Measurement Problems in Regulation

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1 INTRODUCTION

Regulation of business activity is required for at least two reasons:

- For health and safety reasons and
- For the prevention of monopolistic pricing behaviour.

Various forms of regulation have been developed to limit monopolistic pricing "abuses". The old style rate of return form of regulation suffered from incentive problems[1] and has been replaced by forms of regulation that are thought to induce more efficient firm behaviour.

Joskow and Schmalensee (1986) defined two classes of incentive type regulation schemes:

- *Comprehensive* schemes that induce efficient pricing decisions as well as efficient production decisions and
- *Partial* schemes that induce efficient or cost minimizing production decisions.

In both types of regulation, there are incentives for the regulated firm to either minimize *unit costs* or maximize *productivity gains*. In the case of a firm producing only one output, *unit cost* is defined as cost divided by the output produced during the period under consideration. In the case of a firm producing only one output and using only one input, *productivity* is defined as output produced divided by input used during the period. However, as soon as the regulated firm produces many outputs and uses many inputs, there is some ambiguity in deciding exactly how to define unit costs and productivity for the firm; i.e., we encounter (conceptual) *measurement problems* in the many output, many input case. These conceptual problems are rather technical and require some knowledge of index number theory so we will not deal with them in this paper.[2] However, in addition to these conceptual measurement problems, there are practical measurement problems associated with decomposing input and output value flows into their price and quantity components. We will address these practical measurement problems in section 2 below in the context of asking what data are required to measure the productivity performance of a regulated firm.

In section 3, we address some of the difficult conceptual problems involved in measuring service sector output prices and quantities.

Section 4 deals with some additional measurement problems that arise when the list of outputs being produced changes over time.

Section 5 concludes.

2 MEASURING PRODUCTIVITY GROWTH

In many forms of incentive regulation, it is necessary to compare the productivity growth performance of a regulated firm with the corresponding productivity growth performance of a peer group of firms. Alternatively, the performance of a particular regulated firm may be *benchmarked* with respect to a peer group of firms or production units. In either case, *detailed information on the*

[1] There is little incentive to minimize costs in rate of return regulation.
[2] These conceptual and index number issues are discussed in Diewert and Fox (2000).

prices and quantities of all inputs used and outputs produced by the target firm is required. In this section, we go through the major classes of inputs used and outputs produced by a "typical" regulated firm and note some of the measurement problems that face a regulatory agency when it attempts to construct productivity growth rates for the firms that it regulates.[3]

2.1 Gross Outputs

In order to measure the productivity of a firm, industry or economy, we need information on the outputs produced by the production unit for each time period in the sample along with the average price received by the production unit in each period for each of the outputs. In practice, period by period information on revenues received by the firm for a list of output categories is required along with either an output index or a price index for each output. In principle, the revenues received should not include any commodity taxes imposed on the industry's outputs, since producers in the industry do not receive these tax revenues. The above sentences sound very straightforward but many firms produce thousands of commodities so the aggregation difficulties are formidable. Moreover, many outputs in service sector industries are difficult to measure conceptually: think of the proliferation of telephone service plans and the difficulties involved in measuring insurance, gambling, banking and options trading.

2.2 Intermediate Inputs

Again, in principle, we require information on all the intermediate inputs utilised by the regulated firm for each time period in the sample along with the average price paid for each of the inputs. In practice, period by period information on costs paid by the firm for a list of intermediate input categories is required along with either an intermediate input quantity index or a price index for each category. In principle, the intermediate input costs paid should include any commodity taxes imposed on the intermediate inputs, since these tax costs are actually paid by producers in the industry.

The major classes of intermediate inputs at the industry level are:

- materials
- business services
- leased capital.

Firm accounts will typically list the value flows associated with the above classes of intermediate inputs but decomposing these value flows into price and quantity components is always difficult, since financial accounts are geared towards recording value flows and *not* price and quantity flows. Also, a sizable number of intermediate input purchases may be for unique services and hence it may be impossible to obtain a price and quantity decomposition that is stable from period to period. Often statistical agency price indexes will be used as proxies for the actual price index and these proxy indexes may be far from being accurate. There is also the problem of a lack of statistical

[3] See Schreyer (2001), Balk (2003) and Diewert and Nakamura (2003) for recent surveys on the measurement of Total Factor Productivity. The modern literature on this topic starts with Jorgenson and Griliches (1967). The first statistical agency productivity program was started by the Bureau of Labor Statistics (1983); see also Dean and Harper (2001). This section draws heavily on Diewert (2001).

agency price surveys for intermediate inputs: typically, a price index for an intermediate input class into some industry is approximated by an output price index, which may have a different mix of detailed products in it.

2.3 Labour Inputs

Using the number of employees as a measure of labour input into a regulated firm will not usually be a very accurate measure of labour input due to the possibility of changes in average hours worked per full time worker and possible changes in the use of part time workers. However, even total hours worked in the firm is not a satisfactory measure of labour input if the firm employs a mix of skilled and unskilled workers. Hours of work contributed by highly skilled workers generally contribute more to production than hours contributed by very unskilled workers. Hence, it is best to decompose aggregate labour compensation into its aggregate price and quantity components using index number theory.[4] The practical problem is: how should the various categories of labour be defined? There is no definitive answer to this question.

2.4 Reproducible Capital Inputs

When a firm purchases a durable capital input, it is not appropriate to allocate the entire purchase price as a cost to the initial period when the asset was purchased. It is necessary to distribute this initial purchase cost across the useful life of the asset. Financial accountants recognize this and use depreciation accounts to do this distribution of the initial cost over the life of the asset. However, historically, accountants are reluctant to recognize the interest tied up in the purchase of the asset as a true economic cost. This means that for productivity measurement purposes, the regulator will have to manipulate accounting data in order to construct user costs for capital components. These user costs are made up of three components: depreciation, interest tied up and anticipated asset price change over the accounting period. However, each of these components pose practical measurement problems. For example, which interest rate should be used?

- An ex post economy wide rate of return which is the alternative used by Christensen and Jorgenson (1969) (1970)?
- An ex post firm or sectoral rate of return? This method seems appropriate from the viewpoint of measuring ex post performance.
- An ex ante safe rate of return like a Federal Government one year bond rate? This method seems appropriate from the viewpoint of constructing ex ante user costs that could be used in econometric models.
- Or should the ex ante safe rate be adjusted for the risk of the firm or industry?

Since the ex ante user cost concept is not observable, the regulator will have to make somewhat arbitrary decisions in order to construct expected capital gains.[5] This is a strong disadvantage of the ex ante concept. On the other hand, the use of the ex post concept will lead to rather large

[4] The current SNA recommends a wage index to deflate employee compensation; see Eurostat (1993).

[5] Alternatively, the regulatory agency could combine the nominal interest rate term in the user cost formula with the expected capital (or holding) gains term and simply assume a real interest rate.

fluctuations in user costs, which in some cases will lead to negative user costs, which in turn may be hard to explain to interested parties. However, a negative user cost simply indicates that instead of the asset declining in value over the period of use, it rose in value to a sufficient extent to offset deterioration. Hence, instead of the asset being an input cost to the economy during the period, it becomes an intertemporal output. This makes sense from the ex post point of view but not from the ex ante point of view. Thus it is necessary to be clear whether an ex ante or ex post user cost should appear in the productivity accounts.[6]

A further complication is that our empirical information on the actual efficiency decline of assets is weak. We do not have good information on the useful lives of assets. The UK statistician assumes machinery and equipment in manufacturing lasts on average 26 years while the Japanese statistician assumes machinery and equipment in manufacturing lasts on average 11 years; see the OECD (1993; 13).

A final set of problems associated with the construction of user costs is the treatment of business income taxes: should we assume firms are as clever as Hall and Jorgenson (1967) and can work out their rather complex tax–adjusted user costs of capital or should we go to the accounting literature and allocate capital taxes in the rather unsophisticated ways that are suggested there?

2.5 Inventories

Because interest is not a cost of production in financial accounting and the depreciation rate for inventories is close to zero, many productivity studies neglect the user cost of inventories. This leads to misleading productivity statistics for industries where inventories are large relative to output, such as retailing and wholesaling. In particular, rates of return that are computed neglecting inventories will be too high since the opportunity cost of capital that is tied up in holding the beginning of the period stocks of inventories is neglected.

The problems involved in accounting for inventories are complicated by the way accountants and the tax authorities treat inventories. These accounting treatments of inventories are problematic in periods of high or moderate inflation. A treatment of inventories that is suitable for productivity measurement can be found in Diewert and Smith (1994).

2.6 Land

The cash flow and income accounts in the current system of financial accounts has no role for land as a factor of production, perhaps because it is thought that the quantity of land in use remains roughly constant across time and hence it can be treated as a fixed, unchanging factor in the analysis of production. However, the quantity of land in use by any particular firm or industry does change over time. Moreover, the price of land can change dramatically over time and thus the user cost of land will also change over time and this changing user cost will, in general, affect correctly measured productivity.

Land ties up capital just like inventories (both are zero depreciation assets). Hence, when computing ex post rates of return earned by a production unit, it is important to account for the

[6] Our preference is for the ex ante user cost concept to be used in the productivity accounts. Actual capital gains on assets could appear in the balance sheet accounts.

opportunity cost of capital tied up in land. Neglect of this factor can lead to biased rates of return on financial capital employed. Thus, industry rates of return and TFP estimates may not be accurate for sectors like agriculture which are land intensive.

Finally, property taxes that fall on land must be included as part of the user cost of land. In general, it may not be easy to separate the land part of property taxes from the structures part.

It should be noted that the TFP programs in the U.S., Canada and Australia all recognize the need to have land and inventories in their measures as inputs and they work out user costs for these inputs.

2.7 Resources

Examples of resource inputs include:

- depletion of fishing stocks, forests, mines and oil wells
- improvement of air, land or water environmental quality (these are resource "outputs" if improvements have taken place and are resource "inputs" if degradation has occurred).

The correct prices for resource depletion inputs are the gross rents (including resource taxes) that these factors of production earn. Resource rents are usually not linked up with the depletion of resource stocks in financial accounts or in the national accounts although some countries, including the U.S. and Canada, are developing statistics for forest, mining and oil depletion; see Nordhaus and Kokkelenberg (1999).

The pricing of environmental inputs or outputs is much more difficult. From the viewpoint of traditional productivity analysis based on shifts in the production function, the 'correct' environmental quality prices are marginal rates of transformation while, from a consumer welfare point of view, the 'correct' prices are marginal rates of substitution; see Gollop and Swinand (2001). Needless to say, there are many difficulties involved in estimating these environmental prices.

The above seven major classes of inputs and outputs represent a minimal classification scheme for organizing information to measure TFP at the sectoral level. Unfortunately, financial accounts typically do not provide satisfactory price and quantity information on all seven of these classes of outputs and inputs. It should be recognized that constructing a firm database that will support the accurate measurement of firm productivity for regulatory or benchmarking purposes is a nontrivial exercise!

We now turn to a discussion of some of the difficulties that are involved in constructing prices and quantities for service sector outputs.

3 THE PROBLEMS ASSOCIATED WITH THE MEASUREMENT SERVICE SECTOR OUTPUTS

We use developments in North America to illustrate some of the difficulties involved in measuring service prices.[7] In the North American Industrial Classification System, there are some 926 NAICS 6-digit industries. Of these, 381 are goods industries. The remaining 545 service sector industries

[7] The difficulties involved in measuring service sector output prices were stressed by Griliches (1992) (1994).

break down as follows:

- Public administration (29 industries).
- Religious, grant-making, civic and professional service industries (10 industries).
- Education, health and social assistance industries (49 industries).
- Wholesale and retail trade (147 industries).
- Transportation (51 industries).
- Services 1 (Communication Services consisting of 37 industries), including postal and courier services, warehousing, periodicals and books, software publishers, movies, music, radio and television, telecommunications, news and data processing.
- Services 2 (Business Services consisting of 98 industries) including property leasing, real estate management, car and other rental and leasing, lawyers, accountants, architectural engineering, drafting, design and similar business services, computer services, administrative services, consulting and R&D services, advertising, photography, veterinary services, head office services, employment agencies, telephone call centres, collection agencies, travel agencies, security services, janitorial and cleaning services, and waste collection and disposal services.
- Services 3, (Personal Services consisting of 79 industries), including performing arts, professional sports, museums, parks, zoos, gambling, sports facilities, hotels and other accommodation, food services, drinking places, auto repair, car washes, equipment maintenance and repair, barber shops and beauty salons, funeral homes, laundries, pet care, photo finishing and parking lots.
- Finance and insurance, (45 industries), including the Bank of Canada, banking and related services, brokerages, exchanges, investment advice, accident, property and life insurance agencies, brokerages and carriers, pension funds and other financial services.

Some of the above industries have outputs that seem fairly straightforward to price. Statistics Canada has very rough and ready price indexes for the wholesale and retail trade industries (147 industries)[8] and more accurate price indexes for the 51 transportation industries.[9] Statistics Canada also has approximately 60 indexes from the Consumer Price Index that it uses to deflate the outputs of some of the remaining service sector industries. *This leaves about 290 industries for which we have no deflator at present*. The reader is invited to think about how he or she would formalize price concepts for the outputs of these 290 industries!

Now it is not entirely Statistics Canada's fault that many service industries do not have specific price indexes. The problem is partly the fault of academics! *The outputs of many service sector industries are extremely difficult to measure in a manner that will command general acceptance*. Hence, this would seem to be a natural area for academics to enter and develop methodologies for measuring these difficult to measure outputs. However, with a few exceptions, this has not happened.

[88] A detailed methodology for pricing the outputs and intermediate inputs of a distribution firm can be found in Diewert and Smith (1994).

[9] The methodology for measuring the prices of transportation outputs is generally well developed.

We conclude this section by commenting on some general categories of difficult to measure service products (the categories overlap).

- *Unique products*. That is, in different periods, different products are produced. This prevents routine matching of prices. This is a pervasive problem in the measurement of the prices of services.
- *Complex products*. Many service products are very complicated; e.g., telephone service plans.
- *Tied products*. Many service products are bundled together and offered as a single unit; e.g., newspapers, cablevision plans, banking services packages. In principle, hedonic regression techniques could be used to price out these first three types of service products.
- *Joint products*. For this type of product, the value depends partially on the characteristics of the purchaser; e.g., the value of a year of education depends not only on the characteristics of the school and its teachers but also on the social and genetic characteristics of the student population.
- *Marketing and advertising products*. This class of service sector outputs is dedicated to influencing or informing consumers about their tastes. A standard economic paradigm for this type of product has not yet emerged.
- *Heavily subsidized products*. In the limit, subsidized products can be supplied to consumers free of (explicit) charges. Is zero the "right" price for this type of product?
- *Financial products*. What is the "correct" real price of a household's monetary deposits? Somewhat surprisingly, this question has not yet been resolved in a definitive manner.
- *Products involving risk and uncertainty*. What is the correct pricing concept for gambling and insurance expenditures? What is the correct price for a movie or a record original when it is initially released?

Our conclusion here is that regulators of service sector industries face some difficult challenges in implementing theoretical incentive schemes for their industries. Virtually all of these incentive schemes assume that it is straightforward to measure costs and outputs for the regulated firms but as we have seen from the above material, this may not be the case. Thus the outcomes of regulation may be very much affected by the particular output and input price measures that are used by the regulated firms and the regulator.

3.1 Measuring Output in Network Industries

The main challenge in calculating productivity for a network business is the specification of exactly what the network's outputs are and how to measure the quantity and value of each of them. Take the example of electricity distribution, for instance. Distribution output can be measured from either a 'supply side' or a 'demand side' perspective. At the simplest level, the output would be the amount of energy 'throughput' and its value would be the distributor's total revenue. This approach essentially treats the distribution system in an analogous fashion to a pipeline and was a common approach of early studies of electricity distribution using TFP or other comprehensive indicators. It simply concentrates on the demand for the final product delivered by the distribution network.

However, there are other important dimensions to a distributor's output that need to be taken into account. These include the reliability and quality as well as the quantity of the electricity supply and the coverage and capacity of the system (ie the fact that the system is there to meet the highest potential peak as well as actual day to day demand).

A number of distributor representatives in Australia have drawn the analogy between an electricity distribution system and a road network. The distributor has the responsibility of providing the 'road' and keeping it in good condition but it has little, if any, control over the amount of 'traffic' that goes down the road. Consequently, they argue it is inappropriate to measure the output of the distributor by a volume of sales or 'traffic' type measure. Rather, the distributor's output should be measured by the availability of the infrastructure it has provided and the condition in which it has maintained it – essentially a supply side measure.

This way of viewing the output of a network industry can be extended to a number of public utilities. For instance, a number of analysts have measured the output of public transport providers using both a 'supply side' and a 'demand side' measure of output. The supply side measure of a passenger train system, for instance, would be measured by the number of seat kilometres the system provides while the demand side output would be measured by the number of passenger kilometres. In the case of public transport this distinction is often drawn because suppliers are required to provide transport for community service obligation and other non–commercial reasons. Using the supply side measure looks at how efficient the supplier has been in providing the service required of it without disadvantaging the supplier as happens with the demand side measure because of low levels of patronage beyond its control.

In previous work on distribution efficiency we have estimated both supply side and demand side output models. In the Australian context, the demand side models tend to favour urban distributors with dense networks while the supply side models tend to favour rural distributors with sparse networks (but long line lengths). In Tasman Asia Pacific (2000a,b) and other recent work in New Zealand (Meyrick and Associates 2003) we have further advanced the output specification by combining the key elements of the demand and supply models to form a comprehensive output measure which contains three components – throughput, network line capacity and the number of connections. The connection component recognises that some distribution outputs are related to the very existence of customers rather than either throughput or system line capacity. This will include customer service functions such as call centres and, more importantly, connection related capacity (eg having more residential customers requires more small transformers and poles). This three output specification has the advantage of incorporating key features of the main density variables (customers per kilometre and sales per customer).

There is also a fourth dimension to a lines business's output. This is the quality of supply which encompasses reliability (the number and duration of interruptions), technical aspects such as voltage dips and surges and customer service (eg the time to answer calls and to connect or reconnect supply). Reliability is likely to be the most important of these service quality attributes and the one for which the most data is available. However, previous attempts to include reliability measures as a fourth output have proven unsuccessful due to the way output is measured. As both the frequency and duration of interruptions are measured by indexes where a decrease in the value of the index represents an improvement in service quality, it would be necessary to either include the indexes as 'negative' outputs (ie a decrease in the measure represents an increase in output) or else to convert them to measures where an increase in the converted measure represents an increase in output. Most indexing methods cannot readily incorporate negative outputs and inverting the measures to produce an increase in the measure equating to an increase in output leads to non–linear results. Measuring reliability by the time on supply each year rather than the time off supply effectively produces a constant as the time off supply is such a small proportion of the total time each year. Finding ways to adequately incorporate measures of service quality into productivity measures remains a high priority.

Of the three outputs that can readily be included, energy throughput can be measured by the number of kWh of energy delivered. The line capacity of the system can be measured by the number of MVA–kilometres formed by summing the product of line length for each voltage capacity and a conversion factor based on the voltage of the line. This measures not only the length of line but also its overall capacity. Finally, the connections variable can be measured by the number of connections or customers.

To aggregate the three outputs into a total output index using indexing procedures, we have to allocate a weight to each output. For most industries which produce multiple outputs these output weights are taken to be the revenue shares. However, in the network case we cannot observe separate amounts being paid for the different output components. In this case we can either make some arbitrary judgements about the relative importance of the output components or we can draw on econometric evidence. One way of doing this using econometrics is to use the relative shares of cost elasticities derived from an econometric cost function.

4 OTHER MEASUREMENT ISSUES

In this section, we mention a few additional measurement problems that the regulator is likely to encounter.

4.1 The Problem of Seasonal Prices

Index number theory (and hence the construction of productivity indexes) relies on the assumption that the list of commodities being compared in the two situations under consideration is exactly the same. But this assumption is not warranted: in most countries, some 5 to 10 % of all commodities are generally not available in all quarters. In this context, a quarter to quarter productivity index will not be as "accurate" as a year over year productivity index that compares the prices of commodities in this quarter of the year with the corresponding commodities in the same quarter a year ago.[10] However, a "best practice" methodology for dealing with *seasonal prices* has not yet emerged and so this topic remains on the list of challenges for the future.

4.2 The Problem of Quality Change

Another reason why the list of commodities produced and used by a regulated firm may not be the same over time is that *quality change* takes place. Interest in the quality change problem among

[10] See Diewert (1999), Alterman, Diewert and Feenstra (1999), Diewert, Alterman and Feenstra (2004), Diewert, Finkel and Artsev (2004) and the ILO (2004) CPI Manual for some suggestions on how to deal with the seasonality problem.

index number theorists and practitioners is substantial at the present moment. It might be argued that this is not really a new development, since many of the early index number theorists were very concerned about the problem of introducing new goods into their preferred indexes.[11] Index number practitioners have also been interested in the problems of quality adjustment for a long time as well.[12] However, interest in this topic is now at unprecedented levels, perhaps due to the fact that about 2 per cent of the price quotes collected by a typical statistical agency in one month are no longer available in the following month. Some of these disappearing price quotes can be traced to seasonal and other factors but a substantial amount of the problem of disappearing quotes can be traced to new products replacing old products.

There are two main classes of methods that can be used to address the problem of adjusting prices for quality change:

- Hedonic regression techniques and
- Econometric estimation of reservation prices.

Hedonic regression techniques date back to Waugh (1929) and Court (1939),[13] while the reservation price methodology for dealing with the introduction of new goods dates back to Hicks (1940, 114). Hausman (1997) (1999) has implemented the Hicksian methodology but it has not been adopted by any statistical agency as of this date.

Hedonic regression methods also have recently been reviewed in Chapter 4 of Schultze and Mackie (2002), where a rather cautious approach to the use of hedonic regressions was advocated due to the fact that many issues had not yet been completely resolved. A series of recent papers by Heravi and Silver (2001) (2002) (2003) also raised questions about the reproducibility of hedonic regressions since these papers presented several alternative hedonic regression methodologies and obtained different empirical results using the alternative models.[14]

Some of the more important issues that need to be resolved before hedonic regressions can be routinely applied by statistical agencies include:

- Should the dependent variable be transformed or not?
- Should separate hedonic regressions be run for each of the comparison periods or should we use the dummy variable adjacent year regression technique initially suggested by Court (1939; 109-11) and used by Berndt, Griliches and Rappaport (1995; 260) and many others?
- Should regression coefficients be sign restricted or not?
- Should the hedonic regressions be weighted or unweighted? If they should be weighted, should quantity or expenditure weights be used?

[11] Walsh (1901; 207) argued that Lehr (1885; 45-46) was motivated to introduce the chain system in order to facilitate the introduction of new goods into price indexes. Marshall (1887; 373), Fisher (1911; 204) and Divisia (1926; 44-47) all made similar arguments for the use of the chain principle as an aid to introducing new products into price indexes.

[12] The Stigler (1961) report stressed the importance of quality change as did the more recent Boskin (1996) and Schultze and Mackie (2002) reports on the Consumer Price Index.

[13] The manual on methods for quality adjustment by Triplett (2004) gives the most comprehensive review of hedonic regression methods.

[14] The observation that different variants of hedonic regression techniques can generate quite different answers empirically dates back to Triplett and McDonald (1977; 150) at least.

- How should outliers in the regressions be treated? Can influence analysis be used?

Thus there is a bit of work to be done before a consensus on “best practice” hedonic regression techniques emerges.

All of this is not encouraging news for the regulator. It means that there is no agreement on a “best practice” method for dealing with the problem of quality change and varying standards of service quality.

5 CONCLUSIONS

In view of the above material, it can be seen that there will generally be significant measurement problems associated with the implementation of a form of incentive regulation that requires information on either the productivity or the unit costs of the regulated firms. In fact, the list of measurement difficulties seems quite formidable that one might wonder if incentive regulation is worthwhile. Our view is that it is worthwhile but one must be aware of the measurement pitfalls. Perfect data will never be available but it is our belief that one should work with the imperfect data that are available, while at the same time, making practical efforts to improve the data quality.

In many ways the ‘rolling average’ X factor applied to US railroads represents an ideal to strive for in incentive regulation. This process involves an agreed and long established process for collecting the necessary data and calculating TFP growth. As information for the latest year becomes available, that for the sixth last year is dropped out and the rolling average is updated. However, it needs to be recognised that this is a much more mature regulatory process with a long history of data collection. Approaching this ideal will take time and, importantly, require ongoing effort on data collection and the specification of outputs and inputs.

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