatively, if the capital expenditure is directed at quality improvements then the capital input *price* will rise. This will show up as a reduction in a firm's total price performance, assuming no other changes.

2.3 Methodology

There are two main parts to the PCA index formula:

- TFP and TPP 'drivers' which measure the underlying quantity and price movements; and
- value-based 'weights' which are applied to the drivers to estimate the nominal dollar value impacts.

In general, index numbers are used to measure price (eg, consumer price index) and quantity changes over time. The choice of price and quantity index formula can significantly influence the measurement of the particular change.

PCA uses a 'symmetric' or chain index approach. In simple terms, this means the current period is compared to the previous period for all observations, rather than comparing each period to a fixed base period as in non-symmetric indexes. Comparisons to the previous period are likely to be more relevant than comparisons to a fixed base period which may not adequately capture changes in production technology and management practice.

Appendix A provides a review of productivity measurement approaches to explain the context for PCA followed by a theoretical evaluation of the methodology. Appendix B contains the PCA index formula in nominal dollar value form. Appendix C extracts the underlying productivity and price 'drivers' from the PCA index formula.

2.4 Uses

Profit Composition Analysis complements the SVA framework as it provides unique information about enterprise performance for both managers of government businesses and economic regulators.

Managers can use PCA:

- to evaluate the results of productivity improvement strategies in terms of their impact on profit;
- to analyse a pricing strategy by quantifying whether output prices are recovering input prices and contributing to profit; and
- to evaluate the commercial impact of economic regulation on business performance.

Moreover, PCA can be readily adapted as an internal management tool, particularly in a financial planning and budgeting context. Three types of performance comparisons can be undertaken:

Type of performance comparison	Example
(i) Comparison of actual performance between two periods	Year 1 ^{actual} vs Year 2 ^{actual}
(ii) Comparison of actual to targeted performance between two periods	Year 1 ^{actual} vs Year 2 ^{target}
(iii) Comparison of actual to targeted performance within a single period	Year 2 ^{actual} vs Year 2 ^{target}

This feature of PCA facilitates analysis of the reasons for a year-to-year change in actual profit, as well as evaluation of actual to targeted performance differences between two periods and within a single period. This paper illustrates the first two types of performance comparison.

The third type of comparison identifies the extent to which an SVA variation is due to divergences of actual TFP and TPP from their respective targets within a single period. This type of analysis shares some similarities with the management accounting practice of 'variance' analysis. Variance analysis involves comparisons of targeted/budgeted performance, 'standard' performance and actual performance. Price and quantity standards represent performance "targets that can be achieved with a reasonably efficient effort. As such, they are difficult but possible to attain and include allowances for departures from maximum efficiency" [Hoggett & Edwards (1990): 1082]. Variance analysis uses an accrual accounting approach to the measurement of costs and revenues and is generally applied to benchmarking the efficiency of manufacturing and service industry processes.[9] It is beyond the scope of this paper to evaluate the linkages between these two approaches in detail.

Economic regulators can use PCA to ascertain possible exercise of market power and to assist the determination of regulated prices for a monopoly business.

PCA provides a framework for analysing the nature of profits earned by private and public monopolies. A good economic principle is that a monopoly should not earn more than a 'normal' rate of return. Where a monopoly is earning a 'super-normal' rate of return through excessive total price performance there is evidence of market power being exercised.

The sharing of productivity gains generated by monopolies is a key issue in determining regulated prices for a monopoly business. Productivity gains can be shared among consumers (in the form of lower prices), employees (as higher wages) and owners (as higher profits). Where a regulated monopoly is consistently enjoying super-normal profits there are grounds for its output prices to be reduced. Alternatively, if a regulated monopoly is not even earning a normal profit and its productivity performance is sound, then there is a case for allowing output prices to increase.

3. ILLUSTRATIVE EXAMPLE

3.1 Model Specification

Since the results from the PCA pilot study are confidential, an illustrative example is provided here. The illustrative example is a fictitious electricity distribution network business, XYZ Energy, which is subject to economic regulation. Electricity distribution involves the transportation of electricity from transmission terminal stations to points of use at customers' premises. XYZ Energy earns revenue from regulated distribution network charges for electricity sold to customers connected to its network.

The model specification has a nine-year time horizon: a six-year historical series (Years 1 to 6) and a three-year projection series (Years 7 to 9).

The model uses one output quantity, gigawatt hours of energy supplied. It uses five input quantities: labour, materials, contract services, other operating inputs, and capital. Capital comprises three subgroups: network circuit length, installed transformer capacity, and other fixed assets.

Actual physical quantity measures are used for the labour input and the capital sub-groups except other fixed assets. Implied physical quantity measures are calculated for other fixed assets, materials, contract services and other operating inputs. For the operating inputs, the implied measure is calculated by deflating the input's nominal operating expenditure by an appropriate non-capital price index.[10] For other fixed assets, the implied quantity measure is calculated by deflating its capital stock value by an appropriate capital price index.[11]

PCA uses Shareholder Value Added, an economic measure of profit, rather than an accounting measure to conceptually link financial performance with productivity measurement. Profit is defined in terms of revenues from outputs less expenditures on inputs. It excludes non-core line items like asset sale proceeds.

The output and input prices are calculated residually from the quantity and financial data. For example, the labour price is calculated as labour expenditure divided by the number of equivalent full time staff.

The calculation of the expenditure component in the service price of capital warrants special note. The annual expenditure of each capital category is calculated as the sum of its share of the total depreciation expense, income tax equivalent payment and capital charge. The shares for each capital sub-group are calculated from the disaggregated depreciation expense for Year 1.

A summary of the model specification is presented in Table 3.1.

Table 3.1: XYZ Energy Model Specification

Feature	Details
Time horizon	Nine year time series: • Years 1 to 6 (historical) • Years 7 to 9 (projected)
Outputs	Output quantities: • Total energy delivered (GWh) Output prices: • Total operating revenue divided by total energy delivered

Inputs	Input quantities:
	• Labour (number of employees)
	• Materials (implied quantity)
	• Contract services (implied quantity)
	• Other operating inputs (implied quantity)
	• Capital:
	  • Network circuit length (km)
	  • Installed transformer capacity (MVA)
	  • Other fixed assets (implied quantity)
	
	Input prices:
	• Individual input expenditure divided by its corresponding quantity measure; eg, labour expenditure divided by number of employees.

Economic profit	Total operating revenue less total expenditure which is rearranged as the *sum of output prices multiplied by corresponding output quantities less the sum of input prices multiplied by corresponding input quantities.*

3.2 Results

3.2.1 Overview

As a monopoly infrastructure provider, XYZ Energy's prices are subject to economic regulation to prevent any exercise of its market power. The utility's regulated distribution network charges are designed to cover the cost of distributing electricity to customers and provide a profit margin. No assumptions are made concerning the approach to price regulation.

Annual growth in the consumer price index is assumed to be 3 per cent throughout the nine-year period.

The utility experiences a profit fall between Years 1 and 2 and a corresponding fall in its return on invested capital. This fall is due to a decline in productivity and deterioration in its output price relative to its input prices. At the start of Year 3, management attempts to improve the declining profit by reducing net inputs while maintaining sales unit growth. The result is a significant improvement in financial performance during Years 3 to 5.

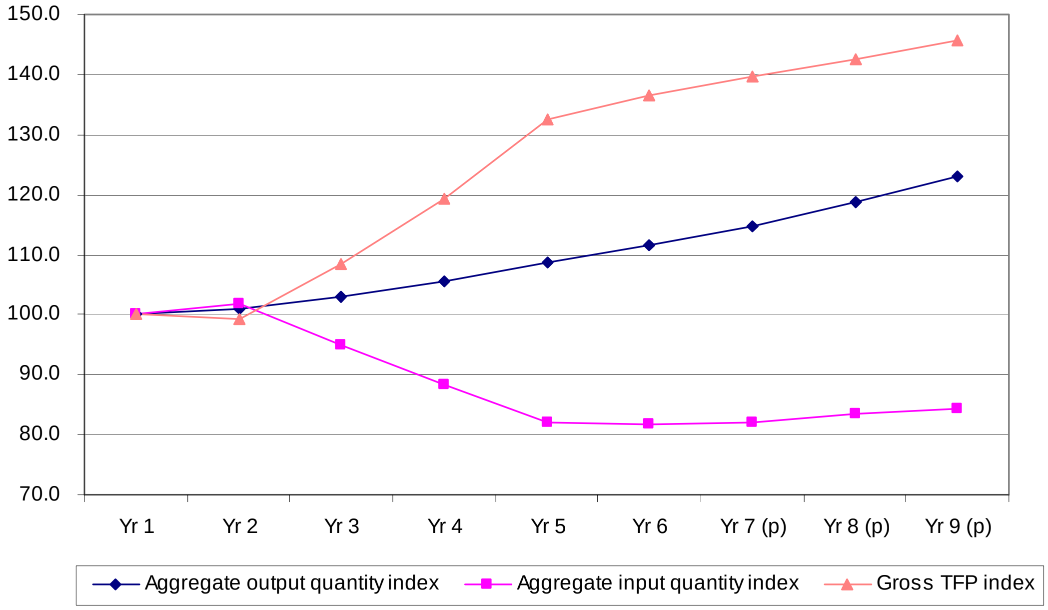
In Year 6, although there has been a significant improvement in XYZ's profitability and the company now compares favourably with its peers in efficiency benchmarking exercises, the utility is not earning a normal profit. As there is limited scope for continued net input reductions, management now turns its attention to pricing. For the next regulatory period (Years 7 to 9), the utility proposes annual real increases in its prices of 2 per cent to enable it to earn a normal profit over the duration of the next three year regulatory period.

The productivity and price index series results – which illustrate the underlying drivers of performance – are presented in Sub-section 3.2.2. In Sub-section 3.2.3, the PCA dollar value results are presented.

Given the lumpy nature of investment in infrastructure assets, productivity results for infrastructure industries should ideally be interpreted over a medium to long term time horizon. The commissioning of new fixed assets often leads to capacity greatly exceeding demand, which in turn adversely affects short-term productivity performance.

3.2.2 Underlying Productivity and Price Performance

Chart 3.1: Gross Total Factor Productivity Index (Year 1=100)

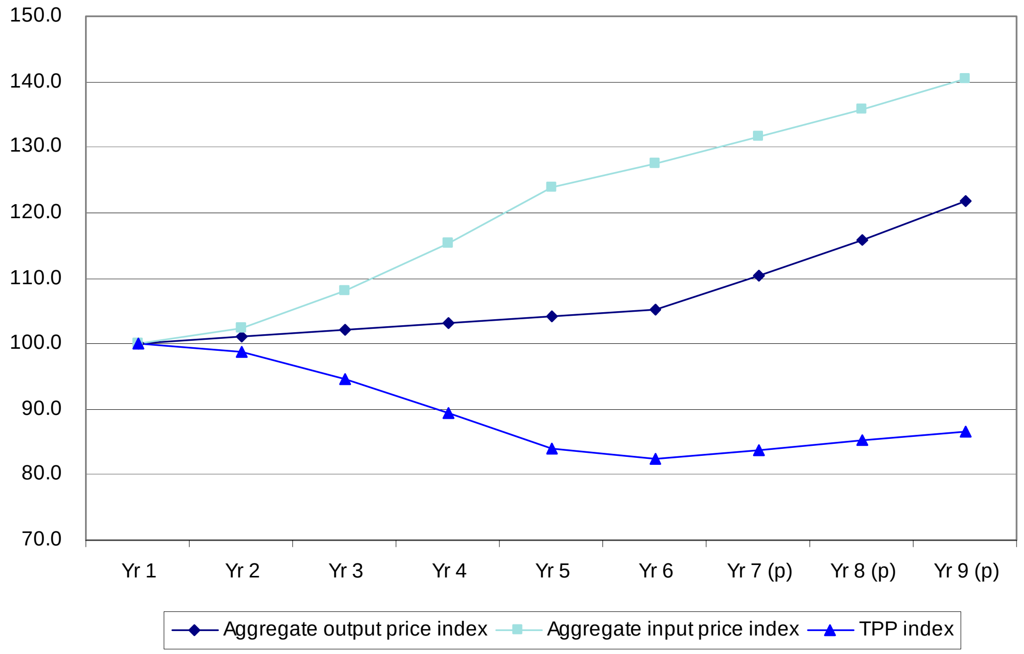


- **In PCA, total factor productivity (TFP) is measured by an index of the ratio of all output quantities (weighted by average period output prices) to all input quantities (weighted by average period input prices). TFP improves when growth in the aggregate output quantity index exceeds that of the aggregate input quantity index; or more simply, when more outputs are produced using the same or fewer inputs.**

- Between Years 1 and 2, the utility's TFP index declines by about 1 per cent. Between Years 2 and 5, TFP increases by about 33 per cent mainly through net input reductions. The rate of increase in TFP growth slows in Year 6 reflecting limited scope for continued net input reductions.

- Modest productivity growth of about 3 per cent per year is projected for Years 7 to 9.

Chart 3.2: Total Price Performance Index (Year 1=100)



- **In PCA, total price performance (TPP) is measured by an index of the ratio of all output prices (weighted by average period output quantities) to all input prices (weighted by average period input quantities). TPP improves when growth in the aggregate output price index exceeds that of the aggregate input price index; or more simply, when growth in output prices is greater than input price growth.**

- From Years 1 to 6, XYZ Energy's output prices increase by 1 per cent annually in nominal terms (-2 per cent annually in real terms). In contrast, input prices rise on average by about 5 per cent per annum in nominal terms during the period. Hence, growth in input prices exceeds that of output prices, resulting in annual declines in TPP of about 4 per cent on average.

- For the next regulatory period (Years 7 to 9), XYZ proposes annual nominal output price increases of 5 per cent (2 percentage points above the expected inflation rate). This would improve its TPP and underpin continued improvements in the utility's financial performance.

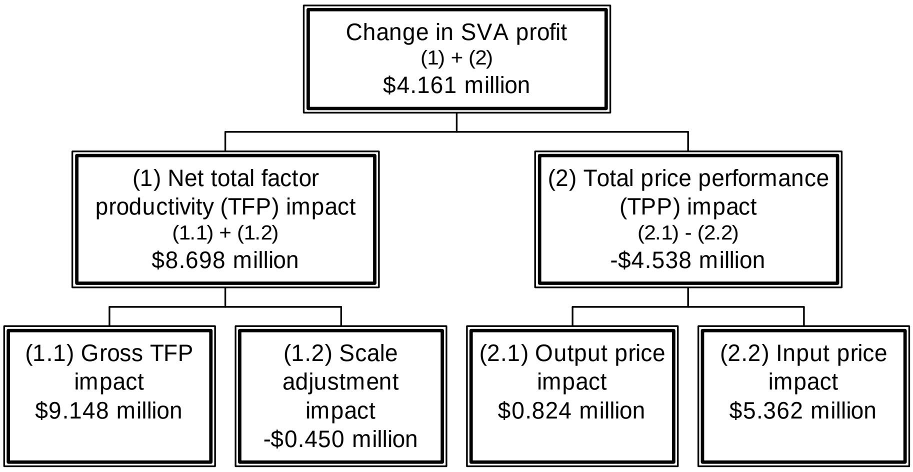
3.2.3 Profit Composition Analysis Results

Table 3.2: Profit Composition Analysis Results

Impact ($000)	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7 (p)	Yr 8 (p)	Yr 9 (p)
SVA profit level	*(20,005)*	*(15,845)*	*(12,231)*	*(8,566)*	*(7,705)*	*(4,033)*	*(138)*	*4,118*
SVA profit change [1+2]	**(2,565)**	**4,161**	**3,614**	**3,665**	**861**	**3,672**	**3,895**	**4,255**
1. Net total factor productivity impact [1.1 + 1.2]	**(1,026)**	**8,698**	**9,261**	**9,917**	**2,906**	**2,275**	**2,040**	**2,485**
1.1 Gross TFP impact	(844)	9,148	9,734	10,387	3,146	2,486	2,150	2,461
1.2 Scale adjustment impact	(182)	(450)	(473)	(470)	(240)	(211)	(111)	24
2. Total price performance impact [2.1 - 2.2]	**(1,540)**	**(4,538)**	**(5,647)**	**(6,252)**	**(2,045)**	**1,397**	**1,856**	**1,770**
2.1 Output price impact	804	824	851	883	917	4,757	5,157	5,605
2.2 Input price impact	2,344	5,362	6,498	7,135	2,961	3,360	3,302	3,835

- Table 3.2 shows the PCA results by component over the study period. A single year to year change is shown in Figure 3.1.

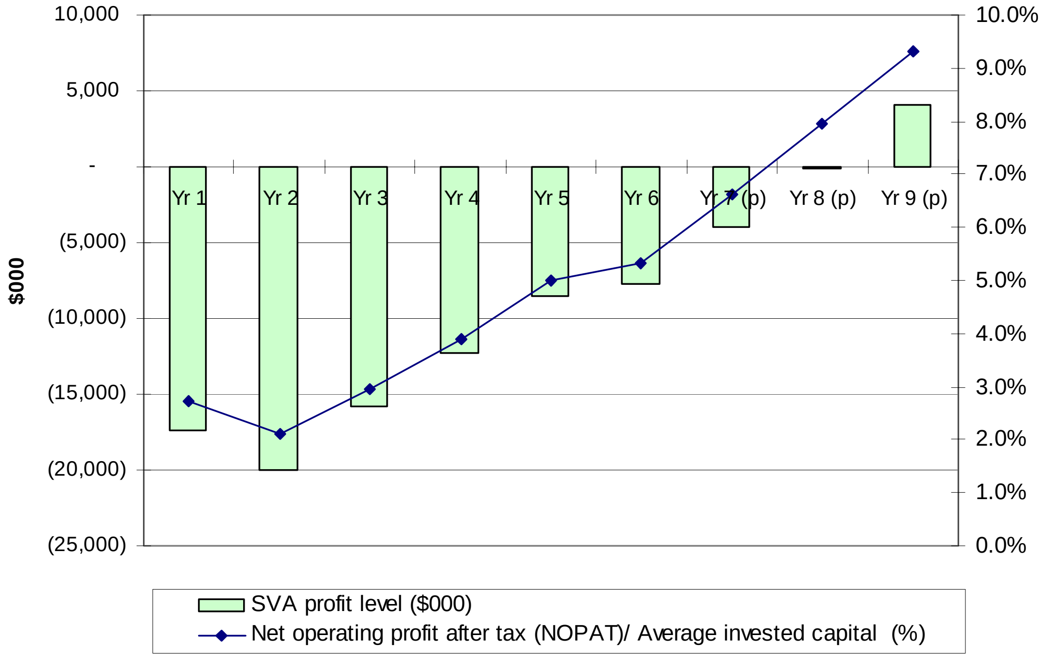
Figure 3.1: Composition of SVA Profit Change, Years 2 to 3



- Figure 3.1 shows the composition of an SVA profit change from Years 2 to 3 using the PCA analytical framework. XYZ Energy has an historical change in SVA profit of $4.161 million during the period. This change is dissected into a net TFP impact of $8.698 million and a TPP impact of -$4.538 million.

- The net TFP performance is dissected into a gross TFP impact of $9.148 million and a scale adjustment impact of -$0.450 million. The TPP impact is split into an output price impact of $0.824 million and an input price impact of $5.362 million. XYZ records a positive cost impact of $3.336 million [ie, net TFP impact – input price impact = $8.698m – $5.362m]. The cost savings generated from productivity improvements offset the cost-increasing effects of higher input prices.

Chart 3.3: SVA Profit Level ($000) & Net Operating Profit after Tax/ Average Invested Capital (%)

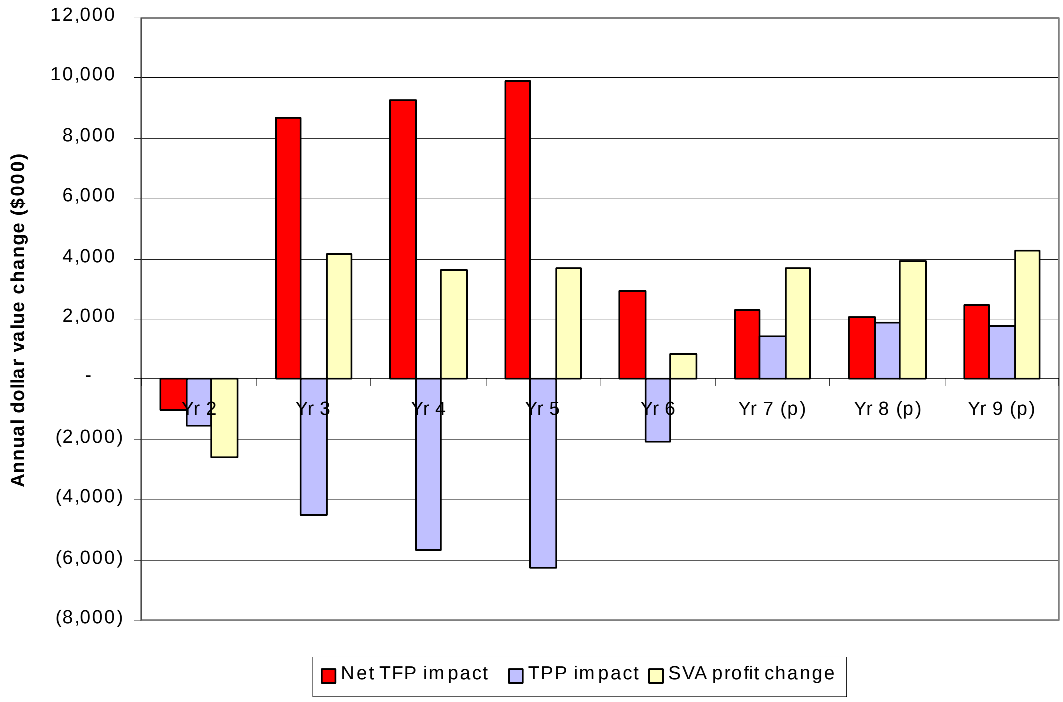


- **The Shareholder Value Added (SVA) *profit level* is defined as net operating profit after tax and capital charge. *Return on invested capital* is defined as net operating profit after tax divided by average invested capital. *Invested capital* is calculated as the sum of working capital and entity-funded fixed assets, measured on an historic cost basis. The *capital charge* is calculated as the product of XYZ's weighted average cost of capital (WACC) benchmark and average invested capital. A nominal WACC of 8.0 per cent is assumed throughout the period.**

- The overall SVA profit *level* trend is one of initial decline followed by improvement. This is reflected by the changes in the rate of return on invested capital.

- The focus of PCA is the dissection of annual profit *changes*. Note that there is one negative profit change (Years 1 to 2) followed by seven consecutive positive profit changes (Years 3 to 9).

Chart 3.4: Composition of SVA Profit Change

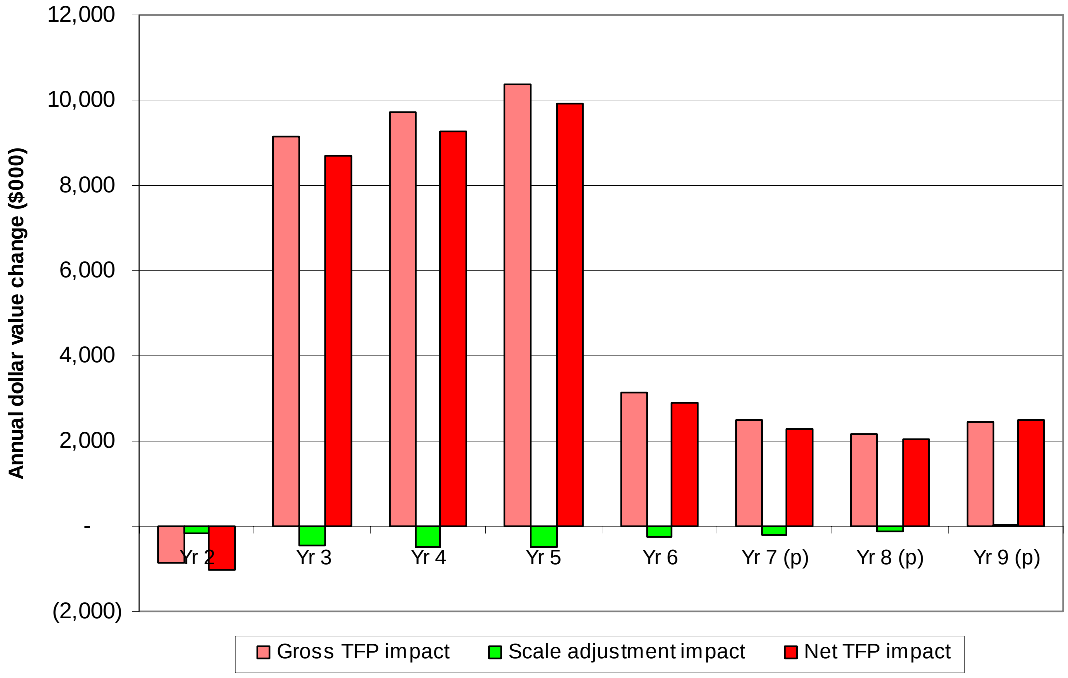


- This chart identifies the *causes* of the SVA changes.

- The negative profit change from Years 1 to 2 is due to declines in both productivity and total price performance.

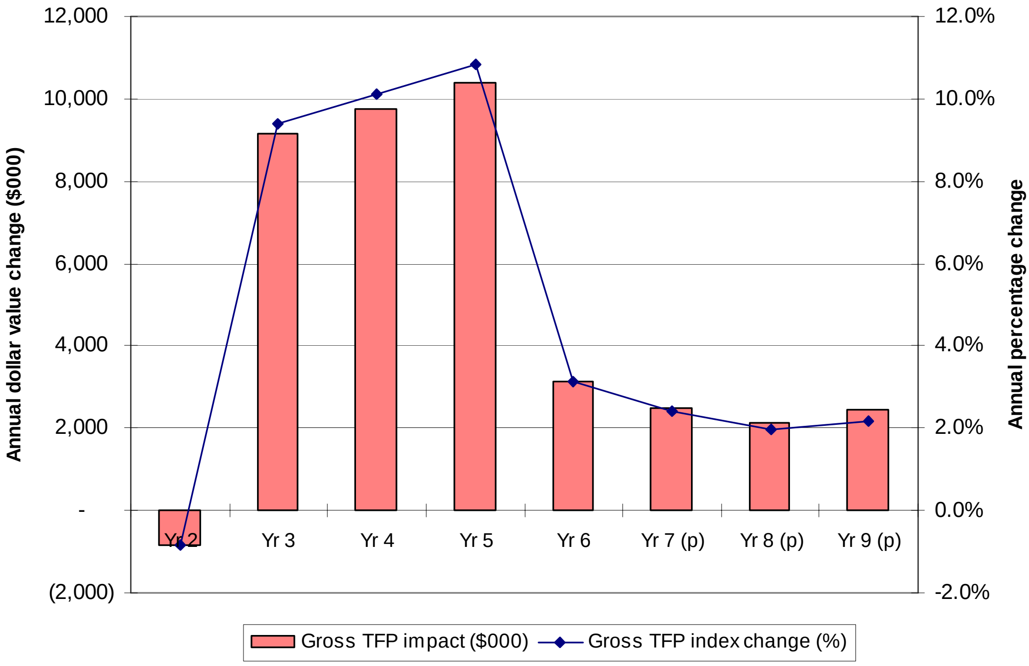
- For Years 3 to 9, XYZ's annual profit changes are positive. For Years 3 to 6, improvements in XYZ's financial performance are driven by better productivity. Falls in the utility's terms of trade constrain the financial improvement during this period. For Years 7 to 9, improvements in XYZ's financial performance are projected to come from improvements in both productivity and total price performance.

Chart 3.5: Composition of Net Total Factor Productivity Impact



- **The net total factor productivity (TFP) impact is calculated as the sum of the gross TFP impact and the scale adjustment impact.**
- The gross TFP impact dominates the composition of this impact.

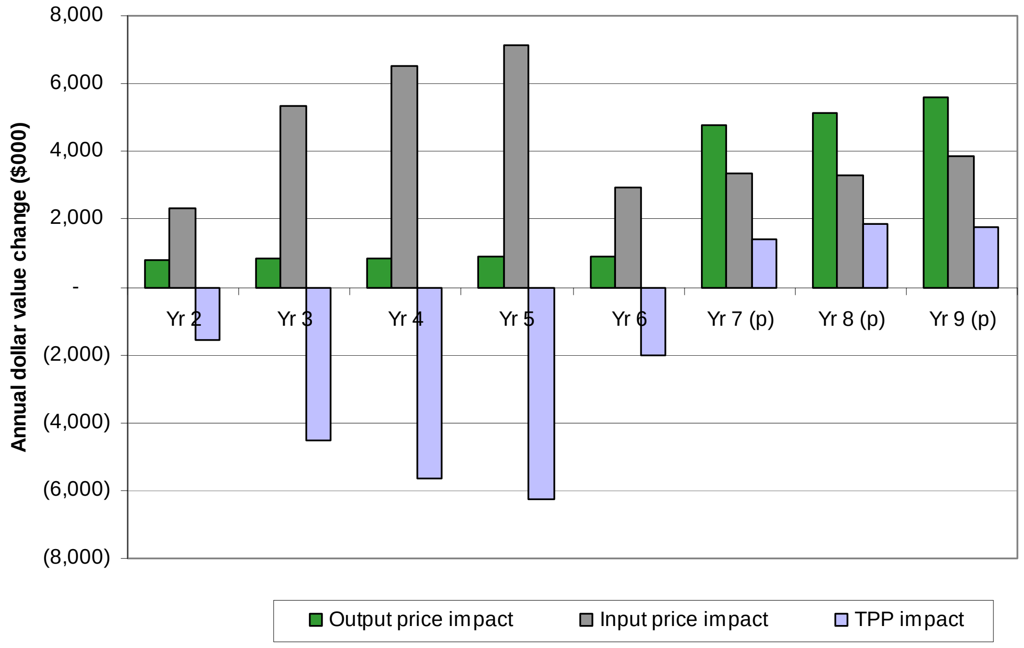
Chart 3.6: Comparison of Gross Productivity Measures: Impact ($000) and Underlying Rate (%) of Change



- **PCA links the impact ($) and underlying rate (%) measures of total factor productivity change.**

- A gross TFP impact of $1.1 million is equivalent to an annual productivity gain of 1 percentage point on average in this example.

Chart 3.7: Composition of Total Price Performance Impact

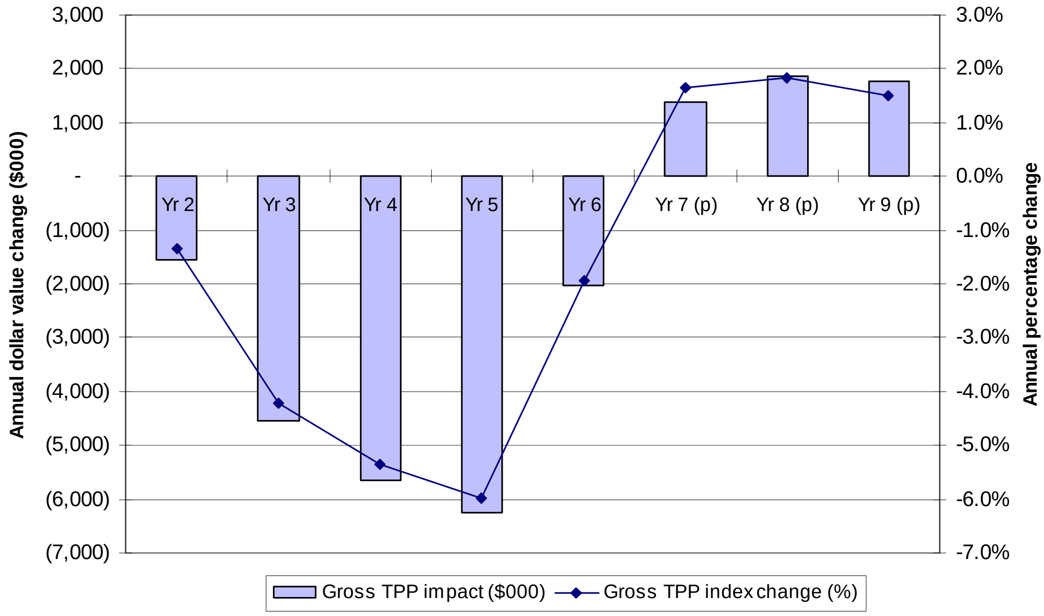


- **Total price performance (TPP) is calculated as the difference between the output price and input price impacts.**

- For Years 2 to 5, TPP trends downwards as growth in input prices exceeds that of output prices. In Year 6, TPP improves reflecting a narrowing of the gap between the output and input price impacts, but it is still negative.

- For the next regulatory period, XYZ's proposal for nominal annual increases in its output prices of 5 per cent (2 percentage points above the expected inflation rate) would result in positive TPP and contribute to continued improvements in financial performance.

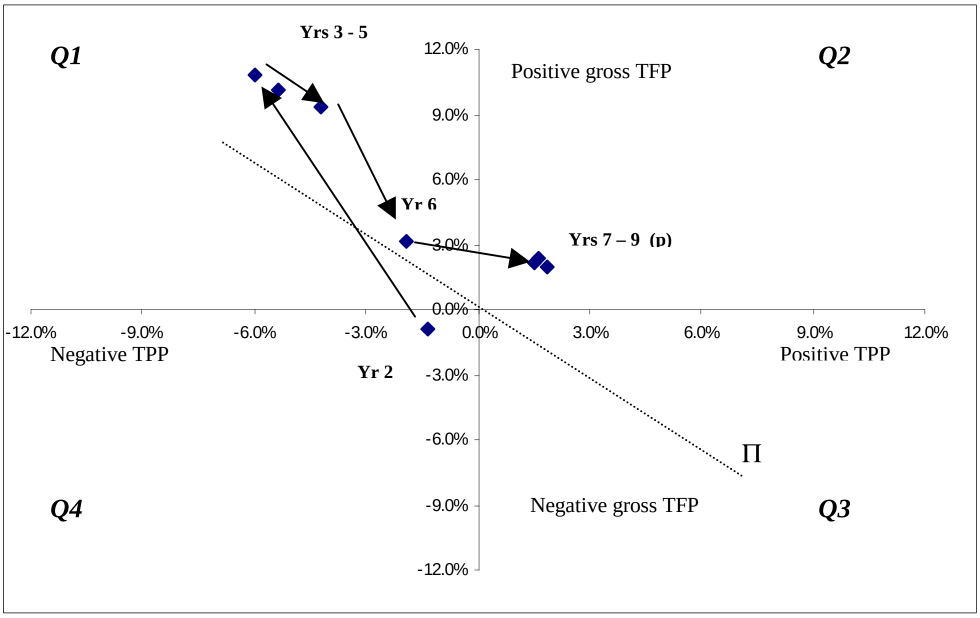
Chart 3.8: Comparison of Total Price Performance Measures: Impact ($000) and Underlying Rate (%) of Change



- **PCA links the impact ($) and underlying rate (%) of total price performance change.**

- A gross TPP impact of $1.0 million is equivalent to an annual productivity gain of 1 percentage point on average in this example.

Chart 3.9: Four Quadrant View of Gross TFP and TPP, Annual Underlying Rates of Change (%)



- **This chart plots the combinations of annual percentage changes in gross TFP and TPP using four quadrants:**

  - **Quadrant 1 – positive gross TFP% & negative TPP% combinations**
  - **Quadrant 2 – positive gross TFP% & positive TPP% combinations**
  - **Quadrant 3 – negative gross TFP% & positive TPP% combinations**
  - **Quadrant 4 – negative gross TFP% & negative TPP% combinations**

  The 45 degree line plotted through the origin, denoted by Π, shows points where changes in XYZ's profitability (defined as the ratio of total revenues to total costs) are zero. Along this line changes in TFP and TPP completely offset each other (ie, they have equal changes but opposite signs). Points to the right of Π indicate a positive change in economic profitability while points to the left indicate a negative change.

- For Year 2, XYZ Energy records negative changes in both TFP and TPP, represented by the point in Quadrant 4. SVA profit falls during this period.

- For Years 3 to 5, the XYZ Energy records high, positive TFP changes and negative TPP changes, represented by the cluster of three points in the upper part of Quadrant 1. The decline in XYZ's total price performance is more than offset by its strong productivity growth, which underpins a strong recovery in profit. Consumers benefit from XYZ's productivity gains in the form of lower real product prices.

- For Year 6, XYZ records modest, positive TFP growth and negative TPP which is represented by the point in the lower part of Quadrant 1. Productivity growth exceeds the decline in price performance resulting in a positive profit change.

- For Years 7 to 9, the utility proposes real annual increases in its output prices, represented by the cluster of three points in Quadrant 2. The combination of projected positive TFP and TPP would contribute to a further improvement in financial performance. Shareholders would be the sole beneficiaries of future productivity gains for a *limited* period.

3.3 PCA Application – Some Practical Issues

The data requirements for PCA are the same for a traditional TFP study.[12] The input and output price series required for PCA are calculated residually from the financial (ie, cost and revenue series) and operational (ie, input and output quantity series) data used in traditional TFP modelling. For the pilot study, fixed assets funded by the entity were valued on an historic cost basis. Developer funded assets were excluded from the entity's fixed asset base. A nominal WACC was used to calculate the capital charge.

The standard of TFP and TPP estimates depends on the quality of data used. In order to obtain an accurate picture of enterprise performance, it is important that the data chosen accurately reflects the true nature of the production process.

Generally, obtaining accurate estimates of capital inputs is the main problem encountered in undertaking any type of TFP analysis. In particular it is necessary to calculate measures of: (i) the capital stock, and (ii) the annual service flow of the capital stock. This, however, was not a problem for the pilot study entity as it had comprehensive fixed asset data, including physical measures of most capital sub-groups.

As noted above, broad-based price indexes were used in the pilot study to impute quantities where physical measures were not available. Generally it is preferable to use sector-specific price indexes where available to improve the degree of precision in the quantity measure.

The lack of familiarity of government businesses with the concepts of total factor productivity measurement and its relationship to financial performance makes the provision of training a priority in the conduct of PCA studies. Treasury therefore developed a PCA demonstration model for the pilot study entity.

PCA does not require specialist software. Any standard spreadsheet application can be used to undertake the analysis.

4. CONCLUSIONS

Productivity is usually measured on a partial factor and non-financial basis (eg, steel produced per employee hour). As PCA measures productivity on a total factor and financial basis, it can be directly related to profit.

PCA complements the Shareholder Value Added framework, providing unique information about enterprise performance for managers. It can be applied as a high level, 'top down' internal management tool for firms engaged in manufacturing and infrastructure activities to analyse productivity performance.

For government businesses, which typically operate in markets where competition is lacking, PCA can help to inform price regulation, assisting the assessment of how productivity gains should be shared between customers (as lower prices) and owners (as higher retained profits).

The feasibility of applying the PCA technique was confirmed through the successful completion of a pilot study on a major NSW government business during 1998-99. The lack of familiarity with total factor productivity concepts and techniques makes the provision of training a priority in the conduct of PCA studies. NSW Treasury developed a PCA demonstration model for use by the pilot study entity.

ENDNOTES

1 Economic or shareholder value added (EVA/SVA) is a financial performance system developed by consulting firm Stern Stewart & Co which adopts the micro-economic theory of profit. This approach defines profit as the surplus remaining after the opportunity costs of all inputs have been met. Two types of profit are distinguished. 'Normal' profit is the opportunity cost of equity funds invested in an activity; that is, the minimum amount necessary to attract equity investment into an activity or to induce it to remain in it. 'Super-normal' profit is any profit in excess of normal profit. Supernormal profit will be earned only in the short run and is a return to market power, which unless there are barriers to entry will be eroded by new entrants. SVA is defined as net operating profit after tax minus an appropriate charge for the opportunity cost of all capital invested (ie, equity and debt) in an enterprise. As such, SVA is a measure of supernormal profit.

2 Grifell-Tatjé and Lovell (1999) use a similar framework for decomposing profit change. They use an accrual measure of operating profit rather than an economic measure (the EVA/SVA measure could in principle be used). The net total factor productivity impact is equivalent to their quantity impact while the total price performance impact corresponds to their price impact. Grifell-Tatjé and Lovell decompose the quantity impact into a productivity change effect and an activity change effect. The former effect is equivalent to the gross TFP impact in the PCA framework while the activity effect corresponds to the scale adjustment impact. Using a linear programming approach the authors further dissect the productivity change effect into technical change and operating efficiency effects; and further decompose the activity effect into product mix, resource mix and scale effects. Due to the nature of the PCA methodology, this additional decomposition is not possible. See Grifell-Tatjé and Lovell for a more detailed discussion.

3 It is possible to measure 'variable' SVA profit (total revenue less variable economic costs). In this case, a total variable productivity measure is derived – the ratio of all outputs to all variable inputs.

4 Diewert (1998) uses the term, 'indicator' to represent the difference or the absolute change of prices or quantities, as opposed to the term, 'index', which represents the relative change of prices or quantities in ratio form. The indicator measure is implicitly equivalent to the dollar value of changes in prices or quantities.

5 The gross TFP impact measures productivity change from both technological change (which can be represented by a shift in a production frontier) and changes in operating efficiency (which can be represented by the gap between the existing production frontier and the firm's actual operational position). It should be noted that the PCA methodology assumes the absence of any operating inefficiency; however, in practice, it captures productivity change from both these sources.

6 The gross productivity impact measures the extent to which technological change is neutral with respect to inputs and outputs. If technological change is not neutral, any unmeasured bias will be captured in the scale adjustment impact. Similarly, if the expansion or contraction of output involves either a disproportionate expansion or contraction of inputs for a given production technology, then the presence of the scale economies would show up in the scale adjustment impact.

7 The TPP impact, unlike the TFP impact, uses the difference form (which measures absolute change) of index number theory rather than the ratio form (which measures relative change) for greater ease of interpretation. It should be noted that the TPP impact can be easily converted to the ratio form (relative change) without losing any information. Using this approach, the TPP impact comprises a price recovery impact and an escalation impact. The price recovery impact directly measures movements of output prices relative to the input prices. The escalation impact captures price impacts from sources other than those generated from the relative changes of output and input prices. The escalation impact can be interpreted as the impact due to absolute changes in base period prices (either output or input prices) or a numeraire.

8 Griffel-Tatjé and Lovell (1999) develop a similar concept. It is possible to define an analogous revenue impact as the sum of the scale adjustment impact and the output price impact in the PCA framework [ie, (1.2) + (2.1)].

9 Variance analysis can be applied at firm wide level; see Barlev, B. & J.L. Callen (1986), "Total Factor Productivity and Cost Variances: Survey and Analysis," Journal of Accounting Literature 5, 35-56.

10 The Australian Bureau of Statistics' (ABS) private final consumption deflator from the National Accounts was used in the pilot study (Cat. No. 5206.0).

11 The ABS' public trading enterprise capital deflator from the National Accounts was used in the pilot study (Cat. No. 5206.0).

12 The PCA framework facilitates the analysis of profit changes for a single firm. In addition, PCA can be applied to a cross-section of firms for a single year or to panel data. For these cases, weights could be calculated from the average quantities or prices of all firms in a single year or for the whole panel data set. Caves and Christensen (1980) developed a multilateral version of the Törnqvist TFP index for cross section and panel data using this approach.

GLOSSARY OF TERMS

Allocative efficiency	For given input prices, inputs are used in the proportion that minimises total production costs.
Cost efficiency	Where an operational unit exhibits both *technical* and *allocative efficiency* and hence, produces a given quantity of output at minimum possible cost.
Optimal scale	An operational scale where the production technology exhibits constant returns; ie, where a proportionate increase in all inputs results in the same proportional increase in all outputs.
Partial factor productivity	A ratio of a subset of outputs to a subset of inputs; eg, tonnes of steel produced per labour hour.
Production frontier	A curve plotting the minimum quantities of inputs required to produce a given amount of output.
Production technology	An engineering term to describe the technical relationship between inputs and outputs. A change in production technology can be represented as a shift in a *production frontier*.
Productivity	Productivity is a measure of the ratio of physical output produced from the use of a given quantity of inputs. Productivity change refers to the rate of growth or decline in the ratio over time. Productivity growth stems from advances in production technology, improvements in technical efficiency and exploitation of scale economies. A productivity measure may include all inputs and all outputs – *total factor productivity* – or a subset of inputs and outputs – *partial factor productivity*.
Returns to scale	Returns to scale in a particular output are increasing/constant/ decreasing when an equi-proportionate change in all inputs leads to a larger/equal/ smaller proportionate change in the designated output.
Scale efficiency	The extent to which an operational unit can take advantage of *returns to scale* by altering its size towards *optimal scale*.
Technical efficiency	*Technical efficiency* is a relative concept. It is measured by comparing an organisation's actual ratio of outputs to inputs to the optimal or best practice ratio of outputs to inputs. The combination of managerial practices, and the impact of the external operating environment affect a firm's technical efficiency. It is defined independently of input and output prices.
Total factor productivity	A ratio of the quantity of all outputs divided by the quantity of all inputs. Index number procedures are commonly used to aggregate multiple quantities.

APPENDICES

A REVIEW OF PRODUCTIVITY MEASUREMENT APPROACHES AND THEORETICAL EVALUATION OF PROFIT COMPOSITION ANALYSIS METHODOLOGY

A1 INTRODUCTION

This appendix provides a review of productivity measurement techniques to explain the context for PCA. This is followed by a theoretical evaluation of the PCA methodology.

A2 REVIEW OF PRODUCTIVITY MEASURMENT APPROACHES

A2.1 Non-financial Approaches to Total Factor Productivity Measurement

Grosskopf (1993) classifies the various non-financial approaches to total factor productivity (TFP) measurement using two criteria: (i) whether or not a frontier approach is adopted; and (ii) the type of technique used – econometric or deterministic. The approaches are summarised in Table A1.

Table A1: Non-financial Approaches to Total Factor Productivity Measurement

	Non-frontier	**Frontier**
Econometric	Econometric estimation of production (and cost) functions • Diewert (1973) • Christensen, Jorgenson & Lau (1971)	Econometric estimation of production frontiers • Aigner, Lovell & Schmidt (1977) • Meeusen & van den Broeck (1977)
Deterministic	Function-based index number formulae Diewert (1976, 1978, 1992) • Paasche • Laspeyres • Törnqvist • Fisher • Vartia	Mathematical programming models • Data envelopment analysis – Farrell (1957), Lovell (1993) • Malmquist index – Caves, Christensen & Diewert (1982)

Grosskopf identifies two causes of productivity growth, change in technical efficiency and technical (or technological) progress. A firm's level of technical inefficiency refers to the *gap* between the observed and optimal (best practice) values of its outputs and inputs. A change in the level of technical efficiency refers to the change in the position of the gap over time. A change in production technology is represented by a *shift* in the production (best practice) frontier. The frontier approaches "explicitly incorporate inefficiency and account for changes in efficiency" over time (p. 161). The non-frontier approaches "generally (implicitly) assume that observed output is best practice or frontier output" (p. 170).

The assumption of competitive optimising behaviour underpins the non-frontier approach. This assumption implies that firms are technically efficient. TFP change is defined as the net change in a firm's output due to changes in production technology only.

Relaxing the assumption of competitive optimising behaviour allows for the possibility of technical inefficiency. A change in TFP is measured as the net change in a firm's output due to changes in both production technology and technical efficiency.

TFP change can be measured using two major techniques: econometric and deterministic. Econometric techniques require explicit specification of a production function and the direct linkage of productivity growth to the function's parameters. They assume that the relationship between inputs and outputs in a production function cannot be exactly specified. Therefore, econometric techniques have the advantage of allowing for measurement error in estimating productivity change. However, there is a risk of specification error from using a wrong form for a production function.

Deterministic methods do not involve explicit specification of a production function (there is no estimation of parameters). These techniques assume a 'deterministic' or exact relationship between inputs and outputs. Therefore, deterministic techniques are sensitive to measurement error. They can be divided into function-based index number and mathematical programming methods. Major index number formulae, such as the Laspeyres and Fisher, are attractive in terms of their relative ease of calculation, familiarity and flexible modelling of underlying production functions. The major mathematical programming methods for measuring productivity are data envelopment analysis and the Malmquist index. The programming methods are able to decompose productivity change into both technical efficiency and production technology sources.

A2.2 Financial-based Total Factor Productivity Analysis

Financial-based productivity analysis links TFP measurement to financial outcomes. Grifell-Tatjé and Lovell (1999) distinguish between 'business' and 'economic' approaches.

In several studies within the business literature, a profit change between two periods is dissected into three parts: a TFP effect; a price recovery effect (reflecting changes in relative output and input prices) which is equivalent to the TPP impact in the PCA framework; and an activity effect (reflecting changes in the size of a firm's operations) [Genescà Garrigosa and Grifell-Tatjé (1992)]. Other studies within the business approach propose variations on this three-way decomposition. The various models in this approach use index number formulae to dissect profit change. However, the index formulae used to dissect profit change in the business literature are based on restrictive assumptions about the underlying production technology.

The economic approach to profit decomposition allows for technical inefficiency in the TFP measure and dissagregation of the activity impact. Grifell-Tatjé and Lovell (1999) propose a three-stage profit decomposition model. The first stage dissects profit change into price and quantity effects. The quantity effect is divided into productivity and activity effects in the second stage. In the third stage the productivity effect is decomposed into production technology and technical efficiency effects. The activity effect is split into effects for product mix, resource mix and scale. Their model uses a Malmquist productivity index to dissect profit change.

The PCA methodology uses an index number technique and thus fits broadly into the business approach to productivity-based financial analysis. The PCA methodology is, however, consistent with the economic approach of Griffel-Tatjé and Lovell (1999) up until the second stage. We shall now turn our attention to index number theory, which provides the methodological underpinnings of PCA.

A2.3 Application of Index Number Theory to Non-financial Productivity Measurement

One of the key results of the 'economic-theoretic' approach to the construction of index numbers of productivity is the finding of a unique correspondence between the type of index used to aggregate multiple inputs and outputs, and the structure of underlying production technology. For example, it has been shown that the Laspeyres index implies (or is 'exact' for) a linear production function in which all inputs in the production process are perfect complements (ie, where inputs can be combined only in fixed proportions). In comparison, the Törnqvist index is exact for a flexible (homogeneous translog) production function [Diewert (1976)]. Thus, any given index number implies a particular structure for the underlying production technology. Consequently, the choice of indexing procedure is an important consideration as it affects the measurement of productivity change.

Diewert (1976, 1978) defines an exact index as 'superlative', if the underlying technology or cost function is flexible. A production function is flexible where it can provide a second order approximation (ie, up to a degree of substitutability) to an arbitrary production function. As the translog function is flexible while a linear production function is not, so the Törnqvist index is superlative, whereas the Laspeyres index is not.

Diewert (1978) also demonstrated that all known superlative index number formulae such as the Törnqvist and Fisher Type I approximate each other to the second order in a time series context.

In addition, Diewert (1978) showed that the Paasche and Laspeyres indexes approximate the superlative indexes to the first order at an equivalent price and quantity point. In a time series context, for adjacent periods, the Paasche and Laspeyres price indexes typically differ by a very small amount. Hence these indexes may also provide acceptable approximations to a superlative index, even though these indexes imply linear or Leontief technology only.

Thus, if an index formula is a weighted average of the Paasche and Laspeyres indexes then it is *pseudo-superlative* provided this weighted average is a symmetric mean [Diewert (1976)]. The symmetric mean property is satisfied if an identical index form is derived when the Paasche (Laspeyres) index is replaced with the Laspeyres (Paasche) index. The Fisher Type II index, which is a simple average of the Paasche and Laspeyres index, satisfies the condition of a symmetric mean; thus it is pseudo-superlative.

The above index theorem implies that where TFP analysis is based on time series data, the choice of an index formula is less critical, even though it is desirable to use 'superlative' indexes.

In most of the recent applied productivity literature, the Törnqvist index formula proposed by Christensen and Jorgenson (1970) was used for time-series data for a single production entity. Diewert (1976) showed that this index formula can be derived from a homogeneous (ie, constant returns to scale) translog transformation function that is separable in both outputs and inputs, and exhibits neutral differences in production technology.

However, Caves and Christensen (1980) demonstrated that separability and neutrality are not required to derive Christensen and Jorgenson's (1970) index formula from a homogeneous translog transformation function.

The above conclusion is quite powerful as potentially complex relationships between inputs and outputs (for example, multiple inputs and outputs with joint technology) can be represented by a Törnqvist index (and all other forms). However, there are nevertheless limitations with the Törnqvist index formula. For example, it assumes that technological change is 'neutral'; that is, not biased to a specific input such as capital. This seems to be at odds with most observed technological change.

Therefore, Cowing and Stevenson (1981) conclude that the index number approach, unlike the econometric approach, has difficulties in disentangling the source of technical change from two effects: scale economies, and input substitution.

The first effect implies that where TFP analysis is based on an index number approach, it may not be possible to separate pure technical change from changes in scale if the underlying production technology exhibits non-constant returns to scale. The former implies a shift in an underlying production function or a production possibilities set, while the latter implies that productivity can change due to a variation in scale for a given production function. However, if the period of analysis has a relatively short horizon (say, up to five years) then it is generally reasonable to assume that the production function exhibits constant returns to scale.

This limitation may be of particular concern for capital-intensive production activities such as those found in regulated industries, if capital utilisation is not appropriately adjusted for. That is, if the capital input is measured on an installed capacity basis (ie, the measure is invariant to changes in output levels) then TFP measures will be biased.

The second issue implies that it may not be possible to isolate the contribution of each individual input to a change in TFP when measured using an index approach unless the underlying technology is Leontief (ie, fixed coefficients technology without any possibility of substitution).

To use the index number approach to measure pure technical change, it is also necessary to assume competitive optimising behaviour to make it an appropriate measure of a shift in an underlying production frontier [Diewert (1981b)]. This implies that in order to implement the exact index number approach, we require the correct shadow prices[1] of inputs and outputs, in particular, capital services. This requires measures of a firm's capital stock because it is necessary to estimate rental prices for each category of capital in order to develop accurate measures for the aggregate capital input quantity.

This fundamental assumption associated with the index approach may limit its usefulness for regulated industries. However, where the regulated prices approximate the true marginal costs of production then the resulting TFP estimates will be valid.

In sum, the index approach to the measurement of TFP has significant problems in identifying a 'pure' technological change if the underlying technology exhibits non-constant returns to scale and the prices of outputs do not reflect the pure marginal costs of production. Furthermore, it is not possible to make a meaningful decomposition of a change in TFP into each of the contributing factors.

A2.4 Application of Index Number Theory to Financial-based Productivity Analysis

Valuing the TFP Impact and Choice of Index

Under the index number approach, aggregation of multiple types of inputs and outputs can be achieved by: (i) using 'base' or 'reference' period prices to weight each type, or (ii) using cost shares to weight inputs and revenue shares to weight outputs.

Under the first approach, using the Laspeyres index, TFP can be interpreted easily as the change in constant dollar profitability (defined as the ratio of revenue to cost using base period prices). However, construction of an index using approach (ii) provides measures of changes in TFP that are less easy to understand than (i). The Törnqvist index, which is the most popular index form in the economic literature, takes the second approach using average cost and revenue shares of the base and the comparison periods.

Ease of calculation is one of reasons the Laspeyres index form is frequently used in the management literature. Furthermore, the Laspeyres index is algebraically convenient when decomposing a change in profit. However, the Laspeyres index is neither superlative nor pseudo-superlative. Although the Lapeyres index can provide a good approximation of a superlative index in a time series context, this desirable property may not be valid *when*

[1] In practice, the assumption of competitive optimising behaviour for some regulated industries is frequently violated; that is, prices do not equal marginal costs. This may be due to cross-subsidies.

underlying prices move substantially over the period. Moreover, it represents an implausible production technology - a linear production function in which all inputs are perfect complements in the production process. Accordingly, the choice of price weights to form aggregate outputs and inputs in the management literature is problematic.

In order to estimate the 'current' dollar impact of a TFP change that has been measured in 'constant' dollars in the context of a profit change, an appropriate price deflator is required. Therefore, the current dollar impact measure of TFP can be decomposed into components for the price deflator and underlying driver. Even where TFP estimates generated from different index forms produce similar results, their corresponding price deflators can be substantially different. This means that the current dollar value impacts of TFP can vary significantly according to the choice the TFP index form. As there is no unique way to decompose profit change, it may be necessary to explore how sensitive the estimates of the 'current' dollar impacts of TFP are to the choice of its index form.

Value of Scale Impact and Sensitivity of Decomposition

Genescà Garrigosa and Grifell-Tatjé (1992) compare various approaches to productivity-based financial analysis and rearrange these approaches in terms of three decompositional impacts – total factor productivity, price recovery and activity (or scale).

In order to dissect a change in profit, it is necessary to decompose the quantity component further into TFP and scale impacts. Usually, the dollar value of a TFP impact is measured in terms of the cost saving per unit of output in constant prices; ie, the input requirements per unit of output, which is also equivalent to the inverse of a TFP index weighted by constant prices. As discussed above, the TFP impact bundles both the scale impact and the pure technology impact. It is possible that a TFP impact is purely a consequence of scale impacts. In general, unless the underlying production technology exhibits constant returns to scale, scale impacts will be reflected in both the TFP and activity impacts in productivity-based profit analysis.

There is a degree of arbitrariness in dissecting a profit change (even where the same TFP index form is used) as demonstrated by Genescà Garrigosa and Grifell-Tatjé (1992). They show that decomposition results can vary significantly according to the method of arranging the equation. Therefore, care should be taken in the use of the decomposition results.

Joint and Non-Joint Technology

Some approaches like the ones surveyed in Genescà Garrigosa and Grifell-Tatjé (1992) assume a non-joint technology of production. Non-joint technology is defined as the sum of single-output production technologies. That is, for a firm producing multiple outputs, it is possible to separately allocate all inputs (including capital) to a particular output. However, in practice, most multiple output production processes exhibit joint technology, where different outputs share common inputs.

The assumption of non-joint technology adopted in the business approaches can be easily modified in line with the models in the economic literature.

A3 EVALUATION OF THE PROFIT COMPOSITION ANALYSIS METHODOLOGY

NSW Treasury developed two index methodologies to decompose profit changes; PCA Mark I and PCA Mark II. PCA Mark I [see Han and Hughes (1997)] transforms the Törnqvist TFP productivity index to be applied to financial measures. Following the models in the business literature, PCA Mark I dissects a change in profit into three sources: TFP, price recovery and demand (equivalent to the activity effect in the business literature). PCA Mark I dissects a change in profit level using a two-stage process: first, the change in profit level is decomposed into the TFP, price recovery and demand effects in *percentage change* terms; second, absolute dollar value changes for the three effects are derived from their percentage changes. In comparison, the approaches in the business literature decompose a change in profit level using simpler indexing procedures.

The Törnqvist index is simplified by replacing the logarithm form with the simple percentage change form for calculating the ratio of quantities for two adjacent periods. The logarithm and percentage change approaches provide weighted aggregate quantity changes that are close to each other.

Despite the simplification improving the transparency of the formula, this was not sufficient to promote its attractiveness to a broader audience of accountants and financial analysts. Furthermore, adoption of the two-stage methodology makes the profit decomposition subject to linearisation errors. Although linearisation errors can be 'smoothed' by proportional adjustments, this adds to computational complexity.

The greater clarity of the profit decomposition models in the business literature spurred development of PCA Mark II. PCA Mark II assumes non-joint technology, thereby avoiding the weaknesses of the non-joint technology assumption of the approaches contained in the business literature.

PCA Mark II uses the Edgeworth-Marshall (EM) index to decompose profit changes proposed by Edgeworth (1925) and Marshall (1923). The EM index is equivalent to the Fisher Type II index *in dollar form*. Reference prices are calculated as the simple average of the base-period and comparison-period prices.[2] The use of this weight is particularly appealing when the base and comparison period prices diverge significantly. Moreover, the EM index formula is able to incorporate joint technology.

[2] For the index form, the weights were developed by Edgeworth (1925) and Marshall (1923). For the indicator (difference) form, the weights were developed by Bennet (1920). Diewert (1998) shows that the Bennet indicator is preferable from the viewpoint of the test or axiomatic approach as it approximates any superlative indicator; ie, it is second best from the perspective of an economic approach. In the PCA framework, the quantity impacts are analysed in terms of an index form, while the price impacts are measured in terms of an indicator form. The price impacts can be easily represented by a price recovery index with an adjustment factor.

The EM index is in fact a weighted average of the Laspeyres and Paache indexes and satisfies the first of two conditions for a ‘pseudo’ superlative index. The EM index does not precisely satisfy the second condition of a symmetric mean. However, it does provide an acceptable numerical approximation. Thus, the EM index can be regarded as an approximate pseudo superlative index. In addition, Mark II measures change in terms of whole numbers rather than percentages and is therefore free of linearisation errors.

In sum, the PCA Mark II approach satisfies the two desirable properties of the TFP index – interpretational transparency and theoretical consistency.

A4 CONCLUSIONS

The PCA Mark II methodology has three major advantages. First, it has a strong theoretical foundation, using a pseudo superlative index. Second, compared with other index number approaches PCA is attractive in terms of its relative ease of calculation, familiarity and flexible modelling of underlying production functions. Third, unlike production frontier approaches, it is not data intensive.

The main limitation of the PCA Mark II methodology is that while estimates of TFP changes comprise efficiency, scale and technological sources it is not possible to disentangle these sources.

B PROFIT COMPOSITION ANALYSIS INDEX FORMULA (MARK II)

Profit level for period *i* is given by:

$$\pi_i = P_i Y_i - W_i Q_i$$

Change in profit level from the base period (0) to the comparison period (1) is given by:

$$\pi_1 - \pi_0 = \left[P_1 Y_1 - W_1 Q_1\right] - \left[P_0 Y_0 - W_0 Q_0\right]$$

Decomposition of the change in profit level is given by:

$$\pi_1 - \pi_0 = \underbrace{\left[\frac{\overline{W}Q_0}{\overline{P}Y_0} - \frac{\overline{W}Q_1}{\overline{P}Y_1}\right]\cdot\left(\overline{P}Y_1\right)}_{(a)} + \underbrace{\left[\overline{P}Y_1 - \overline{P}Y_0\right]\cdot\left(1 - \frac{\overline{W}Q_0}{\overline{P}Y_0}\right)}_{(b)} + \underbrace{\left[P_1 - P_0\right]\cdot\overline{Y}}_{(c)} - \underbrace{\left[W_1 - W_0\right]\cdot\overline{Q}}_{(d)}$$

The above terms are defined on page 35.

PCA dissects a profit change between two periods into two major sources:

- a **net total factor productivity (TFP) impact**, equal to the sum of the gross TFP impact [corresponding to part (a) of the equation] and the scale adjustment impact [part (b)]; and
- a **total price performance (TPP) impact**, equal to the difference between the output price impact [corresponding to part (c) of the equation] and the input price impact [part (d)].

(a) Gross Total Factor Productivity Impact

$$\underbrace{\left[\frac{\overline{W}Q_0}{\overline{P}Y_0} - \frac{\overline{W}Q_1}{\overline{P}Y_1}\right]}_{(i)}\cdot\underbrace{\left(\overline{P}Y_1\right)}_{(ii)}$$

Part (i) of the equation defines the gross TFP impact. It measures the change in productivity as a change in the aggregate input/output ratio between two periods of production in constant prices. The change in productivity is weighted by (ii) comparison period revenue in constant prices. A reduction in a firm's aggregate input/output ratio from the base period to the comparison period, representing an improvement in productivity, will therefore lead to an increase in profit (assuming no other changes).

(b) Scale Adjustment Impact

$$\underbrace{\left[\overline{P}Y_1 - \overline{P}Y_0\right]}_{\text{(i)}} \cdot \underbrace{\left(1 - \frac{\overline{W}Q_0}{\overline{P}Y_0}\right)}_{\text{(ii)}}$$

The scale adjustment impact captures the value of changes in the scale of operations evaluated at the base period production technology. It is used to adjust the gross TFP impact for changes in the scale of operations. Part (i) measures the change in a firm's output quantities at constant prices. The scale adjustment impact uses the base period production technology at constant prices in part (ii) to weight the output quantity change. An increase in output with a positive value for the weight will lead to an increase in the net TFP impact and therefore have a positive effect on profit (assuming no other changes).

(c) Output Price Impact

$$\left[P_1 - P_0\right] \cdot \overline{Y}$$

The output price impact shows the effect on profit of changes in output prices holding quantities fixed. The output price impact uses average period output quantities to weight the price changes. An overall increase in output prices will increase profit (assuming no other changes).

(d) Input Price Impact

$$\left[W_1 - W_0\right] \cdot \overline{Q}$$

The input price impact shows the effect on profit of changes in input prices holding input quantities fixed. The input price impact uses average period input quantities to weight the price changes. An overall increase in input prices will reduce profit (assuming no other changes).

Where:

Profit

π_1 and π_0	comparison period and base period profit levels

Output prices

$P_1 = (p_{11}....p_{i1}....p_{I1})$	current period output prices for I outputs
$P_0 = (p_{10}\ldots p_{i0}\ldots p_{I0})$	base period output prices for I outputs
$\overline{P} = (\overline{p}_1...\overline{p}_i...\overline{p}_I)$	**average** period output prices for I outputs

Output quantities

$Y_1 = (y_{11}\ldots y_{i1}\ldots y_{I1})^T$	current period output quantities for I outputs
$Y_0 = (y_{10}\ldots y_{i0}\ldots y_{I0})^T$	base period output quantities for I outputs
$\overline{Y} = (\overline{y}_1...\overline{y}_i...\overline{y}_I)^T$	**average** period output quantities for I outputs

Input prices

$W_1 = (w_{11}...w_{k1}...w_{K1})$	current period input prices for K inputs
$W_0 = (w_{10}\ldots w_{k0}\ldots w_{K0})$	base period input prices for K inputs
$\overline{W} = (\overline{w}_1...\overline{w}_k...\overline{w}_K)$	**average** period input prices for K inputs

Input quantities

$Q_1 = (q_{11}\ldots q_{k1}\ldots q_{K1})^T$	current period input quantities for K inputs
$Q_0 = (q_{10}\ldots q_{k0}\ldots q_{K0})^T$	base period input quantities for K inputs
$\overline{Q} = (\overline{q}_1...\overline{q}_k...\overline{q}_K)^T$	**average** period input quantities for K inputs

C TOTAL FACTOR PRODUCTIVITY AND TOTAL PRICE PERFORMANCE UNDERLYING INDEX DRIVERS

The underlying gross total factor productivity and total price performance ‘drivers’ are extracted from the PCA index formula (Appendix B) as follows.

Gross Total Factor Productivity

Percentage change in aggregate input quantity index

$$\left[\frac{\overline{W}Q_1}{\overline{W}Q_0} - 1\right] \qquad (1)$$

Percentage change in aggregate output quantity index

$$\left[\frac{\overline{P}Y_1}{\overline{P}Y_0} - 1\right] \qquad (2)$$

Percentage change in gross total factor productivity index

[(2) - (1)] (3)

Reconciliation with PCA Formula, contained in Appendix B

$$\left[\text{Part (a)} = (3) \times \overline{W}\text{Q}_0\right] \qquad (4)$$

Total Price Performance

Percentage change in aggregate output price index

$$\left[\frac{P_1\overline{Y}}{P_0\overline{Y}} - 1\right] \qquad (5)$$

Reconciliation with PCA formula, contained in Appendix B

$$\left[\text{Part (c)} = (5) \times P_0\overline{Y}\right] \qquad (6)$$

Percentage change in aggregate input price index

$$\left[\frac{W_1\overline{Q}}{W_0\overline{Q}} - 1\right] \qquad (7)$$

Reconciliation with PCA formula, contained in Appendix B

$$\left[\text{Part (d)} = (7) \times W_0\overline{Q}\right] \qquad (8)$$

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