REPORT

Estimation of CPI-X in the WA Rail Industry

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by

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And

GHD Pty Ltd

for

The Office of the Rail Access Regulator

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1. Introduction

This paper presents the results of an application of a novel methodology to calculate the X-Factors in CPI-X regulation, undertaken by the Institute for Research into International Competitiveness (IRIC), and GHD Pty Ltd (GHD) for the Rail Division of the Economic Regulation Authority (ERA). The paper builds upon a methodological paper prepared by IRIC (see www.railaccess.wa.gov.au/html/pub00.php?type=cat&id=23). The example used in this paper is the WestNet Rail (WNR) freight network.[1] It should be noted that there is nothing inherent to the methodology which limits its use to the rail industry. It is equally applicable in any similarly regulated industry, and indeed, it is hoped that further use of the methodology can improve utility regulation in Australia more generally.

The X-factor performs two key roles. Firstly, it ensures that, whilst regulated firms do not suffer an erosion in the real prices they are permitted to charge through inflation, they are also not unduly benefited through being able to appropriate all of the returns from productivity improvements, which would be passed on to consumers through lower prices in the case of a competitive industry. Secondly, the X-factor provides incentives for the regulated firm to engage in cost-reducing productivity improvements in the future. This is achieved by developing an appropriate benchmark, rewarding the firm when the benchmark is exceeded and penalising the firm when it is not. The development of such a benchmark is the topic of this paper.

The findings of this paper in regards to the X-factor may be summarised as follows:

- For the Esperance line, it is 1.54 percentage points per annum.
- For the Leonora line, it is 2.18 percentage points per annum.
- For the Eastern Goldfields Railway line (EGR), it is 0.63 percentage points per annum.
- For the South West Main line (SWM), it is 0.20 percentage points per annum.

These X-factors give rise to the following annualised price adjustments for the four lines:

- For the Esperance line, it is 1.05 percent per annum.
- For the Leonora line, it is 0.41 percent per annum.

[1] Note that the paper calculates X-factors for the four lines of the network described above, not the entire network. Importantly, grain lines are not included, due to a lack of available data at the time of writing. References to 'the network' in this report should be understood to refer to the four lines mentioned above.

- For the Eastern Goldfields Railway line (EGR), it is 1.96 percent per annum.

For the South West Main line (SWM), it is 2.39 percent per annum.

If each of the lines are weighted by their 2003 total costs in the model, this gives a weighted average X-factor for the network of approximately 0.92 percentage points per annum and an annualised price adjustment of 1.78 percent per annum. This compares to the ERA's current determination for the network of 0.675 percentage points for the X-factor, and 2.03 percent for the annual price adjustment. There are some issues surrounding these numbers, which are discussed in Sections 4.2, 5.3 and 6.1.

Section Two of this paper presents a very brief overview of the methodology outlined in the previous IRIC paper, and the changes made to this methodology for this paper. As only one determination of a capital base and floor and ceiling prices in respect to WNR's network has been undertaken to date, it was necessary to calculate proxy regulatory values for many variables for some point in the past, from historical data. This process is outlined in Section Three. Section Four describes the derivation of total factor productivity for WNR. Section Five outlines the derivation of components, other than the total factor productivity of the regulated firm, necessary to calculate the X-factor. Section Six summarises results, provides a final X-factor and highlights potential challenges for the future application of this methodology. Appendix One provides the outputs of the simple model used to calculate TFP and the X-factors. Appendix Two provides the workings underlying some stylised examples (see Section 2.1) of the ramifications of working in changes in, rather than levels of variables.

2. Overview of IRIC Methodology

The methodology suggested by IRIC is discussed in an earlier paper (see www.railaccess.wa.gov.au/html/pub00.php?type=cat&id=23) and is summarised briefly below.

The key task of a regulator is to ensure that the incentives of a competitive market are replicated, as best as possible for a regulated firm. The rationale is not primarily 'fairness' for the firm or its customers, but rather the efficient allocation of resources within the economy. In order to achieve this, prices must reflect the 'reasonable costs' of the regulated firm. This has two elements. Firstly, the price set at the outset of a regulatory period should be at an appropriate level, and secondly, any changes in the price level should accurately reflect what a competitive firm would face over time. The latter is the concern of CPI-X regulation.

For the economy as a whole, price rises are captured by the CPI. However, the prices of all goods and services do not change in unison; some prices may be rising more rapidly than others, and some may actually be falling. For this reason, one cannot simply increase prices for a regulated firm in accordance with CPI. Rather, one has to take into account the two key cost drivers for any firm; changing input costs, and changing productivity. Changing input costs are relatively simple, as most inputs for any firm are traded in some market, and can hence be easily obtained.[2]

Productivity is more challenging for a regulated firm. Decisions on appropriate productivity change are linked to decisions made in regards to the capital base. Unless a firm is at the level of world's best practice efficiency levels, there are two elements to its productivity growth. The first of these is the productivity growth necessary to move from its current level of productivity to the level of world's best practice firms, and the second is the productivity growth of the envelope representing world's best practice. In our earlier paper, we termed these the 'static gap' and 'dynamic change' components

[2] Note that the individual regulated firm may be able to out-perform the market price *level*. However, what is of concern is the *rate of change* of prices. It is reasonable to expect that, even if a firm can obtain a better price at a point in time, over time, that price would change at roughly the same rate as the change in market price. Thus, we do not need to discover the price that the regulated firm paid for each of its inputs, which is a substantial advantage, given informational asymmetries associated with this endeavour.

respectively. In determining the relevant asset base, a regulator may use the current asset base or may use some hypothetical 'world's best practice' efficient asset. Alternatively, the regulator may utilise some combination of the two. If the regulator uses an efficiency benchmark, then logically, any productivity-based adjustments to price should only incorporate the dynamic change component of productivity. The static gap component should be incorporated, only to the extent that the regulator makes a decision on the regulatory asset base which reflects the actual asset base. The ERA, for rail infrastructure, uses a 'modern equivalent asset' (MEA) as the basis for its revenue cap, and hence the X-factor should incorporate only the dynamic change component of productivity growth.[3] The MEA is defined by the regulator as:

> *"An optimised network that is reconfigured using current modern technology serving the current load with some allowances for reasonably projected demand growth for up to five years into the future. The MEA excludes any unused or under utilised assets and allows for potential cost savings that may have resulted from technological improvement." (ORAR, 2002, p23)*

If the key factors affecting price for any firm are the changes in input prices and the changes in productivity, one way to adjust the prices set by a regulated firm would be to change them according to changes in both of these factors directly. Although this seems on the surface to be ideal, in reality, it provides a very poor incentive structure to the firm, as all benefits from cost reduction are passed immediately to consumers. Moreover, it does not reflect how a competitive market works. In a competitive market, a firm which introduces cost reducing technology will not price at its new lower cost immediately, but will price just less than other firms, capturing market share and increasing profits. As the new technology diffuses through the market, other firms will follow, and eventually then industry will price at the new lower cost. If the competitive firm were not able to capture some extra profits from innovation, it would never innovate. The same response to incentives hold for a regulated firm.

Thus, a benchmark is required. The simplest of these is CPI, as data are easily available. However, if it is known that the regulated firm's costs do not move exactly in step with

[3] Some responses to our earlier paper insisted that the ERA was not fully reflecting world's best practice in its MEA, and hence the X-factor should also include some part of the static gap component. However, from the perspective of this paper, the point is irrelevant; we use the MEA as is, and hence any static gap components in it will automatically be included in the X-factor calculation. Adding an extra component to the X-factor to incorporate any static gap component would result in double-counting.

CPI from prior observation, it would be a rather myopic regulator which did not take this into account. The X-factor incorporates the following:

- Historical differences between changes in input prices of the regulated firm, and changes in input prices for some benchmark (usually the 'rest of the economy').
- Historical differences between changes in productivity growth, of the regulated firm, and changes in productivity growth for some benchmark (usually the 'rest of the economy').

It then subtracts these from CPI, as data become available during the regulatory period. This is, in essence (and without the mathematical equations), the approach of Bernstein and Sappington (1999) outlined in IRIC's previous paper.

2.1 A Note of Caution on the Ramifications of Working in First Differences

Before proceeding with the body of the paper, it is important to consider the ramifications of an X-factor based on changes in variables (rather than levels), and in particular, the effect of temporary shocks. By way of example,[4] consider a case where input costs for the regulated firm and the economy grow at precisely the same rate, and productivity in the economy and the regulated firm is growing at one percent per anum; the X factor would be zero. Then suppose that, due to some temporary shock, the regulated firm is able to reduce its costs by two percent per annum in the second year of a ten year period, but then it reverts back to its historical productivity growth of one percent per annum.[5] What occurs is that the regulated firm gets (roughly) two years productivity improvement in one year, and hence, in the years following the shock, its profits are one year ahead of the rest of the economy.

Say inflation is zero, input costs do not change, and revenue in each year is $100, with costs decreasing as outlined above, over ten years. Over the course of this ten year period, if the regulator simply ignored the single year where a two percent shock occurred, the cumulative difference in profits between the regulated and unregulated firm would be $8.65. If, however, the regulator assumed that the two percent shock was permanent (that is, that the regulated firm would lower its cost by two percent each year

[4] The detailed results of this simple modelling exercise are presented in Appendix Two.

[5] For example, the regulated firm might use energy relatively intensely compared to the rest of the economy, and the price of energy might fall sharply for a short period of time.

on an ongoing basis) and imposed an X-factor of minus one percent each year from the third year onwards, then the regulated firm would actually be $61 worse off than the unregulated firm (cumulatively, over the ten year period). By way of contrast, if the productivity change made by the regulated firm in year two was permanent, and the regulator failed to see this, continuing to impose an X-factor of zero, then, over ten years, the cumulative advantage to the regulated firm compared to the rest of the economy would be $41.[6]

If the shock was temporary and the regulator made the adjustment of minus one percent in the year following the two percent shock, then realised its mistake, and continued with an X-factor of zero, then the regulated firm would be $6.49 worse off than the unregulated firm. In actual fact, to make the two firms have equal profits over the ten year period, with the unregulated firm making a cost reduction of one percent every year, and the regulated firm making a cost reduction of two percent in the second year and one percent thereafter, the regulator should impose an X-factor of -0.142% in the third year, and zero thereafter.

Clearly, the example above is rather contrived. However, it shows that, when dealing in changes, intuition gained from the experience of dealing in levels may be misleading. It also highlights the very substantial costs associated with misidentifying a technological change as permanent, when it is temporary both in absolute terms and relative to making the opposite mistake. For these reasons, we would urge caution on the part of regulators when altering these estimates of the X-factor, even across regulatory periods. In cases of uncertainty, it may be better to assume that any changes in productivity by the regulated firm are temporary in nature, unless conclusively proven otherwise. In fact, regulators may wish to adopt a procedure whereby the X-factor is only changed when someone can demonstrate to the regulator's satisfaction that a change in the difference between the growth rates of productivity and/or input prices of the firm, relative to the remainder of

[6] Note that if one had a four percent productivity jump in year two for the regulated firm (with the subsequent X-factor adjustment being minus three, rather than minus one, as appropriate in the discussion above), then the costs of misidentifying a shock as permanent when it was temporary and temporary when it was permanent are roughly the same (in absolute terms). Thereafter, the cost of misidentifying a permanent change as temporary is larger than the converse, although not by as much as the corresponding figures for a two percent change shown above. In regulated industries, a productivity change of more than four percent in a given year seems unlikely, except perhaps in telecommunications.

the economy is permanent rather than temporary.[7] There may also be some scope for devising in regulatory contracts, the benefits to the firm of any temporary productivity shocks, in a similar manner to the overpayment rules used by the ERA in rail.[8]

2.2 Changes from Original Paper

The original IRIC paper was a scoping study, and did not consider the details involved in implementing the methodology it espoused. Following such considerations, two important changes were made in regards to:

- The determination of relevant outputs.
- The use of Shadow prices and Brunker's (1992) methodology.

In our original paper, we were concerned that no reasonable measure of the output of rail infrastructure had been devised, and suggested this be an important priority in the current project. Discussing the matter at a workshop, it quickly became apparent that other infrastructure industries, such as gas and electricity, suggested a simple measure: the available capacity of the system, incorporating some quality of service measure. In rail, this could readily be measured as the number of trains of a certain, common configuration which could be run at a certain, common speed over some time period (for example the number of one kilometre long, 21 tonne axle load train travelling at 110 km/h which could be run per week). However, as is discussed in Section 4.1, the point is actually moot, given the way in which railways are generally regulated in Australia. For this reason, it is not the issue it seemed to be in IRIC's original paper.

On the topic of shadow prices for the beginning of the period of analysis, a much simpler approach was adopted. Expert industry opinion, confirmed in discussions with WNR and the ERA suggests that the substantial inefficiencies Brunker found in Australian railways had largely disappeared by 2000. Of the four cost components, world's best practice efficiency figures for maintenance and capital were available for January 2001 (the start of the period of analysis). For operational and overhead expenditure, we adopted the practice of applying current factor shares to a suitably adjusted actual total cost figure for

[7] In the case of the rail industry in WA, the current regulatory system involves a re-evaluation of the capital base every three years. As such, one might argue that the cumulative effects of mistakes in X-factor adjustments will not be as severe as suggested above. However, this regular review of the capital base might also mean that the best policy is no review of the X-factor during the regulatory period, and the treatment of all intra-period events as temporary shocks.

[8] See Section 47(1) of the Railways (Access) Code 2000

January 2001 (see Section 3.3). This approach is much simpler than the methodology suggested by Brunker, which requires data that are not readily available. Further, under the plausible assumption of unitary elasticity of substitution between inputs, it gives precisely the same results as Brunker's method. When there is a unitary elasticity of substitution, changes in input prices do not affect the shares of each input in total cost (the price and quantity effects are offsetting).

3. Applying the Regulatory Model to Historical Data

There are four major inputs to the production of rail infrastructure. These are:

- Capital
- Maintenance
- Operational expenditures
- Overheads

For June 2003, the MEA model used by the ERA provides appropriate results for all of these factors, but this is the first MEA calculated by the ERA and hence the relevant variables for January 2001 need to be created from historical data. The means by which this has occurred is discussed below. The level of detail is not the same as in the MEA, as the main purpose of this paper is to illustrate the methodology (the X-factor calculated in this paper will not be used by the ERA). In the future, the regulator will have MEA data, and most of the procedures outlined in this chapter will be unnecessary, as the MEA data are to be re-calculated in three years time, and the current actual MEA can form the base case.

3.1 Capital

According to professional engineering advice, there have been few major advances in capital in rail infrastructure since January 2001. For this reason, the current asset base will be utilised for January 2001, but with a Weighted Average Cost of Capital (WACC) appropriate to that time period, rather than the current WACC. This gives rise to annual capital costs, adjusted for 2003 factor shares (see Section 3.3) as shown in Table One.

Table One: Annual Capital Costs, January 2001 and June 2003 ($ million)

	2001	2003
Esperance	25.94	25.50
Leonora	16.65	15.88
EGR	74.74	76.47
SWM	12.72	13.25

3.2 Maintenance

Maintenance expenditure in the MEA is benchmarked to best practice maintenance expenditure for like railways. Adjustments are made to account for the 'capacity factor', discussed in Section 3.4. The value of maintenance expenditure is shown in Table Two.

Table Two: Maintenance Expenditure in January 2001 and June 2003 ($ million)

	2001	2003
Esperance	7.41	7.27
Leonora	2.89	2.76
EGR	29.86	30.45
SWM	5.73	5.96

3.3 Operational Expenditure and Overheads

These two expenditure items have been grouped together, as they are treated jointly. In the MEA model, the actual operational and overhead expenditure (OOE) figures were used for June 2003, as these were deemed by an independent engineer to be at world's best practice levels at the time. However, following discussions with WNR, it is clear that this was not the case in January 2001. Indeed, substantial corporate restructuring has occurred in both of these areas since privatisation. For this reason, we cannot use the actual expenditures on operations and overheads from the immediate post-privatisation period. Rather, we need to extrapolate back, utilising current (MEA) factor shares.

The process is two-fold and can be summarised as follows. Firstly, the absolute amount of OOE in January 2001 was not efficient, which means that the absolute dollar amounts of both the usage of that factor, and overall expenditure need to be adjusted to reflect the inefficiency. Secondly, because OOE was not utilised efficiently, this affects the mix of factor usage overall. Thus, the factor shares of January 2001 do not reflect efficient proportions of factor use. For this reason, it is necessary to apply the current, efficient factor shares to the adjusted January 2001 total costs, to reflect how an efficient firm would have behaved, were it operating in January 2001. An example may clarify matters. Say, for example, that current MEA factor shares were capital, 80 percent, maintenance, 15 percent and OOE five percent, Term the dollar amount of inefficiency in OOE z.[9] To the extent that OOE was inefficient in January 2001, it will have affected

[9] Note that z can be positive or negative, reflecting the fact that 'inefficiency' includes using both too little and too much of a particular factor..

overall expenditure by the same dollar amount *z*. Thus, to work out what OOE should have been in dollar terms in the immediate post-privatisation period, we would need to apply the current efficient factor shares of 80:15:5 to the overall expenditure in the immediate post-privatisation period minus the amount *z*.

The approach of applying current, efficient factor shares to the *z*-adjusted total costs in the immediate post-privatisation period is based on the reasonable assumption of unitary elasticity of substitution and unitary price elasticity amongst inputs.[10] Unitary elasticity means that any proportional increase in price will be offset an exact and opposite proportional decrease in demand for a factor, resulting in no change in the factor share of costs. Thus, even if prices were markedly different in January 2001, factor shares would remain the same over time. For this reason, it is legitimate to apply current factor shares to the adjusted costs of the post-privatisation period in the manner suggested above, as this is precisely what an efficient producer of rail infrastructure would have done were it operating in the period immediately following privatisation.

Empirical evidence concerning the elasticity of substitution between inputs in rail is not substantial. In fact, we have not located any Australian studies detailing the elasticity of substitution between inputs in rail.[11] Bairam (1994, p65) presents an empirical study of the elasticity of substitution between capital and labour in Australian manufacturing, and finds that it is statistically significantly different from unity in only one third of cases (and even then, the elasticities are not very different from unity). Although manufacturing is not the same as rail, it shares the large fixed cost component of rail. For this reason, it seems reasonable, absent of any other evidence, to assume an elasticity of substitution between inputs in rail of unity. Examining the global literature, whilst studies of elasticities between inputs and output in rail exist, very few studies examine elasticities of substation between inputs. One of the few studies that does is Caves, Christenson & Swanson (1981) who found elasticities very close to zero in the US rail industry from 1955 to 1974. However, the authors themselves note that their estimates

[10] This gives rise to a Cobb-Douglas production function, which is a first-order log-linear approximation to any general production function.

[11] Our search was not exhaustive, given that the assumption relates only to the estimation of the January 2001 model, which is important only for the purposes of this paper, and will not form part of the methodology in the future, when actual MEAs are available. Nevertheless, if the authors have overlooked research on the elasticity of substitution between inputs in rail (or transport more generally), which would suggest that the elasticity is different from unity, we would appreciate information about the research.

are not particularly satisfying. Moreover, the way in which rail was regulated in the US prior to 1983 was very different to rail industry regulation in Australia today, particularly, insofar as firms had an incentive to be efficient in their factor usage. For these reasons, we doubt that Caves et al's findings would be replicated in Australian rail. In any case, the unitary elasticity assumption is used as part of the recreation of the January 2001 conditions only. To the extent that the methodology espoused in this paper is used within the context of rail regulation in WA as it currently stands, the elasticity is not critical, as the regulator will be able to utilise MEA figures in his next regulatory determination. If, however, CPI-X regulation as outlined in this paper is used as a replacement to current regulatory practices (see Section 6.2), then empirical estimation of input elasticities for the rail industry as a whole will need to be undertaken as part of a more in-depth examination of rail industry TFP in Australia.

Prior to applying these factor shares, it was necessary to adjust overall expenditure to reflect two key factors. Firstly, when the freight business of Westrail was privatised,[12] its new owners inherited less than a full complement of staff. For this reason, rather than using actual labour expenditure from January 2001, we took the average expenditure per person on labour in January 2001, and multiplied it by the actual number of staff in June 2003 (which was at an efficient level).

Secondly, prior to privatisation, Westrail had very little commercial insurance. WNR has increased its insurance expenditure substantially. Moreover, between January 2001 and June 2003, the event of September 11th 2001 in the US and the collapse of HIH in Australia have lead to increased insurance premiums in Australia. Ergas (2002) cites a JP Morgan study indicating that insurance costs increased by 28 percent between June 2001 and March 2002. Taking into account approximately two percentage points of inflation between March 2002 and June 2003, we therefore replace actual insurance expenditure in January 2001 with the June 2003 figure, reduced by 30 percent; to proxy what a private firm would have paid in insurance premiums at the time. This insurance expenditure is then allocated across the various lines in the same manner as is used in the MEA model. The (capacity adjusted) expenditure on OOE is summarised in Table Three.

[12] Westrail was a government-owned railway business, comprising passenger and freight networks, until the freight network was privatised and the passenger network devolved into the Public Transport Authority.

Table Three: Operational and Overhead Expenditure, January 2001 and June 2003 ($ million)

	2001	2003
Esperance	3.66	3.61
Leonora	1.12	1.07
EGR	13.81	14.11
SWM	8.79	9.17

3.4 Adjustments for Capacity

The MEA inputs were calculated based on the level of demand which exists at present and projected forward for the next five years. However, the relevant capital infrastructure has a capacity in excess of current demand. An issue exists because we are taking the MEA as being the relevant input to the production of rail infrastructure services, to ensure that only best practice inputs are used. Thus, although actual inputs might change to meet changes in demand, the MEA will not change, as its calculation is set for a period of time. We thus need an output measure which is based upon what the capital in the MEA could produce (its capacity), rather than what it currently does produce (current demand).

The capital base is a fixed input and would remain invariant between the current MEA and output measured as capacity. However, the variable inputs of maintenance expenditure, operational expenditure and overheads would not remain constant, and these were calculated in the MEA at current demand levels, not full capacity levels. As such, these inputs will need to be adjusted, both in the current MEA and the variables calculated for January 2001, to reflect what they would be if demand were at full capacity. The adjustment is undertaken by examining each line item in the relevant category and assessing the extent to which it would need to be increased if the rail infrastructure was operating at full capacity. This line-by-line examination is undertaken because not all inputs increase at the same rate with outputs (for example, if demand doubles, you might need twice as many drivers, but no more CEOs). The assessment has been made utilising the judgement of independent engineering experts.

Due to the way in which the MEA is calculated, this capacity adjustment will need to be undertaken in future reviews, which utilise actual MEAs. The adjustment factors used in this paper are shown in Table Four.

Table Four: Capacity Adjustment Factors, January 2001 and June 2003

	OOE	Maintenance
Esperance	1.40	1.80
Leonora	1.15	1.30
EGR	1.60	2.20
SWM	1.60	2.20

3.5 Levels of Disaggregation

The MEA for WNR's infrastructure produces revenue caps for 23 route sections of line, which represents the maximum possible level of disaggregation. Conceptually, it would be possible to calculate the January 2001 variables for each of these route sections. However, from a practical perspective, such a fine level of disaggregation introduces a level of complexity which would arguably not assist in the development of the methodology, which is the purpose of this paper.[13] For this reason, we will disaggregate the model down to the level of the four major lines of the system, and calculate the input component of the TFP for each of these four lines.

[13] As the level of disaggregation is limited by the ease of calculation of an appropriate MEA, not by the TFP methodology, when the ERA uses the methodology of this paper in the next regulatory period, it may wish to disaggregate down to the section level, as it will have an actual MEA to use.

4. Derivation of TFP for WNR

In simple terms, TFP is the weighted sum of the change in revenues minus the weighted sum of the change in input costs (see Chambers, 1998 for more detail). In calculating TFP for WNR, two key issues arise; how to determine the output price and hence revenue, and the best method of indexation.

4.1 Calculation of Revenue

Some considerable effort was devoted towards developing a suitable output measure, and suitable output price. For the output measure, it was considered that the best measure would be the capacity of the relevant portion of the network to handle a certain 'benchmark' train. For example, a one kilometre long, 21 tonne axle load train travelling at 110 km/h. In essence, the choice of the benchmark is not critical, so long as it is consistent, and is a reasonable representation of the traffic on the relevant route.[14]

For price, the best measure would be a weighted average of prices from other reasonably similar railways, where the weights were determined by a matrix of qualitative differences between the railways and the markets and regulatory environments in which they operated insofar as these qualitative differences were cost drivers for the relevant railways. Some progress had been made in developing this matrix based methodology, but there are several methodological difficulties in determining the extent to which a qualitative factor drives costs. Hedonic pricing (whereby prices are estimated based on the inherent characteristics of the rail system) could be used to determine these, but estimation would be a major exercise, beyond the scope of this report.

Almost all railways in Australia set their prices (or at least their price/revenue caps) via a broadly similar method to the ERA; that is, the regulator determines a 'reasonable' capital base, 'reasonable' expenses and then allows these to be recouped (sometimes via a revenue cap, and sometimes via a price cap). Moreover, the approach of almost all Australian regulators is similar; utilise an asset valuation methodology like Depreciated Optimised Replacement Cost (DORC), or GRV, and then apply a WACC calculation (see, for example, Table 7 in BTRE 2003). Different regimes exhibit subtle differences, and the actual prices charged in each regime are generally based on negotiation, rather

[14] As it turns out, this benchmark measure will only be necessary to calculate the full capacity measure in Section 3.4.

than being set at to reflect a ceiling. However, if designed properly, the matrix discussed in the previous paragraph would incorporate these factors, ensuring that a ‘like with like’ comparison could be made.

Thus, taking the appropriately weighted average price of Australian regulated railways and multiplying this by the output of all of the sections of track,[15] would simply give the revenue cap determined by the ERA. Given the errors likely to occur in estimating the weighting mechanism (the matrix referred to previously), it seems, as a second-best solution, most sensible to simply adopt the revenue cap in the TFP calculation.

We stress that this is not the ideal solution. Indeed, it cuts right to the heart of the problem inherent in economic regulation in Australia; the excess of self-reference and the lack of an external reference point with which to judge outcomes. However, whilst the most comparable railways continue to be regulated in a very similar fashion, the likely errors in the weighting mechanism preclude its use. Although beyond the scope of this project, it may prove useful for regulators around Australia to develop an hedonic pricing methodology which does allow for the abstraction from cost-driving qualitative factors in a manner similar to the matrix outlined above, which could then be applied to railways (and other infrastructure) which are priced by a market, not a regulator. When this occurs, an appropriate means of pricing the output of a regulated entity for the purposes of determining X-factors, could occur.[16] Total revenue cap figures are shown in Table Five.

Table Five: Total Revenue Caps, January 2001 and June 2003 ($ millions)

	2001	2003
Esperance	32.66	32.10
Leonora	19.84	18.93
EGR	96.94	99.13
SWM	20.82	21.69

[15] Provided, of course, that the ERA and the other regulators have either all done their WACC calculations correctly or, if these have been done incorrectly, the errors are the same in all cases.

[16] In fact, once this methodology is perfected, the need for the input based method of regulating in Australia would arguably disappear.

4.2 Use of Indexing

Whether technical progress is measured via a divisia index or via a production function approach (which produce the same results with the appropriate choices of indices), the same problem is faced; these measures are based on time being continuous, which allows for derivatives to be calculated, but economic data are generally discrete. A method is required which provides exact results for technological change, using discrete data.

If inputs do not change over time, then the answer to the problem is simple; technological change will be the ratio of outputs at time zero and time *t*. However, this rarely occurs in economics. Rather, as technology changes, the input mix changes. To account for this, under some very restrictive assumptions on functional form, the ratio between the outputs at time zero and time *t* is multiplied by the ratio between the product of all of the inputs raised to the power of their factor shares, at time zero and time *t*. If the restrictive assumptions on functional form do not hold, and more flexible functional form is required, Diewert (1976) shows that it is still possible to construct an exact index measure of technical change using discrete data for each flexible functional form specified.[17] He terms these exact indices 'superlative' indices. If the use of discrete data is not to raise the issue of incorrect indexing failing to take account of changes in factor shares as a response to technological change, a superlative index must be used.

The two most common superlative indices used are the Fisher Ideal Index and the Tornqvist Index. As Diewert (1976) notes, there is no theoretical reason to choose one over the other and, in practice, analysts choose between the two based on practical considerations, such as the form of the data series being used. In fact, as Gullickson (1995) notes, and illustrates for US gross manufacturing output from 1949 to 1952, the two indices produce similar results.

The Fisher Ideal Index is the geometric mean of the Laspeyres (based on prices in the first benchmark year) and Paasche (based on prices in the second index year) indices. The Tornqvist index is found via the following equation:

$$T(x,t) = \ln y_t - \ln y_{t-1} - \sum_{i=1}^{n} \frac{1}{2}\left[V_{it} - V_{i,t-1}\right]\left[\ln x_{it} - \ln x_{i,t-1}\right]$$

[17] Chambers (1988 pp230-49) provides an excellent summary of the theoretical underpinnings of this approach.

Where the *y* terms indicate output, the *x* terms indicate inputs, the *V* terms indicate the ratio at the relevant time period of the cost of input *i* to revenue and ln refers to the natural logarithm of the variables involved.

In this paper, we utilise the Tornqvist Index. There is no theoretical reason for this, however, the ABS utilises a Tornqvist Index for a number of the components in its indices for TFP in the economy as a whole (ABS, 2000). We do likewise, in order to maintain some degree of consistency with the ABS approach, and ensure that errors in results do not arise simply due to methodological differences between the two TFP figures used. Table Six shows the changes in TFP found for each of the four major routes. Note that these changes refer to the entire period from January 2001 to June 2003, and are not annualised figures.

Table Six: Change in Total Factor Productivity, January 2001 to June 2003 (percent)

	Change in TFP (percent)
Esperance	-0.73%
Leonora	-2.04%
EGR	0.97%
SWM	1.77%

Although it might reasonably be expected that rail lines operated by the same company might exhibit reasonably similar changes in productivity, there is substantial variation in the results above. In particular, the presence of some negative TFP results and some positive TFP results is troubling. Esperance and Leonora are both long lines with a relatively small amount of traffic, whilst the traffic amounts on the EGR and SWM are higher. In constructing data for January 2001, we utilised a much simpler apportionment methodology than was possible in the MEA, which was based on much more comprehensive data. In brief, most common costs in the January 2001 model were apportioned according to the proportion of total costs, whilst in 2003, throughput was also considered. On the long (and hence high capital cost) lines with relatively small throughput, this may have skewed results somewhat, and produced the anomalies seen in Table Six. Note that this problem will not be repeated in future, as the ERA will have access to MEA models, formulated on exactly the same assumptions.

5. Derivation of Other Components

Sappington and Bernstein's (1999) methodology requires more than just the estimation of TFP for the regulated firm. It also requires the estimation of the consumer price index, TFP for the economy as a whole, change in input prices for the economy as a whole and changes in input prices for the regulated railway. The derivations of these are discussed below.

5.1 Total Factor Productivity – Whole Economy

The ABS produces estimates for multi-factor productivity (MFP - its terminology for TFP) on an annual basis. Estimates are constructed using a translog production function to explain movements in real GDP per capita given increases in the nation's capital stock and the Australian labour force. These are reported in the *Australian System of National Accounts* (ABS Cat. No.5204.0) and annual estimates exist for the period from 1965 to 2003. Unfortunately, the ABS does not collect capital services data on a quarterly basis. Thus, whilst it does produce a quarterly labour productivity index, it does not produce a quarterly MFP index (or a quarterly capital productivity index). The starting point of our analysis is January 2001 whilst the ABS data are calculated on a financial year basis. As such, the MFP for January 2001 has been calculated as the average of the ABS figures for June 2000 and June 2001.

It should be noted that TFP can fluctuate quite markedly on a quarterly or even an annual basis as a result of the business cycle and lags in the construction of capital and decisions on employment. For instance, Australia recorded 'negative' productivity growth over the two years to June 2001, during a five-year acceleration of productivity growth. Given this, the ABS compiles a 'trend' series (a three to five year moving average) that yields a TFP variable that reflects underlying productivity growth over the course of at least three years. We use the ABS trended TFP statistics from January 2001 to June 2003. This provides a change in TFP of 2.6 percent.

5.2 Consumer Price Index

Estimates of the Australia-wide Consumer Price Index (CPI) are obtained from the ABS publication *Consumer Price Index*, *Australia* (ABS Cat. No. 6401.0). We use quarterly CPI measures from January 2001 to June 2003. This provides a change in CPI of 6.48 percent.

5.3 Changes in Input Prices – Whole Economy

The GDP deflator is the most appropriate measure of input prices, as it includes price of all inputs into the Australian economy, including wages and profit. Estimates of the Australia-wide GDP deflator are obtained from the ABS publication *Australian System of National Accounts* (ABS Cat. 5206.0). We use quarterly GDP deflators from January 2001 to June 2003. The change in the GDP deflator is 5.5 percent.

5.4 Changes in Input Prices – Regulated Rail Firm

The changes in prices for the regulated rail firm come directly from the TFP calculations. We form a composite price for the input prices, which is a weighted average of all of the relevant inputs. To assist in making calculations easier, we assume that each of the four major items (capital, maintenance, operations and overheads) is bought as one item, and its 'price' is the cost of that item in the given year. This gives exactly the same result as would an appropriate weighted average of a finer breakdown of the items which comprise the four major categories. However, such a finer breakdown incorporates a risk of miscalculation for the January 2001 figures which, as discussed previously, need to be estimated. In future determinations, the input prices can be calculated from the MEA model, to whichever degree of precision the ERA deems necessary.

The changes in input prices from January 2001 to June 2003 were as follows:

- Esperance: -1.68 percent.
- Leonora: -4.60 percent.
- EGR: 2.29 percent.
- SWM: 4.16 percent.

As with the TFP results, there is wide variability in results, including some which are negative and some which are positive. This seems counter intuitive, given that the same rail company operates all four lines. However, as with TFP, we believe this is due to differences in assumptions underlying cost apportionment between the estimated January 2001 calculations and the MEA of June 2003. Such differences arose due to the paucity of January 2001 data, but will not arise in future X-factor determinations, when MEA data will be available.

6. Summary of Findings and Future Implementation Challenges

This section provides a brief overview of all of the findings of the study, and suggests some scope for future broadening of the use of the CPI-X methodology outlined in this paper.

6.1 Summary of Findings

Table Seven summarises the outputs of the model.

Table Seven: Summary of Model Outputs

	Esperance	Leonora	EGR	SWM
Weighted Change in Input Prices	-1.68%	-4.60%	2.29%	4.16%
Change in TFP (Tornqvist)	-0.73%	-2.04%	0.97%	1.77%
X-Factor	3.85%	5.45%	1.57%	0.51%
Annualised X-Factor	1.54%	2.18%	0.63%	0.20%
Change in Prices (CPI-X)*	2.63%	1.03%	4.90%	5.97%
Annualised Change in Prices	1.05%	0.41%	1.96%	2.39%

** Based on a CPI over the 30 month period of 6.48 percent*

As previously noted, the results for the changes in input prices and changes in TFP for the two lines which are long with relatively little traffic (Esperance and Leonora) may well be driven by differences in assumptions between the estimated calculations of January 2001 and the MEA of June 2003, with these differences in assumptions necessitated by the paucity of available data for January 2001. In future applications, when actual MEA values are available, such differences in assumptions will not occur, and hence the X-factors for the long, relatively little travelled lines will be more accurate. The results for the EGR and SWM align more closely with expectations because these lines are more heavily trafficked, and hence the differences in underlying assumptions (particularly the MEA approach of apportioning common costs via cost shares and traffic shares) have less of an impact on results.

6.2 Future Uses of CPI-X Regulation

The manner in which the X-factor has been calculated for this paper is based in the context of the manner in which regulation is practised by the ERA in respect to rail infrastructure in WA. For example, much of the data has come from the MEA. This is because, at present, the approach outlined in this paper is intended to calculate X-factors within the context of a broader regulatory system that requires regular review of the asset base, and other elements.

However, the methodology proposed by Bernstein and Sappington has the potential to do far more than be merely a cog in the current regulatory system; it has the potential to replace it, with a less intrusive, and more output based system. There are two reasons we believe that this method of CPI-X regulation has the potential to replace current systems (not only in rail, but in many regulated utilities). Firstly, it is much simpler to understand, and free of much of the intrusiveness of the current regulatory system. Secondly, it deals in rates of change of variables, rather than levels. The levels of variables (for example, the size of a capital base) change frequently. However, the rate of change in variables, particularly the rate of change relative to the rest of the economy, arguably alters much more slowly, particularly when temporary shocks are discounted. For this reason, it affords regulators with the opportunity to adopt a 'hands-off' approach to setting price or revenue caps, but to still ensure that such caps support the goals of an economically efficient allocation of resources.

If the methodology outlined in this paper is to become a replacement of, rather than an adjunct to the current system, the way in which TFP for the regulated firm has been calculated will need to become more sophisticated. We have assumed that the MEA of the ERA is correct, and does represent world's best practice. Also, we have not investigated whether it has incorporated cost reducing technological change that is only temporary in nature. It is not really possible to do this in the context of this study, as we only have one MEA to examine.[18] Within the current regulatory framework, where capital bases are reviewed every three to five years, mis-identification of temporary and permanent shocks might not give rise to substantial issues. However, if CPI-X regulation as outlined in this document is to replace the current system, and regulators are to change X-factors only with extreme caution for the reasons outlined in Section 2.1, it will behove them to devote more effort to the calculation of TFP than has been possible here. At the

[18] In future assessments, the ERA may wish to consider the degree of permanency of the costs of each of the line items in the MEA model, particularly those which have changed substantially from the previous MEA calculation, and to ensure that only permanent technological changes are included (or at least, only changes which are likely to prevail for the next regulatory period).

very least, a lot more than two data points will be needed, particularly if econometric estimation techniques are to be used.[19] Fortunately, the literature on TFP is substantial, and techniques of empirical analysis to ensure such rigour is observed are well established.

[19] The issue of appropriate outputs, and appropriate output prices, would also need to be re-visited.

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Appendix One
Modelling Results Summary

Esperance

Whole of Economy Changes		Dec 2000	Jun.2003		
	Whole of Economy TFP	97.95	100.5		
	%Δ	0.00%	2.60%		
		Dec 2000	Jun.2003		
	Whole of Economy Change in Input Prices	98.2	103.6		
	%Δ	0.00%	5.50%		
		Dec 2000	Jun.2003		
	Change in CPI	132.7	141.3		
	%Δ	0.00%	6.48%		
Raw Data For Firm	Inputs	2001	2003		
	Capital ($M)	27.63	25.5		
	OOE ($M)	1.34	2.58		
	Maintenance ($M)	3.7	4.04		
	TOTAL	32.665328	32.12		
	Revenue Cap	32.665328	32.10		
2003 Factor Shares		2003			
	Capital	79.40%			
	OOE	8.00%			
	Maintenance	12.60%			
Adjustments to raw factor inputs by 2003 factor shares		2001	2003		
	Capital ($M)	25.936271	25.5		
	OOE ($M)	2.6132263	2.58		
	Maintenance ($M)	4.1158314	4.04		
	TOTAL	32.665328	32.12		
Capacity Adjustments	OOE	1.4	1.4		
	Maintenance	1.8	1.8		
Inputs to the Model		2001	2003	log 2001	log 2003
	Output	32.665328	32.12	1.514087	1.5067755
	Inputs				
	Capital	25.936271	25.5	1.4139075	1.4065402
	OOE	3.6585168	3.612	0.5633051	0.5577477
	Maintenance	7.4084965	7.272	0.8697301	0.8616539
	V				
	Capital	0.794	0.7938979		
	OOE	0.112	0.1124533		
	Maintenance	0.2268	0.226401		
Outputs to the Model	Weighted Change in Input Prices	-1.683%			
	Change in TFP (Tornqvist)	-0.731%			
	X-Factor	3.848%			
	Annualised X-Factor	1.539%			
	Change in Prices	2.633%			
	Annualised Change in Prices	1.053%			

Overall formula:	ΔP=ΔCPI-{[ΔTFP firm-ΔTFPeconomy]+[Δinput prices economy-Δinput prices firm]}
ΔTFP Firm	Tornqvist=lny(t)-lny(t-1)-sum0.5[V(I,t)-V(I,t-1)][lnx(I,t)-lnx(I,t-1)]

Leonora

Whole of Economy Changes		Dec.2000	Jun.2003		
	Whole of Economy TFP	97.95	100.5		
	%Δ	0.00%	2.60%		
		Dec.2000	Jun.2003		
	Whole of Economy Change in Input Prices	98.2	103.6		
	%Δ	0.00%	5.50%		
		Dec.2000	Jun.2003		
	Change in CPI	132.7	141.3		
	%Δ	0.00%	6.48%		
Raw Data For Firm	Inputs	2001	2003		
	Capital ($M)	17.56	15.88		
	OOE ($M)	0.34	0.93		
	Maintenance ($M)	1.94	2.12		
	TOTAL	19.83969421	18.93		
	Revenue Cap	19.83969421	18.93		
2003 Factor Shares		2003			
	Capital	83.9%			
	OOE	4.9%			
	Maintenance	11.2%			
Adjustments to raw factor inputs by 2003 factor shares		2001	2003		
	Capital ($M)	16.64550345	15.88		
	OOE ($M)	0.972145016	0.93		
	Maintenance ($M)	2.222045752	2.12		
	TOTAL	19.83969421	18.93		
Capacity Adjustments		2001	2003		
	OOE	1.15	1.15		
	Maintenance	1.3	1.3		
Inputs to the Model		2001	2003	log 2001	log 2003
	Output	19.84	18.93	1.297535	1.2771506
	Inputs				
	Capital	16.65	15.88	1.2212969	1.2008505
	OOE	1.12	1.0695	0.0484289	0.0291808
	Maintenance	2.89	2.756	0.4606963	0.4402792
	V				
	Capital	0.84	0.8388801		
	OOE	0.06	0.0564976		
	Maintenance	0.15	0.145589		
Outputs to the Model	Weighted Change in Input Prices	-4.59771%			
	Change in TFP (Tornqvist)	-2.03843%			
	X-Factor	5.45489%			
	Annualised X-Factor	2.18196%			
	Change in Prices	1.02589%			
	Annualised Change in Prices	0.41036%			

Overall formula:	ΔP=ΔCPI-{[ΔTFP firm-ΔTFPeconomy]+[Δinput prices economy-Δinput prices firm]}
ΔTFP Firm	Tornqvist=lny(t)-lny(t-1)-sum0.5[V(I,t)-V(I,t-1)][lnx(I,t)-lnx(I,t-1)]

EGR

Whole of Economy Changes		Dec.2000	Jun.2003		
	Whole of Economy TFP	97.95	100.5		
	%Δ	0.00%	2.60%		
		Dec.2000	Jun.2003		
	Whole of Economy Change in Input Prices	98.2	103.6		
	%Δ	0.00%	5.50%		
		Dec.2000	Jun.2003		
	Change in CPI	132.7	141.3		
	%Δ	0.00%	6.48%		
Raw Data For Firm	Inputs	2001	2003		
	Capital ($M)	78.36	76.47		
	OOE ($M)	5.8874233	8.82		
	Maintenance ($M)	12.69	13.84		
	TOTAL	96.937423	99.13		
	Revenue Cap	96.937423	99.18		
2003 Factor Shares		2003			
	Capital	0.771			
	OOE	0.089			
	Maintenance	0.14			
Adjustments to raw factor inputs by 2003 factor shares		2001	2003		
	Capital ($M)	74.738753	76.47		
	OOE ($M)	8.6274307	8.82		
	Maintenance ($M)	13.571239	13.84		
	TOTAL	96.937423	99.13		
Capacity Adjustments		2001	2003		
	OOE	1.6	1.6		
	Maintenance	2.2	2.2		
Inputs to the Model		2001	2003	log 2001	log 2003
	Output	96.937423	99.13	1.9864915	1.9962051
	Inputs				
	Capital	74.7388	76.47	1.8735458	1.8834911
	OOE	13.8039	14.1120	1.1400015	1.1495886
	Maintenance	29.8567	30.4480	1.4750422	1.4835588
	V				
	Capital	0.7710	0.7714		
	OOE	0.1424	0.1424		
	Maintenance	0.3080	0.3072		
Outputs to the Model	Weighted Change in Input Prices	2.2925%			
	Change in TFP (Tornqvist)	0.9715%			
	X-Factor	1.5747%			
	Annualised X-Factor	0.6299%			
	Change in Prices	4.9061%			
	Annualised Change in Prices	1.9624%			

Overall formula:	ΔP=ΔCPI-{[ΔTFP firm-ΔTFPeconomy]+[Δinput prices economy-Δinput prices firm]}
ΔTFP Firm	Tornqvist=lny(t)-lny(t-1)-sum0.5[V(I,t)-V(I,t-1)][lnx(I,t)-lnx(I,t-1)]

SWM

Section	Item	Dec.2000 / 2001	Jun.2003 / 2003	log 2001	log 2003
Whole of Economy Changes		Dec.2000	Jun.2003		
	Whole of Economy TFP	97.95	100.5		
	%Δ	0.00%	2.60%		
		Dec.2000	Jun.2003		
	Whole of Economy Change in Input Prices	98.2	103.6		
	%Δ	0.00%	5.50%		
		Dec.2000	Jun.2003		
	Change in CPI	132.7	141.3		
	%Δ	0.00%	6.48%		
Raw Data For Firm	Inputs	2001	2003		
	Capital ($M)	14.05	13.25		
	OOE ($M)	4.2941226	5.73		
	Maintenance ($M)	2.48	2.71		
	TOTAL	20.824123	21.69		
	Revenue Cap	20.824123	21.69		
2003 Factor Shares		2003			
	Capital	0.611			
	OOE	0.264			
	Maintenance	0.125			
Adjustments to raw factor inputs by 2003 factor shares		2001	2003		
	Capital ($M)	12.723539	13.25		
	OOE ($M)	5.4975684	5.73		
	Maintenance ($M)	2.6030153	2.71		
	TOTAL	20.824123	21.69		
Capacity Adjustments		2001	2003		
	OOE	1.6	1.6		
	Maintenance	2.2	2.2		
Inputs to the Model		2001	2003	log 2001	log 2003
	Output	20.824123	21.69	1.3185667	1.3362596
	Inputs				
	Capital	12.723539	13.25	1.1046079	1.1222159
	OOE	8.7961094	9.168	0.9442906	0.9622746
	Maintenance	5.7266337	5.962	0.7578994	0.775392
	V				
	Capital	0.611	0.6108806		
	OOE	0.4224	0.4226833		
	Maintenance	0.275	0.2748732		
Outputs to the Model	Weighted Change in Input Prices	4.1552%			
	Change in TFP (Tornqvist)	1.7692%			
	X-Factor	0.5096%			
	Annualised X-Factor	0.2038%			
	Change in Prices	5.9712%			
	Annualised Change in Prices	2.3885%			

Overall formula:	ΔP=ΔCPI-{[ΔTFP firm-ΔTFPeconomy]+[Δinput prices economy-Δinput prices firm]}
ΔTFP Firm	Tornqvist=lny(t)-lny(t-1)-sum0.5[V(I,t)-V(I,t-1)][lnx(I,t)-lnx(I,t-1)]

Appendix Two

Rate of Change Comparison (Section2.1) Modelling Results

Base Case - Regulator Does Nothing								
	Percentage change in costs		Costs		Revenue		Profits	
Year	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm
1	0.01	0.01	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ -	$ -
2	0.02	0.01	$ 98.00	$ 99.00	$ 100.00	$ 100.00	$ 2.00	$ 1.00
3	0.01	0.01	$ 97.02	$ 98.01	$ 100.00	$ 100.00	$ 2.98	$ 1.99
4	0.01	0.01	$ 96.05	$ 97.03	$ 100.00	$ 100.00	$ 3.95	$ 2.97
5	0.01	0.01	$ 95.09	$ 96.06	$ 100.00	$ 100.00	$ 4.91	$ 3.94
6	0.01	0.01	$ 94.14	$ 95.10	$ 100.00	$ 100.00	$ 5.86	$ 4.90
7	0.01	0.01	$ 93.20	$ 94.15	$ 100.00	$ 100.00	$ 6.80	$ 5.85
8	0.01	0.01	$ 92.27	$ 93.21	$ 100.00	$ 100.00	$ 7.73	$ 6.79
9	0.01	0.01	$ 91.34	$ 92.27	$ 100.00	$ 100.00	$ 8.66	$ 7.73
10	0.01	0.01	$ 90.43	$ 91.35	$ 100.00	$ 100.00	$ 9.57	$ 8.65
Total							$ 52.47	$ 43.82
	Profits of regulated firm minus profits of unregulated firm						$ 8.65	

Worst Case Case - Regulator Assumes 2 percent shift is permanent when it is temporary								
	Percentage change in costs		Costs		Revenue		Profits	
Year	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm
1	0.01	0.01	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ -	$ -
2	0.02	0.01	$ 98.00	$ 99.00	$ 100.00	$ 100.00	$ 2.00	$ 1.00
3	-0.01	0.01	$ 98.98	$ 98.01	$ 100.00	$ 100.00	$ 1.02	$ 1.99
4	-0.01	0.01	$ 99.97	$ 97.03	$ 100.00	$ 100.00	$ 0.03	$ 2.97
5	-0.01	0.01	$ 100.97	$ 96.06	$ 100.00	$ 100.00	-$ 0.97	$ 3.94
6	-0.01	0.01	$ 101.98	$ 95.10	$ 100.00	$ 100.00	-$ 1.98	$ 4.90
7	-0.01	0.01	$ 103.00	$ 94.15	$ 100.00	$ 100.00	-$ 3.00	$ 5.85
8	-0.01	0.01	$ 104.03	$ 93.21	$ 100.00	$ 100.00	-$ 4.03	$ 6.79
9	-0.01	0.01	$ 105.07	$ 92.27	$ 100.00	$ 100.00	-$ 5.07	$ 7.73
10	-0.01	0.01	$ 106.12	$ 91.35	$ 100.00	$ 100.00	-$ 6.12	$ 8.65
Total							-$ 18.12	$ 43.82
	Profits of regulated firm minus profits of unregulated firm						-$ 61.94	

Myopic Case - Regulator Assumes 2 percent shift is temporary but it is permanent								
	Percentage change in costs		Costs		Revenue		Profits	
Year	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm
1	0.01	0.01	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ -	$ -
2	0.02	0.01	$ 98.00	$ 99.00	$ 100.00	$ 100.00	$ 2.00	$ 1.00
3	0.02	0.01	$ 96.04	$ 98.01	$ 100.00	$ 100.00	$ 3.96	$ 1.99
4	0.02	0.01	$ 94.12	$ 97.03	$ 100.00	$ 100.00	$ 5.88	$ 2.97
5	0.02	0.01	$ 92.24	$ 96.06	$ 100.00	$ 100.00	$ 7.76	$ 3.94
6	0.02	0.01	$ 90.39	$ 95.10	$ 100.00	$ 100.00	$ 9.61	$ 4.90
7	0.02	0.01	$ 88.58	$ 94.15	$ 100.00	$ 100.00	$ 11.42	$ 5.85
8	0.02	0.01	$ 86.81	$ 93.21	$ 100.00	$ 100.00	$ 13.19	$ 6.79
9	0.02	0.01	$ 85.08	$ 92.27	$ 100.00	$ 100.00	$ 14.92	$ 7.73
10	0.02	0.01	$ 83.37	$ 91.35	$ 100.00	$ 100.00	$ 16.63	$ 8.65
Total							$ 85.36	$ 43.82
Profits of regulated firm minus profits of unregulated firm							$ 41.54	

Simple Adjustment Case - Regulator adjusts for the productivity shock with the same percentage offset								
	Percentage change in costs		Costs		Revenue		Profits	
Year	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm
1	0.01	0.01	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ -	$ -
2	0.02	0.01	$ 98.00	$ 99.00	$ 100.00	$ 100.00	$ 2.00	$ 1.00
3	-0.01	0.01	$ 98.98	$ 98.01	$ 100.00	$ 100.00	$ 1.02	$ 1.99
4	0.01	0.01	$ 97.99	$ 97.03	$ 100.00	$ 100.00	$ 2.01	$ 2.97
5	0.01	0.01	$ 97.01	$ 96.06	$ 100.00	$ 100.00	$ 2.99	$ 3.94
6	0.01	0.01	$ 96.04	$ 95.10	$ 100.00	$ 100.00	$ 3.96	$ 4.90
7	0.01	0.01	$ 95.08	$ 94.15	$ 100.00	$ 100.00	$ 4.92	$ 5.85
8	0.01	0.01	$ 94.13	$ 93.21	$ 100.00	$ 100.00	$ 5.87	$ 6.79
9	0.01	0.01	$ 93.19	$ 92.27	$ 100.00	$ 100.00	$ 6.81	$ 7.73
10	0.01	0.01	$ 92.26	$ 91.35	$ 100.00	$ 100.00	$ 7.74	$ 8.65
Total							$ 37.33	$ 43.82
Profits of regulated firm minus profits of unregulated firm							-$ 6.49	

Ideal Case - Regulator Adjusts Exactly, so Difference in profits is zero								
	Percentage change in costs		Costs		Revenue		Profits	
Year	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm	Regulated firm	Unregulated firm
1	0.01	0.01	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ -	$ -
2	0.02	0.01	$ 98.00	$ 99.00	$ 100.00	$ 100.00	$ 2.00	$ 1.00
3	-0.0014	0.01	$ 98.14	$ 98.01	$ 100.00	$ 100.00	$ 1.86	$ 1.99
4	0.01	0.01	$ 97.16	$ 97.03	$ 100.00	$ 100.00	$ 2.84	$ 2.97
5	0.01	0.01	$ 96.19	$ 96.06	$ 100.00	$ 100.00	$ 3.81	$ 3.94
6	0.01	0.01	$ 95.22	$ 95.10	$ 100.00	$ 100.00	$ 4.78	$ 4.90
7	0.01	0.01	$ 94.27	$ 94.15	$ 100.00	$ 100.00	$ 5.73	$ 5.85
8	0.01	0.01	$ 93.33	$ 93.21	$ 100.00	$ 100.00	$ 6.67	$ 6.79
9	0.01	0.01	$ 92.40	$ 92.27	$ 100.00	$ 100.00	$ 7.60	$ 7.73
10	0.01	0.01	$ 91.47	$ 91.35	$ 100.00	$ 100.00	$ 8.53	$ 8.65
Total							$ 43.82	$ 43.82
Profits of regulated firm minus profits of unregulated firm							$ 0.00	