# Incentive Indexes for Regulated Industries

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**Abstract**

A range of performance measures are suggested and evaluated in the context of regulated industries with multiple inputs and/or multiple outputs. These measures are intended to induce optimizing behaviour, i.e., to induce unit cost minimization or productivity growth maximization. Intertemporal and practical implementation issues are also considered.

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# 1 Introduction

The issue of incentive regulation has received much attention due to the large potential costs to consumers of not providing the incentives for firms to act as though they are in a competitive environment (Crew 1996; Spulber 1989; National Regulatory Research Institute 1991). In particular, the regulation of public utilities has received considerable attention (e.g., Joskow and Schmalensee (1986); Crew (1994); Brown and Sibley (1986)).

Joskow and Schmalensee (1986) defined two broad classes of incentive regulation schemes, namely "comprehensive" and "partial" schemes. Comprehensive schemes induce efficient pricing and output by the regulated firm, as well as efficient production decisions. Partial schemes address only the issue of efficient production. The incentive indexes proposed in this paper fall into the latter class of regulation schemes. Several such incentive indexes for regulated firms are introduced and evaluated. These indexes are intended to induce optimizing behaviour by the firms, i.e., to induce the manager to either minimize unit cost or to maximize productivity gains.[1] For each period, the indexes give a measure of the performance of a firm, that is then used in determining whether a reward (or penalty) is due. Throughout, it is useful to consider the reward function as being proportional to the "incentive" (performance) index.

Index-number problems will arise if the firm produces more than one output. That is, with more than one output, some method of aggregating across outputs needs to be chosen. The standard method for doing this is to choose an index-number formula, but the choice of index-number formula is then an issue as each of the possible alternatives has distinct properties. Some may have very undesirable properties, and hence should be avoided by regulators. A strong case for the use of the Fisher (1922) ideal index formula for aggregation of either input or output quantities and prices is made. While the Fisher index has become increasingly popular for many index-number contexts it is typical in the regulation literature

[1]It is unclear whether currently used incentive regulation schemes are effective in this regard (Kridel et. al. 1996; Crew and Kleindorfer 1996). However, Sappington and Weisman (1996) proposed a revenue sharing scheme that "can increase incentives for the regulated firm to supply cost-reducing effort" (p. 242).

to use the Laspeyres formula in, e.g., regulatory price-adjustment processes as suggested by Vogelsang and Finsinger (1979), (a "comprehensive" regulation scheme). In the current context, the Laspeyres index formula is shown to be (typically) biased. Also, the problem of welfare-reducing strategic behaviour by the regulated firms is addressed by the introduction of an "intertemporally ideal" incentive plan.

The proposed incentive indexes are applicable to any regulated industry. In many countries, industries which have some type of incentive scheme imposed include telecommunications (see Kridel, Sappington and Weisman (1996), and Bernstein and Sappington (1999)), electricity generation (see Berg, Diewert, Kahn, Lewis and Sappington (1992), and Diewert and Nakamura (1999)), and water supply (see Lynk (1993) and Hunt and Lynk (1995)). The applicability of incentive indexes is discussed further by Crew (1994)(1996) and Crew and Kleindorfer (1996).

The paper is organized as follows. Section 2 introduces a useful result on the equivalence of three measures of performance. These equivalences make it possible to consider various incentive indexes in sections 3 and 4. The incentive indexes in section 3 do not explicitly depend on the performance of the rest of the firms in the industry, while in section 4 we introduce peer group ("yardstick") indexes which do depend explicitly on the performance of other firms. Section 5 addresses the potential problem of firms responding to the incentive schemes in a way which increases their profits, but decreases welfare. We suggest a class of incentive schemes that will restrict this possible intertemporal manipulation of incentive schemes. Section 6 discusses practical issues relating to the implementation of the proposed incentive indexes. In particular, theoretical results that aid in the choice of index-number formula, and issues relating to potential data problems are discussed. Section 7 concludes.

## 2 A Useful Result

Suppose that a regulated firm produces $M$ outputs and utilizes $N$ inputs during each accounting period. Let the quantity of output $m$ sold during period $t$ be $y_m^t$ and denote the corresponding average selling price by $p_m^t$. Define the period $t$ output quantity and price vectors by $y^t \equiv (y_1^t, \ldots, y_M^t)$ and $p^t \equiv (p_1^t, \ldots, p_M^t)$ respectively. Denote the quantity of input $n$ utilized during period $t$ by $x_n^t$ and denote the corresponding average period $t$ input price by $w_n^t$. Define the period $t$ input quantity and price vectors by $x^t \equiv (x_1^t, \ldots, x_N^t)$ and $w^t \equiv (w_1^t, \ldots, w_N^t)$ respectively. The *ex post* accounting identity for the firm in period $t$ is

$$p^t \cdot y^t = m^t w^t \cdot x^t \tag{1}$$

where $p^t \cdot y^t \equiv \sum_m^M p_m^t y_m^t$ is period $t$ revenue, $w^t \cdot x^t \equiv \sum_n^N w_n^t x_n^t \equiv c^t$ is period $t$ cost, and $m^t \equiv p^t \cdot y^t / w^t \cdot x^t$ is the ratio of period $t$ revenue to cost for the regulated firm. Put another way, $m^t$ is (one plus) the excess profit margin for the firm in period $t$ so that if $m^t > 1$, the firm makes profits in period $t$; if $m^t < 1$ then the firm makes a loss in period $t$.

An *output price index* is a function which aggregates the individual output price data pertaining to periods 0 and $t$, $p^0$ and $p^t$, into an aggregate output price ratio $P^t/P^0$. The components of the output quantity vectors, $y^0$ and $y^t$, pertaining to periods 0 and $t$ can be used to weight the components of $p^0$ and $p^t$ when calculating the aggregate output price ratio. More formally, an output price index is simply a function of $4M$ variables, say $P(p^0, p^t, y^0, y^t)$.

An *output quantity index* is a function which aggregates the individual quantity data pertaining to periods 0 and $t$, $y^0$ and $y^t$, into an aggregated output quantity ratio, $Y^t/Y^0$. In this case, the relevant prices can be used as weights. Thus, more formally, an output quantity index is also simply a function of $4M$ variables, say $Q(p^0, p^t, y^0, y^t)$.

The output price and quantity indexes should satisfy the following identity so that the conservation of value property holds (Fisher 1911, 418)(Frisch 1930, 399):

$$P(p^0, p^t, y^0, y^t) Q(p^0, p^t, y^0, y^t) = (P^t/P^0) \cdot (Y^t/Y^0) = p^t \cdot y^t / p^0 \cdot y^0. \tag{2}$$

That is, the product of the output price and quantity indexes should equal the ratio of period $t$ revenue to period 0 revenue. Alternatively, we can think of (2) as requiring that growth in revenue between periods 0 and $t$ be decomposable into price and quantity growth effects. Therefore, using (2), for any $P(p^0, p^t, y^0, y^t)$ we can define $Q(p^0, p^t, y^0, y^t)$ residually.

Entirely analogous considerations apply to the problem of defining the price and quantity aggregates for inputs. Thus, denote generic price and quantity indexes for inputs by the functions of $4N$ variables $P^*(w^0, w^t, x^0, x^t)$ and $Q^*(w^0, w^t, x^0, x^t)$. The input counterpart of the conservation of value property of (2) is

$$P^*(w^0, w^t, x^0, x^t)Q^*(w^0, w^t, x^0, x^t) = w^t \cdot x^t / w^0 \cdot x^0 = c^t / c^0. \tag{3}$$

That is, the product of the input price and quantity indexes should equal the ratio of the period $t$ cost to period 0 cost.

Now define the *excess margin ratio* between periods 0 and $t$ by $m^t/m^0$, and the productivity growth rate between periods 0 and $t$ by $Q(p^0, p^t, y^0, y^t)/Q^*(w^0, w^t, x^0, x^t)$, i.e., the output quantity index divided by the input quantity index. Then we can show the following result.

**Result 1** *The following are equivalent: (i) the output price growth rate divided by the excess margin growth rate; (ii) the input price growth rate divided by the productivity growth rate; and (iii) the growth in unit cost.*

To prove this result, from equation (1) consider the following:

$$p^t \cdot y^t / p^0 \cdot y^0 = (m^t/m^0)(w^t \cdot x^t / w^0 \cdot x^0). \tag{4}$$

Now substitute (2) and (3) into (4), and rearrange to get:

$$P(p^0, p^t, y^0, y^t)/(m^t/m^0) = P^*(w^0, w^t, x^0, x^t)/[Q(p^0, p^t, y^0, y^t)/Q^*(w^0, w^t, x^0, x^t)], \tag{5}$$

which shows the equivalence of parts (i) and (ii) of the result. To prove part (iii), substitute (2) and $w^t \cdot x^t / w^0 \cdot x^0$ into (4), and rearrange until we get

$$P(p^0, p^t, y^0, y^t)/(m^t/m^0) = (c^t/c^0)/Q(p^0, p^t, y^0, y^t) = (c^t/Y^t)/(c^0/Y^0). \tag{6}$$

Note that the last equality follows from the definition of $Q(p^0, p^t, y^0, y^t)$ as a ratio of two aggregate output indexes. The right hand side of the last equality is then the growth in unit cost between periods 0 and $t$, and the equality proves part (iii) of the result. Therefore, minimization of (i), (ii) or (iii) can be taken as equivalent measures of performance.

## 3 Incentive Indexes

In this section we begin to examine possible incentive indexes by suggesting indexes which depend only on information on the "target firm", i.e., the firm which is to be subject to the regulation scheme. The next section looks at a class of incentive indexes that we can describe as peer-group indexes, as they depend explicitly on the performance of other firms in the industry. The objective of all of the indexes considered is to induce optimizing behaviour in regulated firms, e.g., to induce a nuclear power plant to minimize unit cost or to maximize productivity growth. Throughout, we assume that quality is measurable as part of output.

In the first case we consider, the firm's incentive index is based on making the rate of growth of its own unit cost as small as possible. Specifically, the incentive index would be based on the right hand side of (6), i.e.,

$$I^1 \equiv (c^t/c^0)/Q(p^0,p^t,y^0,y^t). \tag{7}$$

The incentive index, $I^1$, has the advantage that it is relatively easy to compute since it depends on data pertaining to the single firm. Moreover, it avoids the potentially difficult measurement issues involved in calculating price and quantity indexes for inputs. However, $I^1$ has the disadvantage that it makes no allowance for exogenous changes in the input prices that a firm might face.

Consider the right hand side of equation (5). If the input price change $P^*(w^0,w^t,x^0,x^t)$ is regarded as exogenous, then we will want the firm to maximize the remaining term, which we can then write as the following incentive index:

$$I^2 \equiv Q(p^0,p^t,y^0,y^t)/Q^*(w^0,w^t,x^0,x^t). \tag{8}$$

Note that $I^2$ is the ratio of the output quantity growth rate to the input quantity growth rate, and hence can be defined as the firm's rate of growth in productivity between periods 0 and $t$.

Consider some exogenously given rate of productivity growth, $\beta^t$, that is considered by the regulators as being "normal". Then, $I^2$ can be modified as follows:

$$\begin{aligned} I^3 &\equiv [Q(p^0,p^t,y^0,y^t)/Q^*(w^0,w^t,x^0,x^t)] - \beta^t, \\ &= [P^*(w^0,w^t,x^0,x^t)Q(p^0,p^t,y^0,y^t)/(c^t/c^0)] - \beta^t, \end{aligned} \tag{9}$$

using equations (5) and (6). The advantages of using the incentive index $I^3$ include: (i) it depends only on the data pertaining to the target firm; (ii) it adjusts for exogenous changes in input prices; and (iii) it allows for "normal" productivity growth, $\beta^t$.

The disadvantages of using $I^3$ include: (i) there is no incentive for the firm to search for lower cost inputs or to bargain diligently with its suppliers and labour unions (i.e., there may be input price "pass through"); (ii) it is difficult to measure the individual input prices and quantities that appear in the input quantity index $Q^*(w^0,w^t,x^0,x^t)$; and (iii) the choice of the productivity offset parameter $\beta^t$ may be contentious.

Let $W^0$ and $W^t$ be industry input price vectors for periods 0 and $t$ and let $X^0$ and $X^t$ be the corresponding industry input quantity vectors. The industry counterpart to the firm's input price index introduced in section 2 is then $P^*(W^0,W^t,X^0,X^t)$. Our fourth incentive index is the same as $I^3$ defined in (9) except that the firm-specific input price index is replaced by the industry input price index, i.e.,

$$I^4 = [P^*(W^0,W^t,X^0,X^t)Q(p^0,p^t,y^0,y^t)/(c^t/c^0)] - \beta^t. \tag{10}$$

Thus $I^4$ is essentially the reciprocal of the unit cost index for the target firm, $(c^t/c^0)/Q(p^0,p^t,y^0,y^t)$, multiplied by an industry input price index, $P^*(W^0,W^t,X^0,X^t)$, less a "normal" productivity offset term, $\beta^t$. The target firm should aim to maximize $I^4$.

The advantage of $I^4$ over $I^3$ is that the target firm now has an incentive to search for lower input prices and to bargain hard with its suppliers and unions. Disadvantages associated with the use of the incentive index $I^4$ include: (i) industry data on inputs must now be collected in addition to target firm data on costs and output prices and quantities; (ii) the industry input price index may not be appropriate for the target firm; and (iii) the choice of the productivity offset parameter $\beta^t$ may still be contentious.

To ensure that the firm has no incentive to manipulate the index, the industry data should exclude the outputs and inputs of the target firm. It should be noted that choosing which firms should go into the industry aggregate may also be contentious, as it may not always be clear which firms are legitimate peers for the target firm.

In order to deal with the problem that the industry input price index may not be appropriate for the target firm, the incentive index $I^4$ may be modified as follows: replace the industry input price index which uses industry input prices, $W^0$ and $W^t$, and industry quantities, $X^0$ and $X^t$, by a hybrid input price index which uses industry input prices and target firm input quantities, $x^0$ and $x^t$. We then have the following incentive index which is to be maximized by the firm:

$$I^5 \equiv [P^*(W^0, W^t, x^0, x^t)Q(p^0, p^t, y^0, y^t)/(c^t/c^0)] - \beta^t. \tag{11}$$

Thus $I^5$ is essentially the reciprocal of the unit cost index for the target firm $(c^t/c^0)/Q(p^0, p^t, y^0, y^t)$ multiplied by an input price index, $P^*(W^0, W^t, x^0, x^t)$, less a "normal" productivity offset term, $\beta^t$.

The advantages associated with the use of the performance indicator $I^5$ include: (i) the target firm has an incentive to minimize period $t$ costs, $c^t$; (ii) since the input price pass-through term $P^*(W^0, W^t, x^0, x^t)$ depends on exogenous industry input prices $W^0$ and $W^t$, the target firm will have an incentive to search for lower priced inputs in period $t$ and to bargain effectively with its suppliers and labour unions; and (iii) the use of the target firm's input quantity vectors $x^0$ and $x^t$ as weights in the input price index $P^*(W^0, W^t, x^0, x^0)$ will ensure that this exogenous input price adjustment term is applicable to the target firm.

The disadvantages associated with the use of $I^5$ are: (i) firm input quantity data and industry input price data are required and thus the data requirements are more onerous compared to the data requirements associated with $I^1$, $I^2$ and $I^3$, which required only data for the target firm, and (ii) it may be difficult to choose the appropriate productivity growth offset factor, $\beta^t$.

It should be noted that the regulator may well prefer to use $I^4$ rather than $I^5$, because the use of $I^4$ gives the target firm the incentive to choose a technology that will minimize costs in the long run, i.e., to use a technology which uses inputs which are less expensive than the industry average. This incentive to minimize long-run costs is largely absent in $I^5$. However, from the viewpoint of the target firm, the use of $I^4$ will be "riskier" than the use of $I^5$, i.e., if the target firm invests in a technology that turns out to be more costly than the industry average, then it could be penalized heavily if $I^4$ were used as the incentive index.

# 4 Peer Group Indexes and Yardstick Competition

For the following indexes $I^6 - I^9$, we require the industry output price and quantity data for periods 0 and $t$, which we denote by $P^0$, $P^t$, $Y^0$ and $Y^t$, respectively. The following incentive index $I^6$ is similar to the kind of unit cost indexes first proposed by Caves and Christensen (1982) and Christensen and Lowry (1992, 38):[2]

$$I^6 \equiv [(c^t/c^0)/Q(p^0,p^t,y^0,y^t)] - [(C^t/C^0)/Q(P^0,P^t,Y^0,Y^t)] \qquad (12)$$

where the period $t$ industry cost is defined as $C^t \equiv W^t \cdot X^t$.

Note that the first set of terms on the right hand side of (12) is our single firm unit cost index $I^1$ defined by (7). The second set of terms on the right hand side of (12), $[(C^t/C^0)/Q(P^0,P^t,Y^0,Y^t)]$, is an analogous unit cost index which uses industry data in place of the target firm data. The target firm is asked to minimize $I^6$, which means it has an incentive to minimize period $t$ cost, $c^t$.

Using equations (5) and (6), it can be seen that $I^6$ may be rewritten as follows:

$$\begin{aligned} I^6 &= \{P^*(w^0,w^t,x^0,x^t)/[Q(p^0,p^t,y^0,y^t)/Q^*(w^0,w^t,x^0,x^t)]\} \\ &\quad -\{P^*(W^0,W^t,X^0,X^t)/[Q(P^0,P^t,Y^0,Y^t)/Q^*(W^0,W^t,X^0,X^t)]\}. \end{aligned} \qquad (13)$$

[2]For incentive compatibility reasons, we prefer to compare the period $t$ data for the target firm to the fixed period 0 data, rather than to the data pertaining to period $t-1$, where the latter alternative was followed by Caves and Christensen (1982) and Christensen and Lowry (1992). The problem with using period $t-1$ data in an incentive plan that covers several periods is that the target firm may have an incentive to engage in artificial productivity cycles (e.g., raising productivity in one year and then lowering it in the next) depending on the exact way the period-by-period incentive indexes are mapped into rewards for the target firm. This "cycling" problem is discussed more fully by Sappington (1992) and in section 5.

The first set of terms on the right hand side of (13) equals the target firm's input price index divided by the target firm's rate of productivity growth between periods 0 and $t$. The second set of terms is similar to the first, but uses industry data in place of the target firm's data.

From (13), we see that $I^6$ will be less than 0 if the target firm can make its rate of growth of unit costs smaller than the industry rate of growth of unit costs over the same period. An advantage of $I^6$ over $I^1$ is it does not appear to require an adjustment for exogenous changes in input prices. However, (13) shows that the problem of adjusting for exogenous changes in input prices is not entirely absent in $I^6$. The productivity growth rates are pure numbers and are not affected by inflation rates. However, the two input price indexes will generally be affected by changes in the rate of inflation and hence in periods of high inflation, the difference between the target firm's productivity growth rate and the industry's productivity growth rate (reciprocated) will generally be *magnified* by the inflation rate if we use $I^6$ as our incentive index. The regulators may or may not be concerned with this magnification effect, or they may be able to control for this effect by setting up an appropriate reward mechanism which maps the numerical value of the incentive index into a specific reward for the firm.

A primary advantage of $I^6$ is that it avoids the difficult measurement problems that are associated with the calculation of input prices and quantities: we require only information on costs, output prices and output quantities for the target firm and the industry.

Disadvantages associated with the use of $I^6$ include: (i) industry data on costs, output prices and output quantities must be collected; (ii) the index is not invariant to changes in the general inflation rate; and (iii) the target firm is subject to increased risk if $I^6$ is used in place of $I^1$ through $I^5$, since these earlier indexes did not depend on an *a priori* unknown and variable industry productivity growth rate.[3]

In order to avoid the effects of inflation that arise from the use of $I^6$, we propose an index based on productivity differences between the target firm and the industry, rather than unit

[3]However, it is possible that the target firm's productivity growth rate is correlated with the productivity growth rate for the industry. In such a case, the firm may face less risk under $I^6$ than if a productivity offset parameter $\beta$ is chosen exogenously, as in $I^3$ through $I^5$.

cost differences:

$$
\begin{aligned}
I^7 \;\equiv\; & [P^*(w^0, w^t, x^0, x^t)Q(p^0, p^t, y^0, y^t)/(c^t/c^0)] \\
& -[P^*(W^0, W^t, X^0, X^t)Q(P^0, P^t, Y^0, Y^t)/(C^t/C^0)] \qquad (14) \\
= \; & [Q(p^0, p^t, y^0, y^t)Q^*(w^0, w^t, x^0, x^t)] - [Q(P^0, P^t, Y^0, Y^t)/Q^*(W^0, W^t, X^0, X^t)] \qquad (15)
\end{aligned}
$$

where the equality between (14) and (15) follows from the equality between (5) and (6). Equation (15) shows that $I^7$ is equal to the difference between the target firm's productivity growth and the industry's productivity growth. Equation (14) shows that $I^7$ is also equal to a weighted difference between the target firm's and the industry's growth in unit cost (reciprocated). The target firm's weight term is its own input price index, and the industry's weight term is also its own input price index. The target firm is supposed to maximize $I^7$.

A comparison of $I^3$ defined by (9) reveals that $I^7$ is just $I^3$ except that the productivity offset term $\beta^t$ in $I^3$ has been replaced by the industry productivity growth rate.

The advantages associated with the use of $I^7$ include: (i) the indicator adjusts for exogenous changes in input prices, and (ii) the problem of choosing an *a priori* productivity offset term, $\beta^t$, is avoided. Some disadvantages include: (i) complete sets of price and quantity data for inputs and outputs are required for both the target firm and the industry; (ii) the target firm is exposed to more risk when $I^7$ is used rather than $I^3$, since in $I^7$ the fixed productivity offset term has been replaced by the *a priori* unknown and variable industry productivity growth rate; and (iii) there is little incentive for the target firm to search diligently for lower priced inputs.

Now consider the following counterpart to $I^4$ defined above by (10):

$$
I^8 \equiv [P^*(W^0, W^t, X^0, X^t)Q(p^0, p^t, y^0, y^t)/(c^t/c^0)] - [Q(P^0, P^t, Y^0, Y^t)/Q^*(W^0, W^t, X^0, X^t)] \qquad (16)
$$

Thus $I^8$ is essentially $I^4$, except that the productivity offset term $\beta^t$ has been replaced by the industry productivity growth rate.

This incentive index shares the same advantages and disadvantages as $I^4$, except that $I^8$ is risker than $I^4$ for the target firm since the old fixed productivity offset term has been replaced by the *a priori* unknown variable industry productivity growth rate.

If output prices are set by the regulator and the target firm has to supply whatever quantities of output $y^t$ are demanded at the prices $p^t$, then $Q(p^0, p^t, y^0, y^t)$ is essentially an exogenous term to the firm. Furthermore, indexes depending on industry input and output prices and quantities can also be regarded as exogenous terms to the regulated firm. Thus all terms in the definition of $I^8$ are exogenous to the target firm, except the term $1/c^t$. Since the target firm is supposed to maximize $I^8$, the firm will have an incentive to minimize $c^t$. The other indexes which possess this highly desirable incentive to minimize costs are: $I^1$ defined by (7), $I^4$ defined by (10), and $I^6$ defined by (12).

We now replace the exogenous industry input price index, $P^*(W^0, W^t, X^0, X^t)$, by the semiexogenous industry input price index that uses target firm quantity weights, $P^*(W^0, W^t, x^0, x^t)$ and get:

$$I^9 \equiv [P^*(W^0, W^t, x^0, x^t)Q(p^0, p^t, y^0, y^t)/(c^t/c^0)] - [Q(P^0, P^t, Y^0, Y^t)/Q^*(W^0, W^t, X^0, X^t)]. \tag{17}$$

Alternatively, we can view $I^9$ as being equal to $I^5$ defined by (11) above, except that the exogenous productivity offset term $\beta^t$ has been replaced by the industry productivity growth rate, $Q(P^0, P^t, Y^0, Y^t)/Q^*(W^0, W^t, X^0, X^t)$. Thus the target firm should perceive $I^9$ to be risker than $I^5$. The target firm should also view $I^9$ as being less risky than $I^8$. In general, $I^9$ and $I^5$ share the same advantages. Unfortunately, neither of these indexes have the period $t$ cost minimization incentive that $I^1$, $I^4$, $I^6$ and $I^8$ possess.

# 5 Combating Strategic Behaviour

The potential problems with regulated firms behaving in a strategic fashion to increase profits, (and the resulting adverse welfare effects), are well known (Sappington 1980; Hagerman 1990). Hence the design of any incentive scheme must consider the possibility that firms may behave in a way which is not intended by the regulator. In this section, we derive an "intertemporally ideal" incentive plan in order to remove any potential benefit for regulated firms from manipulating the above incentive indexes over time.

The incentive indexes presented above compare the target firm's performance in a single period $t$ with its performance in a base period 0. For incentive schemes that cover several accounting periods, some new problems arise which are related to a problem which we have not yet discussed: how should the numerical value of the incentive index be mapped into a specific reward or bonus for the target firm?

If the target firm is rewarded only for good performance but not penalized for bad performance, then the following problem could arise in the multiple period context; the target firm does well in the first period, does poorly in the second period, does well in the third period, and so on. Under these conditions, the target firm could earn a substantial bonus for a very mediocre average performance. This is the *cycling problem* discussed by Sappington (1992).[4]

More generally, suppose the target firm has the ability to defer costs from one period to the next (at an interest penalty). Then it would be very desirable to have an intertemporal, multi-period performance indicator that remained invariant to these strategic shifts in costs.[5] This invariance can be achieved if the firm's reward function is proportional to the firm's stream of discounted costs.

A second reason for wanting the target firm's reward function to be proportional to discounted costs is that under these conditions, the target firm will have an incentive to undertake more rational long term investment decisions. Finally, competitive firms always have an incentive to minimize discounted costs. Thus under a proportional-to-discounted-

[4]See Richardson and Wilkie (1986) for an example of similar strategic behaviour, but in the context of export subsidies.

[5]Mark Reeder, Chief of Regulatory Economics for the New York Public Service Commission, suggested this property for an incentive plan. We can note that under the Incremental Surplus Subsidy (ISS) mechanism of Sappington and Sibley (1988), firms never have the incentive to incur purely wasteful expenditures. See Lyon (1996) for a comparison of the ISS mechanism with Hagerman's (1990) version of the Vogelsang-Finsinger (1979) mechanism.

costs incentive plan, the target firm will be induced to behave more like a competitive firm.

In previous sections, we considered the merits and demerits of various incentive indexes that applied to the performance of the firm for only a single period $t$. Suppose that we want to use these single period indexes in order to construct a multiple period incentive index that will give the target firm an inducement to minimize discounted costs. Then obviously, we must restrict our attention to single period indexes that give the target firm a clear incentive to minimize period $t$ costs. Four such indexes have been considered: $I^1$ defined by (7); $I^4$ defined by (10); $I^6$ defined by (12); and $I^8$ defined by (16). $I^1$ and $I^6$ were to be minimized and $I^4$ and $I^8$ were to be maximized. We did not consider $I^1$ favourably because it makes no allowance for exogenous changes in the input prices that a firm might face. This leaves us with three acceptable one-period incentive indexes that seem reasonable and provide an incentive for the target firm to minimize period $t$ costs.

We now transform each of the incentive indexes $I^4$, $I^6$ and $I^8$ into a *standard form*, which has the mathematical structure $a^t - b^t c^t$ where $a^t$ and $b^t$ are positive constants (that do not depend on the period $t$ actions of the target firm) and $c^t$ is the period $t$ total cost for the target firm. By cross multiplying terms in $I^4$, $I^6$ and $I^8$, we obtain the following transformed standard-form one-period incentive indexes, $I^{t4}$, $I^{t6}$ and $I^{t8}$:

$$\begin{aligned} I^{t4} &\equiv \frac{P^*(W^0, W^t, X^0, X^t) Q(p^0, p^t, y^0, y^t)}{\beta^t} - \frac{c^t}{c^0} \\ &\equiv a_4^t - b_4^t c^t; \qquad (18) \\ I^{t6} &\equiv \frac{C^t}{C^0} \frac{Q(p^0, p^t, y^0, y^t)}{Q(P^0, P^t, Y^0, Y^t)} - \frac{c^t}{c^0} \\ &\equiv a_6^t - b_6^t c^t; \qquad (19) \\ I^{t8} &\equiv \frac{P^*(W^0, W^t, X^0, X^t) Q^*(W^0, W^t, X^0, X^t) Q(p^0, p^t, y^0, y^t)}{Q(P^0, P^t, Y^0, Y^t)} - \frac{c^t}{c^0} \\ &\equiv a_8^t - b_8^t c^t. \qquad (20) \end{aligned}$$

Recall that lower case variables signify target firm data while upper case variables signify data pertaining to the industry (excluding the target firm). Using (3) applied to industry data, we have

$$P^*(W^0, W^t, X^0, X^t) Q^*(W^0, W^t, X^0, X^t) = C^t / C^0. \qquad (21)$$

Using (21), it can be seen that $I^{t6} = I^{t8}$. Hence out of all of the one period incentive indexes that we have considered, there are only two acceptable standard-form incentive indexes that are reasonable and have the period $t$ cost minimization property: $I^{t4}$ and $I^{t6}$.

Now consider a generic standard-form incentive index for period $t$:

$$I^t \equiv a^t - b^t c^t, \qquad a^t > 0,\, b^t > 0 \tag{22}$$

where $a^t$ and $b^t$ are constants which do not depend on the actions of the target firm for periods $t = 1, 2, \ldots, T$. Note that we allow $a^t$ and $b^t$ to depend on the target firm's actions prior to period 1. We assume that the multi-period incentive plan starts in period 1 and lasts until period $T$. Let the *period $t$ reward* for the target firm, $R^t$, be proportional to the standard-form period $t$ incentive index, $I^t$; i.e., we have

$$R^t \equiv RI^t = R(a^t - b^t c^t) \quad \text{where } R > 0. \tag{23}$$

Note that the period $t$ reward for the target firm, $R^t$, will increase if $c^t$ is decreased when $R^t$ is defined by (22) and (23). Note also that $R^t$ could be negative or positive, depending on the behaviour of $c^t$, the target firm's total cost for period $t$.

We can now prove the following very useful result.

**Result 2** *If the target firm has a period $t$ reward function defined by (22) and (23), then the target firm will have an incentive to minimize the discounted sum of costs over the lifetime of the incentive plan if and only if the parameters $b^t$ do not vary with $t$; i.e., if and only if we have*

$$b^t = b > 0 \quad \textit{for } t = 1, 2, \ldots, T. \tag{24}$$

To see why this result is true, assume that (24) holds and consider the interest-rate-indexed sum of the rewards that the firm would have at the end of the plan (where $r^t$ is the end-of-period $t$ interest rate):

$$\begin{aligned} &R^1(1+r^1)(1+r^2)\ldots(1+r^{T-1}) + R^2(1+r^2)\ldots(1+r^{t-1}) + \ldots + R^T \\ &= R[a^1(1+r^1)(1+r^2)\ldots(1+r^{t-1}) + a^2(1+r^2)\ldots(1+r^{t-1}) + \ldots + a^T] \\ &-Rb[c^1(1+r^1)(1+r^2)\ldots(1+r^{T-1}) + c^2(1+r^2)\ldots(1+r^{T-1}) + \ldots + c^T]. \end{aligned} \tag{25}$$

To find the target firm's discounted sum of rewards, divide both sides of (25) by $(1+r^1)(1+r^2)\ldots(1+r^{T-1})$. The resulting right hand side of the transformed equation (25) is equal to a constant plus the term

$$-Rb[c^1+(1+r^1)^{-1}c^2+\ldots+(1+r^1)^{-1}(1+r^2)^{-1}\ldots(1+r^{T-1})^{-1}c^T] \tag{26}$$

which is $-Rb$ times discounted costs over the lifetime of the plan. Thus if (24) holds, the target firm will have a clear incentive to minimize the sum of discounted costs over the lifetime of the incentive plan. Conversely, if (24) does not hold, then under the incentive plan defined by (23), the target firm will not have a clear incentive to minimize the sum of discounted costs.

If (24) does hold, then it can be verified that it will be fruitless for the target firm to, say, defer some costs from period 1 to period 2, provided that the interest penalty that the firm has to pay to its suppliers for these cost deferrals uses the same interest rate $r^1$ that appears in (25). Thus reward schemes of the form defined by (22)–(24) are *invariant to* (interest rate adjusted) *shifts in costs.* In addition, incentive plans of this type *provide the target firm with a clear incentive to minimize discounted costs* over the lifetime of the plan. Let us call a multi-period incentive plan that has these two properties an *intertemporally ideal incentive plan.*

Note that $b_4^t$ defined in (18) and $b_6^t$ defined in (19) are both equal to $1/c^0$, which is a constant independent of $t$. Hence using the standard-form incentive functions $I^{t4}$ defined by (18) or $I^{t6}$ defined by (19) as the $I^t$ in the period $t$ reward function defined by (23) will lead to intertemporally ideal incentive plans.

If the period $t$ reward function $R^t$ is defined by (22)–(24), then to ensure that the resulting incentive plan is intertemporally ideal, it will be necessary for the regulator to take away any excess profits that might be earned by the target firm in period $t$ that are additional to the allowable amount of excess profits, $R^t$. These excess profits would be returned to consumers as rebates that would be proportional to their period $t$ bills.[6] On the other hand, if the

[6]Alternatively, the regulator could keep these excess profits in an interest bearing account. These funds could then be used to help offset target firm deficits that might occur in subsequent periods.

regulator had set output prices for the target firm too low in period $t$ so that firm revenues were less than costs $c^t$ plus the reward $R^t$, then output prices would have to be raised in the following period so that the revenue shortfall could be recovered.

We note that an intertemporally ideal incentive plan based on the period $t$ reward function defined by (23), where $I^t$ is defined by (18) or (19) could expose the target firm to a considerable amount of financial risk if the productivity parameters $\beta^t$ in (18) were chosen to be too large or if industry costs $C^t$ in (19) turned out to be unusually low. This risk can be limited by modifying the plan as follows. If the reward in period 1 is positive (i.e., $R^1 > 0$), then the target firm receives this reward at the end of period 1. If $R^1 < 0$, then the target firm is *not* penalized by the amount $R^1$ at the end of period 1. However, the period 1 penalty is interest rate adjusted and carried forward as an offset to the period 2 reward $R^2$. Thus if $R^1(1 + r^1) + R^2 > 0$, then this amount is paid out as a net reward covering the performance of the target firm for the first two periods of the plan. However, if $R^1(1 + r^1) + R^2 < 0$, then the target firm gets no reward and pays no penalty at the end of period 2, but $R^1(1 + r^1)(1 + r^2) + R^2(1 + r^2)$ is carried forward as a negative offset to the period 3 reward, $R^3$, and so on. The net effect of these adjustments is that the target firm will never have to pay a penalty and hence will always earn at least a safe rate of return on its invested capital. Unfortunately, the resulting modified incentive plan will no longer be intertemporally ideal: the target firm could defer costs from the first period into later periods and perhaps earn a large period 1 reward which it would keep even though its performance in subsequent periods was so bad that in an intertemporally ideal plan, the target firm would be forced to pay back the first period reward. However, in the modified plan, the target firm could only play the above cost deferral game *once* in order to obtain a temporary advantage.[7] Thus we might call our modified plan an *almost intertemporally ideal incentive plan*.

[7]To use Sappington's (1992) terminology, the cycling problem would be limited to only one push of the pedals.

# 6 Implementation

We now turn to issues relating to the practical implementation of the suggested theoretical incentive indexes. We have yet to discuss the choice of the price and quantity index formulae for the theoretical indexes, $P(\cdot)$ and $Q(\cdot)$, introduced in section 2. There are many possible choices, so we turn to the literature on the "economic approach" to index numbers, and systematically present results which can guide us in this choice. The next section demonstrates that there is a strong case here for the use of the Fisher (1922) ideal index, rather than the Laspeyres index which is commonly used in the incentive regulation literature, (e.g., in Vogelsang-Finsinger-type plans: Vogelsang and Finsinger (1979), and Hagerman (1990)). This then gives us a solid theoretical basis on which construct our empirical incentive indexes. However, there remain some practical problems with generating actual incentive indexes, such as how to take into account the existence of durable assets, and the possibility of there being a large number of outputs or new outputs. These issues are addressed in section 6.2.

## 6.1 Choice of Index-Number Formula

Examples of commonly used functional forms for a price index are the Laspeyres price index, $P_L$, the Paasche price index, $P_P$, the Fisher ideal index, $P_F$, and the Törnqvist price index, $P_T$:

$$
\begin{aligned}
P_L(P^0, p^t, y^0, y^t) &\equiv p^t \cdot y^0 / p^0 \cdot y^0; && (27)\\
P_P(p^0, p^t, y^0, y^t) &\equiv p^t \cdot y^t / p^0 \cdot y^t; && (28)\\
P_F(p^0, p^t, y^0, y^t) &\equiv (P_L \cdot P_P)^{1/2}; && (29)\\
\ln P_T(p^0, p^t, y^0, y^t) &\equiv \sum_{m=1}^{M} (1/2)(s_m^0 + s_m^t) \ln(p_m^t / p_m^0), && (30)
\end{aligned}
$$

where $s_m^0 \equiv p_m^0 / y_m^0 / p^0 \cdot y^0$ and $s_m^t \equiv p_m^t y_m^t / p^t \cdot y^t$ are the revenue shares for output $m$ for periods 0 and $t$ respectively. Note that the Fisher ideal price index is the square root of the product of the Laspeyres and Paasche price indexes.

From the following conservation of value property, we can deduce the corresponding quantity index for each of the above price indexes:

$$P(P^0, p^t, y^0, y^t)Q(P^0, p^t, y^0, y^t) = p^t \cdot y^t / p^0 \cdot y^0, \tag{31}$$

so then

$$Q(p^0, p^t, y^0, y^t) = p^t \cdot y^t / (p^0 \cdot y^0 P(p^0, p^t, y^0, y^t)). \tag{32}$$

Substituting each of $P_L$, $P_P$ and $P_F$ into (32) we get the following quantity indexes respectively:

$$Q_P(p^0, p^t, y^0, y^t) \equiv p^t \cdot y^t / p^t \cdot y^0; \tag{33}$$

$$Q_L(p^0, p^t, y^0, y^t) \equiv p^0 \cdot y^t / p^0 \cdot y^0; \tag{34}$$

$$Q_F(p^0, p^t, y^0, y^t) \equiv (Q_P \cdot Q_L)^{1/2}. \tag{35}$$

The quantity index $\tilde{Q}_T$ that corresponds to the price index $P_T$ is known as the implicit Törnquist quantity index. Input price and quantity indexes can take the same forms as those given above for the output price and quantity indexes.

There are two generally accepted approaches to the problem of choosing between these alternative functional forms for the price and quantity indexes to be used in implementing the suggested incentive indexes. They are (i) the *test* or *axiomatic* approach, and (ii) the *economic* approach. Diewert (1992) showed that $P_F$ is the only price index that satisfies twenty reasonable tests, or properties, that could be expected of a price index. Therefore, from the viewpoint of the test or axiomatic approach to index-number theory, the choice of the Fisher ideal index seems best. Given that we are interested in the economic behaviour of regulated firms, we also consider the choice of index-number formula from the economic approach.

Practical economic approaches to the index-number problem rely on the assumption of optimizing behaviour on the part of the firm. For example, if the firm is minimizing cost in each period, then the period $t$ observed cost, $c^t = w^t \cdot x^t$, will be equal to the firm's period $t$ cost function, $C^t(y^t, w^t)$ evaluated at the period $t$ output vector produced by the firm, $y^t$, and at the period $t$ input prices, $w^t$, faced by the firm; i.e., we will have

$$w^t \cdot x^t = C^t(y^t, w^t). \tag{36}$$

The period $t$ cost function, $C^t$, is defined using the firm's period $t$ technology set, $S^t$, which is the set of feasible output vectors, $y$, that the firm can produce in period $t$ using nonnegative input vectors, $x$. More formally, the firm's period $t$ cost function is defined for all feasible output vectors, $y$, and positive input price vectors, $w$, as follows:

$$C^t(y, w) \equiv \min_x \{w \cdot x : (x, y) \quad \text{belongs to } S^t\}. \tag{37}$$

The period $t$ cost function, the observed period $t$ output vector, $y^t$, and the observed period 0 and period $t$ input price vectors, $w^0$ and $w^t$, can be used to define the following economic input price index, $P^{*t}$:

$$P^{*t}(w^0, w^t) \equiv C^t(y^t, w^t)/C^t(y^t, w^0). \tag{38}$$

Thus $P^{*t}$ is equal to the ratio of two minimum costs using the period $t$ technology and the period $t$ output vector, $y^t$. Note that on the right hand side of (38), the input prices which appear in the numerator cost function are the period $t$ input prices $w^t \equiv (w_1^t, \ldots, w_N^t)$ and the input prices which appear in the denominator cost function are the period 0 input prices $w^0 \equiv (w_1^0, \ldots, w_N^0)$.

Instead of using the period $t$ cost function (which is based on the period $t$ technology set, $S^t$) and the period $t$ observed output vector, we could define an analogous input price index, $P^{*0}$, using the period 0 cost function (which is based on the period 0 technology set $S^0$), and the period 0 observed output vector:

$$P^{*0}(w^0, w^t) \equiv C^0(y^0, w^t)/C^0(y^0, w^0). \tag{39}$$

Unfortunately, when the number of inputs, $N$, is greater than one, $P^{*t}(w^0, w^t)$ cannot be evaluated precisely without a knowledge of the firm's period $t$ cost function (or equivalently, without a knowledge of the firm's period $t$ technology set). Similarly, when $N$ exceeds one,

$P^{*0}(w^0, w^t)$ cannot be evaluated without a knowledge of the firm's period 0 cost function. However, it is possible to develop bounds for the economic indexes defined by (38) and (39).

Assume that there is cost minimizing behaviour on the part of the firm in period $t$ so that (36) holds. Now consider the cost minimization problem that defines $C^t(y^t, w^0)$:

$$\begin{aligned} C^t(y^t, w^0) &\equiv \min_x \left\{ w^0 \cdot x : (x, y^t) \quad \text{belongs to } S^t \right\} \\ &\leq w^0 \cdot x^t \end{aligned} \tag{40}$$

where the inequality in (40) follows from the fact that $x^t$ is a feasible (but not necessarily optimal) solution to the cost minimization problem in (40). Assuming that costs are positive, we may rewrite (40) as follows:

$$1/C^t(y^t, w^0) \geq 1/w^0 \cdot x^t. \tag{41}$$

Now substitute (36) and (41) into the right hand side of (38), and we obtain the following inequality:

$$P^{*t}(w^0, w^t) \geq w^t \cdot x^t / w^0 \cdot x^t; \tag{42}$$

i.e., the unobservable economic input price index $P^{*t}(w^0, w^t)$ is bounded from below by the observable Paasche input price index, $w^t \cdot x^t / w^0 \cdot x^t$.

Now assume that there is cost minimizing behaviour on the part of the firm in period 0 so that

$$w^0 \cdot x^0 = C^0(y^0, w^0). \tag{43}$$

Hence $(x^0, y^0)$ belongs to the period 0 technology $S^0$. Consider the cost minimization problem that defines $C^0(y^0, w^t)$:

$$\begin{aligned} C^0(y^0, w^t) &\equiv \min_x \left\{ w^t \cdot x : (x, y^0) \quad \text{belongs to } S^0 \right\} \\ &\leq w^t \cdot x^0 \end{aligned} \tag{44}$$

where the inequality in (44) follows from the fact that $x^0$ is a feasible (but not necessarily optimal) solution to the cost minimization problem in (44). Now substitute (43) and (44) into the right hand side of (39) and we obtain the following inequality:

$$P^{*0}(w^0, w^t) \leq w^t \cdot x^0 / w^0 \cdot x^0; \tag{45}$$

i.e., the unobservable economic input price index $P^{*0}(w^0, w^t)$ is bounded from above by the observable Laspeyres input price index, $w^t \cdot x^0 / w^0 \cdot x^0$.

The inequalities (42) and (45) indicate that the Paasche and Laspeyres input price indexes are generally *biased* compared to various theoretical economic input price indexes. These biases are called *substitution biases* and are exactly analogous to the substitution biases that occur in the consumer context when Paasche or Laspeyres consumer price indexes are used to approximate a true cost of living index. Thus from the viewpoint of the economic approach to index-number theory, it seems inappropriate to use either the Paasche or Laspeyres functional forms.

It can be shown that a theoretical economic input price index exists such that this economic index will lie between the Paasche and Laspeyres input price indexes.[8] Since the Fisher ideal input price index, $P_F^* \equiv (P_L^* P_P^*)^{1/2}$, is the geometric mean of the Paasche and Laspeyres input price indexes, it should provide an approximation to an underlying theoretical input price index which is known to lie between $P_L^*$ and $P_P^*$. An analogous argument establishes that $P_L$ and $P_P$, defined by (27) and (28), are generally biased estimators for economic output price indexes and that the Fisher ideal output price index defined by (29) will generally provide a closer approximation to an underlying (unobservable) economic price index.

Thus strong justifications for the use of Fisher ideal indexes can be provided from the point of view of the economic approach as well as the axiomatic approach.[9]

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[8]The proof is analogous to the proof of Theorem 3 in Diewert (1983, 1060) except that the role of inputs and outputs is reversed and the cost function replaces the profit function.

[9]The Törnquist index can also be given a strong justification from the viewpoint of the economic approach (Diewert 1976, 122)(1983, 1062); Caves, Christensen and Diewert (1982, 1393)), and empirically it may not differ much from the Fisher ideal index (Diewert 1978, 888). But as noted earlier, the Fisher index has a stronger axiomatic justification.

## 6.2 Some Practical Difficulties

It may be difficult to evaluate the output price and quantity if the number of outputs ($M$) is large and it may be difficult to evaluate the input price and quantity indexes if the number of inputs ($N$) is large. In principle, detailed data on output prices and quantities are available somewhere in the firm's billing and accounting system. However, in the case of input price and quantity data, the situation is quite different. Somewhere in the firm's accounting system, the purchase of each input will be recorded, but there is no necessity for the firm to decompose this individual purchase cost into separate price and quantity components. There are a number of ways of dealing with this difficulty: (i) some quantity information may be available from various data bases other than purchases; (ii) prices could be sampled for various input categories; and (iii) external price indexes could be used to deflate various categories of input cost.

An additional problem with calculating price and quantity indexes arises when a new output is supplied in period $t$ that was not supplied in period 0, or when a new input is utilized in period $t$ that was not utilized in period 0. In both cases, the quantity of the new good for period 0 can be taken to be zero. However, from the viewpoint of the economic approach to index-number theory, the period 0 prices for the new goods should not be zero: in the case of an input, the "correct" price for the new goods should be that price which would just induce the firm to demand 0 units of the input in period 0 while in the case of an output, the "correct" price for the new good in period 0 is that shadow price which would just induce the firm to supply 0 units of that good.[10] Obviously, in the context of a regulated industry where the regulator sets output prices, this economic solution to the new goods problem may not make sense. Moreover, finding the correct shadow prices would involve a detailed econometric study for each new good which is too costly. Some methods used to tackle this problem are discussed in Hofsten (1952, 47–50) and Diewert (1980, 498–501),[11]

[10]Hicks (1940, 114) was the originator of this solution to the new goods problem. The case of disappearing goods is analogous.

[11]Diewert's (1980, 500) recommended method for dealing with this problem is to calculate the price index over the subset of goods that are present in both periods. The corresponding quantity index is defined to be

Feenstra (1994)(1997) and Hausman (1996)(1997)(1999).

Finally, the problem with calculating a price for a capital input is that the capital input lasts longer than one accounting period and hence the original purchase price of the asset should not be attributed entirely to the period of purchase. However, it is not clear how the original purchase price should be spread over the useful lifetime of the asset. For detailed discussions of the problems associated with measuring prices and quantities for capital inputs, see the excellent papers by Griliches (1988, 126–129) and Jorgenson (1989). See also Diewert and Lawrence (1999), and Diewert and Fox (1999).[12]

# 7 Conclusion

This paper has introduced and evaluated several incentive indexes for regulated firms. The variety of options offered to regulators was facilitated by a useful result which demonstrated the equivalence of three alternative theoretical performance concepts. Different incentive indexes can be based on these different concepts. This gives regulators some flexibility in their choice of incentive index as each proposed index has different data requirements and different advantages. Potential problems with firms manipulating the incentive indexes by intertemporal shifts of costs are also addressed through the introduction of an "intertemporally ideal incentive plan", which removes the potential benefits to the firms from strategic intertemporal behaviour.

Practical issues relating to the implementation of the proposed indexes are also discussed. While the Laspeyres index-number formula is commonly used in the regulation literature,

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the value ratio deflated by this restricted price index.

[12]We can note briefly that: (i) it appears that in at least some regulated industries (such as telecommunications), gross capital stocks grew considerably faster than net capital stocks over the last 20 years, so that productivity growth rates computed using the net capital concept will be larger than those obtained using the gross capital concept; (ii) under conditions of inflation, the use of historical rather than current cost accounting principles will tend to lead to lower period $T$ costs for a target firm if the target firm has an older capital stock compared to its peer group. See also Kendrick (1975) for a discussion of problems that arise in incentive schemes during periods of high inflation.

it is shown to be generally biased, as is the Paasche index. We argue that the Fisher ideal index formula is the most attractive formula for implementing theoretical incentive schemes in the presence of multiple outputs and/or multiple inputs. This result is not limited to the incentive indexes proposed in this paper, but is a general result. Issues relating to data definitions and other potential problems are also discussed briefly. These problems are not trivial given the reliance of the proposed incentive indexes on accurate data. As with other "high-powered" incentive schemes, large rents or losses may result if the data deviates markedly from the truth.[13] While these problems may be more relevant to some industries than others, they do not reduce the significance of the general ideas presented.

Several issues in incentive regulation have not been considered here as they are beyond the scope of the current paper — for example, optimal pricing (Spulber 1989, 159–251); (Brown and Sibley 1986); (Graaf 1957, 142–155); (Diewert 1990, 452–458). However, the incentive indexes and intertemporally ideal incentive plan introduced in this paper should be of considerable practical relevance for regulators.

[13]For more on the drawbacks of such schemes, see Schmalensee (1989).

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