Assessing productivity in the delivery of public hospital services in Australia: Some experimental estimates

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Abstract

This paper explores productivity measurement within the Australian public hospital system. It uses publicly available data to estimate a series of three input stochastic frontier models for public acute care hospitals in each State and Territory over the period 1996-97 to 2005-06. Random and fixed effects models are used to control for unobserved environmental factors affecting measured productivity in each jurisdiction. The resulting estimates of State and Territory productivity levels vary appreciably, suggesting that, if the *observed* differences in productivity reflect productivity potential, productivity improvements in the order of 10 per cent may be achievable in *aggregate* for Australian public hospitals. The results also highlight the need to better understand the factors underpinning the results, particularly if they are used to assess the scope for improvement in public acute care hospital system productivity in individual jurisdictions.

1 Introduction

Like the wider health system, the public hospital system is under increasing pressure to deliver the same or improved health services using proportionately fewer resources. Many factors contribute to such pressures including the development of new and more expensive medical technologies, catering for the health demands of an ageing population, greater community expectations for access to health services, and limits on the availability of health workers and government funding to support these higher expected levels of service.

Assessments of the productivity of the delivery of health services would ideally be couched in terms of the health sector as a whole and would account for interactions between system components (eg between general practice, preventative, rehabilitation and acute care services and between private and public service providers). In practice, the information to undertake such a holistic exercise is not currently available. This paper therefore considers the measurement of productivity in Australian State and Territory public acute care hospital systems.[1] It undertakes experimental research to statistically identify the gap, if any, between observed public hospital system productivity and that assessed to be feasible. This assessment is based on the relative performance of Australian public hospital systems over the period 1996-97 to 2005-06.

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[1] The Australian Institute of Health and Welfare (AIHW) generally refer to these hospitals as ‘public acute hospitals’ in *Australian Hospital Statistics* (AIHW 2008).

The paper is structured as follows. Section 2 provides an overview of health services delivery in Australia. Section 3 discusses some of the broader issues involved in measuring productivity in health services delivery. Section 4 adapts the discussion of productivity measurement in health services delivery to public hospitals. Section 5 specifies the productivity models estimated in this paper for Australian State and Territory public acute care hospital systems. Section 6 outlines the data used and Section 7 presents experimental measures of public hospital system productivity. Section 8 draws the main points made in the paper together.

2 An overview of health services delivery in Australia

Health services (box 1) had an estimated value-added output of $51 billion (4.9 per cent of GDP) in 2006-07 and employed almost 650 000 people in 2006 (ABS 2007a, 2007b).[2]

The ABS input-output tables indicate that the delivery of health services in Australia is amongst the most labour intensive activities in the Australian economy. However, the relativities between industries are confounded by different conventions for the measurement of capital inputs in private and public sector activities.[3] According to currently available measures, payments to employees account for 69 per cent of total costs in 2001-02 (ABS 2006b). Public hospitals broadly align with the rest of the health sector (ABS 2008).

Collectively, expenditure on public hospitals was the single largest item of recurrent healthcare expenditure in Australia in 2005-06, accounting for around 30 per cent of the $87 billion in health expenditure (figure 1, left panel). State and Territory governments accounted for 51 per cent of this recurrent expenditure in 2005-06, while the Australian Government (including premium rebates) funded 42 per cent with non-government sources accounting for the remainder (figure 1, right panel).

Separations from private hospitals increased ahead of public acute care hospitals over the last 10 years. Thus, the share of separations accounted for by public acute care hospitals declined from 70 to 62 per cent (figure 2). Obviously, comparative analysis between public and private hospitals would need to recognise compositional changes in the separation mix (eg between complex and time consuming procedures and day admissions).

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[2] Health services gross value added was estimated by applying the share of health services in health and community services in 2001-02 (84.1 per cent) to the gross value-added of health and community services in 2006-07 ($61.1 billion) (ABS 2006b and 2007b).

[3] In particular, there is no net surplus recognised for public sector activities.

Box 1 Classifications and definitions of health sector activities

Health sector activities are classified in a number of different ways in Australia.

Prior to the recent introduction of ANZSIC 2006 (ABS 2006a), the Australian Bureau of Statistics (ABS) defined 'health services' (ANZSIC subdivision 86) on a production basis to include:

- hospitals and nursing homes (ANZSIC group 861);
- medical and dental services (862);
- other health services (863); and
- veterinary services (864).

The ABS definition included animal as well as human health services.

The AIHW — the main publisher of national health data in Australia — uses the ABS definition (excluding veterinary services), but also uses other definitions (typically based on purpose of expenditure or educational qualification). For example, some AIHW definitions of health include expenditure on medicines and pharmaceuticals. Reflecting its production rather than consumption focus, the ABS classifies medicines and pharmaceuticals as part of the 'other chemical products' industry. Consequently, taken on face value, statistics from different sources may not be strictly comparable.

While recognising that the ABS definition of health services includes animal health services that operate under a very different set of institutional and regulatory arrangements to human health services, this paper adopts, insofar as possible, the ABS definition of health services to enable comparability with other industries in the Australian economy.[4]

The AIHW (2008, p. 369) defines a *public hospital* as:

> A hospital controlled by a state or territory health authority. Public hospitals offer free diagnostic services, treatment, care and accommodation to all eligible patients.

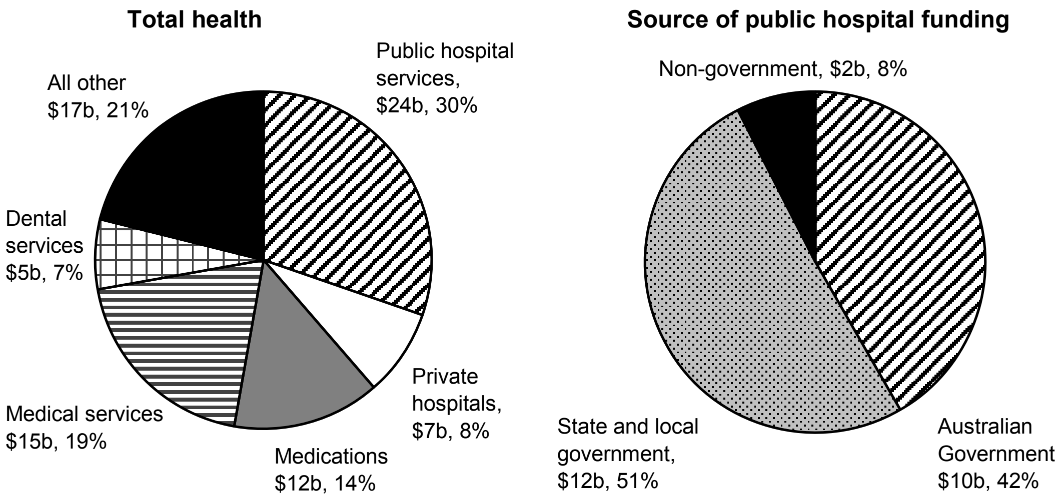
The AIHW defines *acute care hospitals* as:

> Establishments which provide at least minimal medical, surgical or obstetric services for inpatient treatment and/or care, and which provide round-the-clock comprehensive qualified nursing service as well as other necessary professional services. They must be licensed by the state health department, or controlled by government departments. Most of the patients have acute conditions or temporary ailments and the average stay per admission is relatively short. (AIHW *METeOR* database, reference identifier 269971)

[4] Veterinary services accounted for approximately 2 per cent of the output of health services in 1996-97 (ABS 2001).

Figure 1 **Australian recurrent health expenditure and public hospital funding, 2005-06**

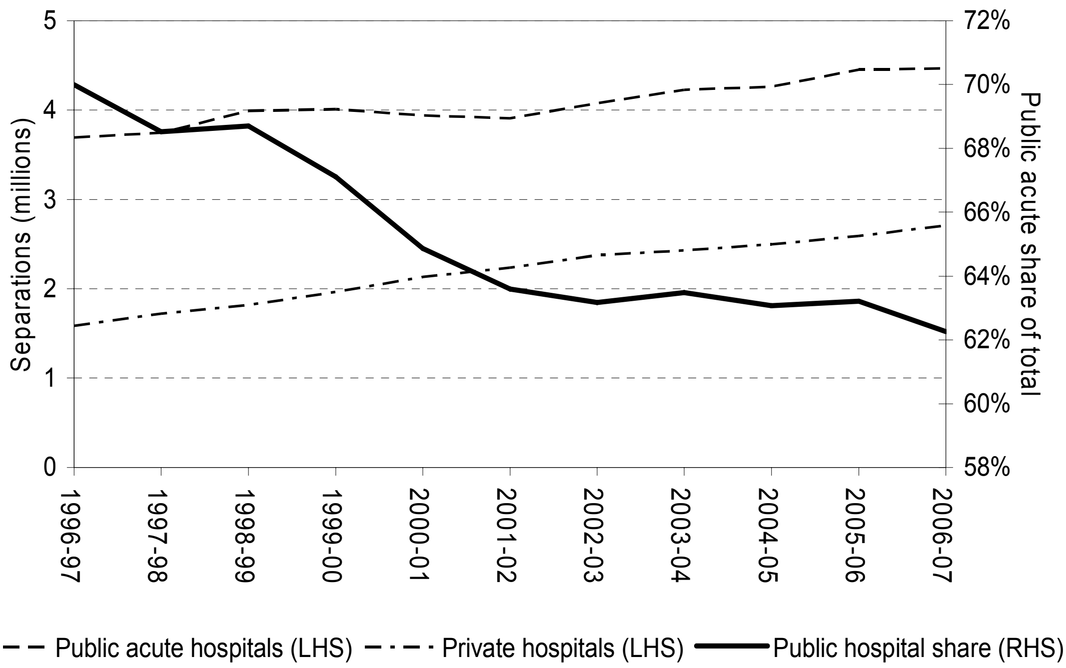
Current prices



[a] Source of funding also includes capital expenditure and consumption ($7 billion).

Source: AIHW (2007, pp. 21 & 118).

Figure 2 **Public acute care and private hospital separations, 1996-97 to 2006-07**[a]



[a] Public acute care hospitals do not include public psychiatric hospitals.

Source: AIHW (2008, p. 19).

Public acute care hospitals in more detail

Public acute care hospitals are all hospitals controlled by State and Territory governments other than public psychiatric hospitals. The AIHW definitions of a 'public hospital' and an 'acute care hospital' are outlined in box 1.

In 2006-07, the State and Territory public acute care hospital systems consisted of:

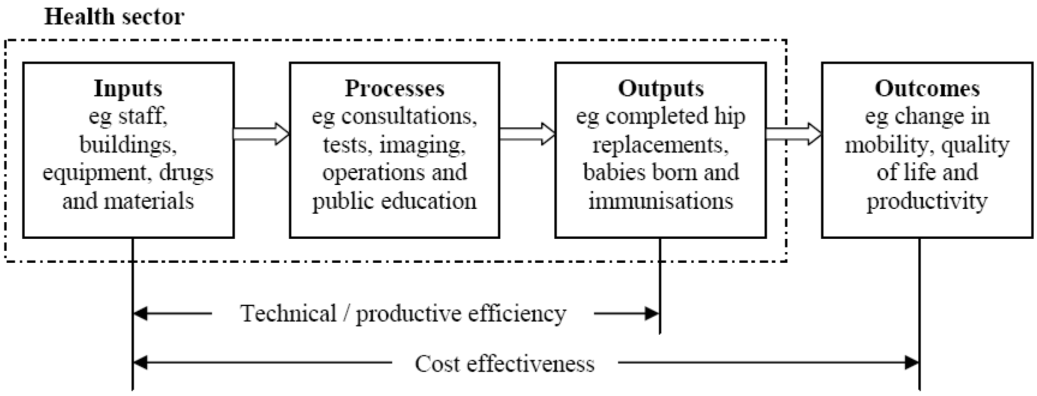
- 739 hospitals;
- 53 563 available or licensed beds (2.57 per 1000 population);
- 4.6 million separations, of which 50.2 per cent were same day separations;
- 234 717 full-time equivalent (FTE) staff and labour costs of $16.4 billion;
- 46.1 million non-admitted occasions of service;
- $25.7 billion in recurrent expenditure;
- 16.8 million patient days (776.5 per 1000 population per annum); and
- an average length of stay of 3.6 days (6.2 days if same day separations are excluded) (AIHW 2008).

Given that public acute care hospitals accounted for 99.7 per cent of all public hospital separations, 97.5 per cent of all public hospitals and 95.8 per cent of all public hospital beds in 2006-07 (AIHW 2008), the performance of the public hospital system can be meaningfully analysed by reference to public acute care hospitals. Accordingly, this paper uses the generic term 'public hospitals' in referring to public acute care hospitals.

3 Measuring productivity in health services delivery

The provision of health services involves the use of physical and human capital resources (inputs) to produce goods and services (outputs) (figure 3). Inputs consist predominantly of the health workforce (staff and their skills), but also buildings, land, technology, medical supplies, food, bed linen, office supplies, utilities, etc. The outputs of the public hospital system are numerous and vary substantially in character, encompassing consultative and procedural services, including acute care treatment (such as hip replacements, cataract operations, organ transplants and oncology treatments), staff training and scientific research. These outputs bestow benefits upon individuals and society (outcomes).

Figure 3 **Relationship between inputs, outputs and outcomes**



Source: PC (2005, p. 370).

The demand for health services, and hence *outcomes required* from the health system, is derived from the desire of individuals for good health and the associated benefits in terms of quality of life and income earning capacity that good health can bring. Public hospital systems are more likely to respond to adverse health events than some parts of the health system such as preventative healthcare and may have a more immediate impact on the health outcomes of patients. However, health outcomes are not just a function of the efficiency of public hospital services delivery, but are also dependent on a wide range of other factors, including community education, housing and the availability of clean water and sanitation.

The character and mix of inputs, processes and outputs, and the outcomes of public hospitals will vary substantially over time. Introduction of new or improved products, technologies and practices all affect the delivery of products and change ways of working, as do broader influences such as relative factor prices and funding levels.

As with all economic activity, public hospital system productivity can be conceived of as the quantity of goods and services produced per unit of input (box 2). As such, productivity incorporates the technical efficiency with which inputs are turned into outputs. Technical efficiency can be measured as the extent to which the same output can be produced using fewer inputs (input-orientated) or the extent to which output can be increased using the same inputs (output-orientated). To simplify the discussion, this paper focuses on output-orientated technical change to provide an indication of the extent to which public hospital outputs could be increased given existing health outlays. This approach is consistent with the assumptions underpinning the econometric techniques used in this paper. It is parallel to the notion that governments determine public hospital system expenditure. Nonetheless, output-orientated technical change also provides an indication of the extent to which resources can be freed up for use in other activities without compromising current output service levels (input-orientated technical change).

Box 2 Productivity and technical efficiency in standard production processes

Productivity is the *quantity* of goods and services produced per *unit* of input at a point in time. It incorporates the technical efficiency with which inputs are turned into outputs.

A production function denotes the relationship between units of output and inputs. If there is a single output, Y, and a vector of inputs ($X_1, X_2, X_3, \ldots$), the corresponding production function can be denoted as $Y = f(X_1, X_2, X_3, \ldots)$. This single output example can be extended to include multiple outputs.

Productivity is commonly measured as Y/X. If X is a single input such as labour (capital), the result is a partial measure of average productivity such as labour (capital) productivity. However, if X is an index of labour and capital inputs (all inputs), the result is a measure of multi-factor (total factor) productivity.

Technical efficiency is the degree to which the same output can be produced using fewer inputs (input-orientated) or the extent to which output can be increased using the same inputs (output-orientated) *given* existing technology.

Technical efficiency is a necessary condition for productive efficiency (producing output at the least cost), allocative efficiency (maximising social welfare at a point in time), dynamic efficiency (maximising social welfare over time) and cost effectiveness (minimising the cost of producing a given outcome).

Estimates of technical efficiency are typically derived quantitatively using a sample of countries or states and territories and, as a result, are relative rather than absolute measures. To the extent that the sample used does not include world's best practice, in reality, the potential gains may be higher than indicated based on an analysis of historical data.

Source: Based on Coelli et al. (2005) and PC (2005, p. 371).

Service quality is an integral part of the care provided by public hospitals and, as such, should ideally be recognised and taken into account in productivity measurement. A failure to properly account for quality changes may result in declines in *measured* productivity to the extent that additional or better quality inputs (such as improved skills) are typically used to provide better quality, rather than more, healthcare (ie quality differences would be incorrectly attributed to technical inefficiency).

At a basic level, health service quality encompasses two key, but distinct, dimensions: length of life (mortality); and quality of life (morbidity). A range of factors may contribute to these overarching measures, such as:

- survival rates;
- the duration and intensity of pain;
- the degree of patient mobility;
- the number, nature and severity of complications;
- waiting time length; and
- the nature of patient care received.

An earlier version of this paper (Gabbitas and Jeffs 2007) explored some of these issues further within a productivity measurement context. Notwithstanding that quality is an important part of health services delivery, it is seldom incorporated into measures of health productivity *in practice*. In part, this stems from conceptual and empirical difficulties in identifying and objectively measuring aspects of change in public hospital inputs, outputs and outcomes (such as what is the appropriate counterfactual to use and how best to incorporate quality measures into productivity analysis) and in isolating the contribution made by the public hospital system (ie its micro foundations). As a result, the failure to explicitly adjust for differences in quality implicitly assumes that there are no quality differences across jurisdictions.

In the absence of a suitable counterfactual with clear links to the services provided by hospitals, the impact of quality is not included in this analysis. Nevertheless, a sensitivity analysis using the macro indicator of quality, life expectancy at birth, is provided.

4 Public hospital productivity

Measuring productivity

Productivity measurement requires independent measures of public hospital outputs and inputs. Moreover, it would be useful if the output and input measures chosen for public hospitals aligned as closely as possible with those used by the ABS for the broader health and community services industry and the rest of the economy. This would enable public hospital productivity to be assessed in a wider context.

The measure of industry output used by the ABS to assess productivity in health and community services and other industries — gross value added (GVA) — is not published for public hospitals, nor for the other activities that make up health and community services. Consequently, an alternative measure or proxy of public hospital output is needed to undertake analyses of productivity.

The most widely used output measure for public hospitals in Australia is the 'separation' (a completed episode of patient care).[5] To account for differences in complexity and resource use across procedures, the number of separations for each procedure is typically weighted up in the calculation of sectoral output using a standardised average cost to obtain 'casemix-adjusted separations'. Separations and casemix-adjusted separations are activity measures and, as such, can be conceived of as services consumed by patients, but differ conceptually from conventional economic measures of output which are valued according to their marginal value in the marketplace. Basic data on separations are not however available on a basis that adjusts for changes in output quality over time (although technological change may result in new procedures). This is equivalent to assuming that the quality of each diagnostic procedure is constant over time.

Measures of the other public hospital outputs, such as teaching, training, and medical and scientific research, are not readily available and are not typically taken into account in productivity measurement.

Aggregate data indicate that labour productivity in Australian public hospitals grew by 4 per cent between 1996-97 and 2005-06. This is less than the 10 per cent published by the ABS for the health and community services sector (ABS 2007b). The difference arises because the ABS measure of output for health and community services (GVA) grew by substantially more over the period than did public hospital casemix-adjusted separations (46 per cent compared to 22 per cent). This suggests that other components of the sector were growing at rates above the sector average. The change in labour productivity, while an important indicator of the development of the sector, is only a partial indicator of productivity performance. In particular, it does not take account of the impact of the use of other inputs (capital services and intermediate inputs) on the productivity of labour. To provide a more complete picture of productivity performance, an analysis should take into account the use of all inputs to production. Such analyses can be adopted to look at the comparative performance of units in the sector and the implied scope for productivity improvement.

[5] In Australia, hospital procedures, or separations, are classified into diagnosis related groups (DRGs). The number of DRGs covered varies from year to year in line with revisions to the Australian Refined-Diagnosis Related Groups (AR-DRGs). The 2004-05 collection covered 664 diagnosis related groups (AR-DRG version 5.0).

Focusing on the public hospital component of the health sector, and when all inputs are taken into account, the statistically estimated gap in productivity between observed public hospital productivity and that assessed to be feasible based on the performance of other public hospitals provides an indication of the scope for improvement in service delivery.

Earlier studies

There have been earlier empirical studies on the efficiency of individual public hospitals across a range of states in Australia (table 1). The implied inefficiency estimates, and hence scope for improvement, range from 3 to 89 per cent, with an arithmetic mean of 25 per cent and a geometric mean of 18 per cent. Furthermore, studies of the Australian health system enable the implied inefficiency gaps for public hospitals to be reported for different measures of productivity. The studies indicate an arithmetic mean of 4 per cent for labour productivity, 27 per cent for multi-factor productivity (MFP) (labour and capital only) and 28 per cent for total factor productivity (TFP).

There appears to be only one Australian study of private hospitals that could be used to derive comparative estimates for all hospitals (table 1). Notwithstanding the dated nature of this study, its estimates of the implied inefficiency gaps of private hospitals, based on their relative performance, are slightly higher than those for public hospitals. That is, the available estimates suggest that public hospitals undertake more casemix-adjusted separations per unit of input than do private hospitals. This result is consistent with a finding of reviews of the international literature (Hollingsworth 2003, 2008). However, such comparisons are confounded by differences in the regulatory and institutional environments under which public and private hospitals operate. In particular:

- there are scope and coverage differences in the analyses;
- public hospitals are less able to influence the level and mix of patients than private hospitals as they operate as healthcare providers of last resort;
- public and private hospitals do not necessarily have the same mix of activities, for example, in relation to the incidence of more complex, cutting-edge and infrequent procedures. Differences in services mix would be reflected in differences in costs associated with use of more specialised and expensive equipment, lower levels of throughput and capital utilisation and longer surgical times and stays in hospital;
- public hospitals generally undertake more teaching, on-the-job medical training and research than do private hospitals; and

- private ‘for profit’ hospitals face commercial incentives and patterns of service demand which are not the focus of public hospital decision making (ie they face different service delivery objectives and constraints, including equity considerations) (Hollingsworth 2008).

Consequently, all other things being equal, it seems unlikely that there would be an alignment of separations per unit of hospital input between public and private hospitals. It is also unlikely that inferences could be drawn about relative economic efficiency between public and private hospitals unless these (and other relevant) differences are taken into account in any analysis. Hence, the findings of studies analysing private hospital productivity may not be strictly comparable with those of public hospitals.

The remainder of this paper considers the empirical estimation of efficiency gaps in the State and Territory public hospital sector.

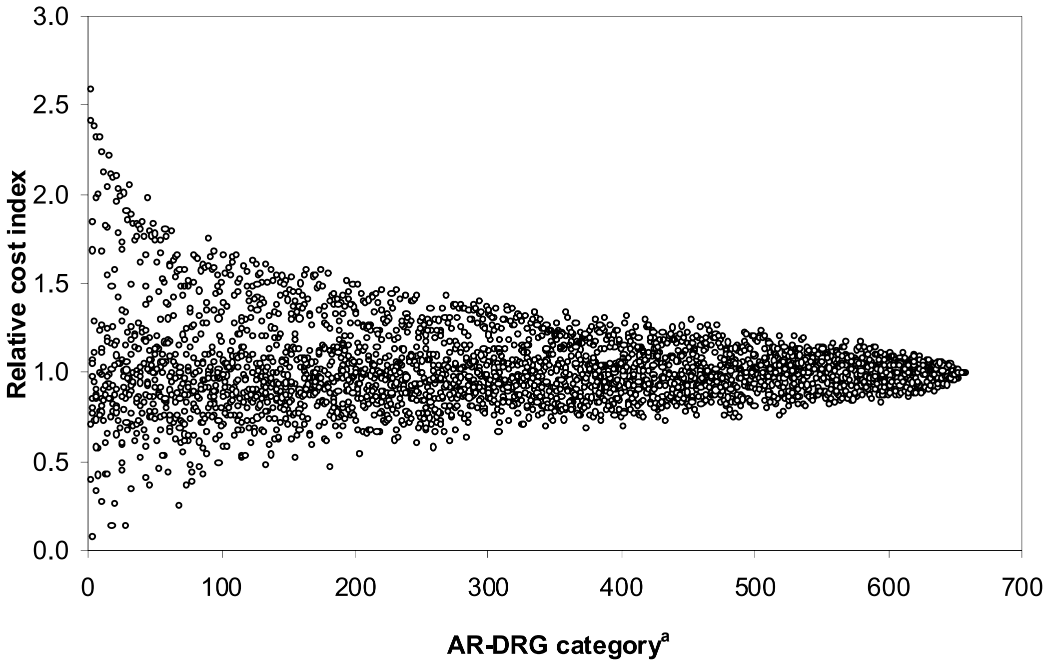
Productivity estimates for the public hospital system as a whole

National public hospital cost data indicate substantial variation across States and Territories in the average cost of each procedure over the 650 odd diagnosis related groups in 2003-04 (figure 4). These differences in average cost for the same procedure are suggestive of differences in public hospital productivity across States and Territories.

To help tell us more about the productivity of the public hospital system as a whole, and to test whether there are differences across Australian States and Territories, experimental productivity estimates are derived from data for the period 1996-97 to 2005-06. The estimates are derived econometrically from a three input production function — with labour, capital services and medical supplies as inputs — estimated using stochastic frontier analysis (SFA).

Figure 4 **Variation in average relative cost of public hospital outputs by procedure and state, ranked by decreasing variation in average costs, 2003-04**[a]

New South Wales, Victoria, Queensland, South Australia and Western Australia



a Medical treatment categories are sorted in descending order of the total variation in the relative cost index of each AR-DRG. Excludes 10 DRGs for which cost data was not available for two or more jurisdictions.

Source: PC (2006, p. 179).

5 Model specification

A range of estimation techniques has been used in the empirical literature to estimate changes in productivity over time. Few Australian studies have evaluated the relative merits of using different estimation techniques (Hollingsworth 2003, 2008).

Data envelopment analysis (DEA) is widely used to empirically estimate differences in technical efficiency across a sample (Coelli et al. 2005, Hollingsworth 2003, 2008). It uses linear programming techniques to non-parametrically estimate a common production function across all cross-sectional units (in this case, States and Territories) and, as a result of not allowing for cross sectional-specific error terms in estimation, attributes the distance that each jurisdiction is from the estimated efficiency frontier to technical inefficiency. By definition, at least one jurisdiction has to lie on the frontier and, hence, be technically 'efficient'.

In comparison, SFA uses econometric techniques to estimate a similar efficiency frontier to DEA. However, unlike DEA, SFA does not attribute all of the observed differences between States and Territories to differences in technical efficiency, as it allows for measurement error (Coelli et al. 2005). As a result, no jurisdiction need lie on an estimated SFA frontier.

Another advantage in using SFA is that, through the use of random or fixed effects specifications, it can control for the influence of other unspecified environmental factors that may affect the relationship between output and the inputs specified in the model (and implicitly *measured* efficiency). In the context of public hospitals, there are potentially a wide range of such factors. Possible examples include differences in area, population density, ethnicity, income levels, educational attainment, access to care and lifestyle factors that all may influence, in some way, the required use of inputs per unit of standard output. Some of these environmental variables may affect the level of productivity, but may not affect changes in productivity over time (eg area). Governments may be able to influence some of these state-specific factors, but not others.

The reason for controlling for these state-specific 'environmental factors' through random or fixed effects specifications is that a failure to do so will result in omitted variable bias, which typically results in biased parameter estimates that will affect the resulting measure of technical inefficiency. The use of random or fixed effects models is a shorthand way of avoiding the need to explicitly identify, measure and include each relevant environmental factor in the model as an additional explanatory variable (input). These techniques may also pick up some of the institutional differences across states that affect the output and resource use across states, such as the prevalence of teaching hospitals that tend to be more resource intensive per unit of output than non-teaching hospitals and systematic differences in service mix and quality.

One disadvantage of SFA compared to DEA is that SFA does not handle multiple outputs. Consequently, the use of a single output in SFA may result in some loss of information compared to that obtainable from DEA (eg the tradeoff between quality and technical efficiency).

This paper uses a series of random and fixed effects SFA models to estimate the productive efficiency in the delivery of Australian public acute care hospital services over the period 1996-97 to 2005-06 using a balanced panel dataset.

SFA models used

As noted, SFA uses actual data on outputs and inputs to estimate a common stochastic production frontier for all States and Territories. The resulting difference between the estimated frontier and the actual data for individual states, after allowing for measurement error, gives an estimate of the extent of technical inefficiency in each jurisdiction. If the State or Territory is determined stochastically to lie on the estimated frontier, the measure of technical inefficiency is zero, while it has a positive value if the State or Territory lies inside the frontier. The resulting inefficiency parameter indicates the extent to which output can be increased using the existing level of inputs (or inputs reduced to produce the existing output levels).

SFA models include random and fixed effects specifications. These specifications make different assumptions about the technical inefficiency term and any unobservable state-specific effects:

- the random effects models estimated assume that unobserved state-specific effects: (i) are uncorrelated with the inputs specified; and (ii) behave as 'white noise' (with a mean of zero and constant variance), or can be easily accounted for through the inclusion of suitable environmental variables; and
- the fixed effects models estimated assume that the unobserved state-specific effects are potentially correlated with the inputs used.

Each of the models considered are detailed below.[6]

Random effects SFA models

The random effects models estimated assume that it is possible to distinguish an independent term that indicates technical efficiency. The general form of a random effects model is:

$$\ln Q_{it} = \alpha + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_S \ln S_{it} + v_{it} - u_{it} \qquad (1)$$

Where:

Q_{it}	casemix-adjusted separations in year t (output);
α	a common intercept term;
$\beta_L, \beta_K, \beta_S$	input coefficients;
L_{it}	FTE employment (input);
K_{it}	real capital services (input);
S_{it}	real medical supplies (input);

6 A fifth alternative model — a 'true' random effects model (Greene 2005) — was also considered, but the resulting estimates of technical inefficiency are not reported here as they appear implausible owing to the absence of *any* measured inefficiency, in *any* jurisdiction, in *any* year over the sample period.

v_{it} — an unobserved symmetric random error for State or Territory i; and

u_{it} — an unobserved non-negative variable associated with technical inefficiency for State or Territory i.

On the basis that v_{it} and u_{it} are both independent and identically distributed (except that $u_{it} \geq 0$), the technical efficiency score in State or Territory i can be expressed as $e^{-u_{it}}$. The estimation of u_{it} requires assumptions about the distribution of v_{it} and u_{it} (such as normal and half-normal distributions, respectively).

There are two distinct versions of the random effects model used in the SFA panel data literature:

- the time invariant model (Pitt and Lee 1981); and
- the time varying model (Battese and Coelli 1995).

The key distinction between these two models is that the technical inefficiency term is assumed to remain constant over time in the time invariant model (ie $u_{it} = u_i$), whereas it is allowed to vary over time in the time varying model (ie $u_{it} \neq u_i$).

The implied inefficiency gap — the extent to which technical efficiency can be increased expressed as a ratio of the technical efficiency score — is calculated in this paper as $\left(1 - e^{-u_{it}}\right)/e^{-u_{it}}$.

A drawback with the time varying random effects model is that it does not allow for 'changes in the rank ordering of firms over time' (ie changes in relative technical efficiency across jurisdictions over time) (Coelli et al. 2005, p. 278).[7]

Fixed effects SFA models

These models are distinguishable from random effects models in that they assume that the unobserved state-specific factors are potentially correlated with the inputs specified.

[7] Some alternative versions of the time varying random effects model relax this somewhat restrictive assumption (eg Cornwell, Schmidt and Sickles 1990), but do not appear to be supported by the *Limdep* econometrics package used in this study (Greene 2007).

Time invariant fixed effects model

The time invariant fixed effects model (Schmidt and Sickles 1984) is expressed as:

$$\ln Q_{it} = \alpha_i + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_S \ln S_{it} + v_{it} \tag{3}$$

Where α_i represents a state-specific fixed effect related to technical inefficiency (ie $\alpha_i = a - u_i$, where a is a constant). Time invariant technical inefficiency (u_i) is then estimated via the formula: $u_i = \max(\alpha_i) - \alpha_i$ and the technical efficiency score and implied inefficiency gaps are calculated in the same way as for the random effects models.

Time varying fixed effects model

As an alternative to the time invariant fixed effects model, Greene (2005) proposes a time varying fixed effects model of the form:

$$\ln Q_{it} = \alpha_i + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_S \ln S_{it} + v_{it} - u_{it} \tag{4}$$

Where α_i represents unobserved state-specific fixed effects that are, in contrast to the time invariant model, assumed to be unrelated to technical inefficiency. The technical efficiency score and implied inefficiency gaps are calculated in the same way as for the other models estimated.

Greene (2005) describes this model as a 'true' fixed effects model in the sense that the unobserved state-specific effects accounted for in the time invariant fixed effects model may actually vary over time.

Selecting the most appropriate model

Statistical tests are generally available in econometrics to help select the preferred model from a range of plausible alternatives. However, unlike their linear panel data counterparts, there do not appear to be well-established and reliable statistical tests to determine which of these SFA models is most appropriate for use in explaining productivity differences. For example, there do not appear to be equivalents of the Hausman and F-tests to select between random and fixed effects SFA models. Consequently, it is difficult to objectively assess the relative merits of each of these models and the implications for the resulting estimates of technical inefficiency.

Neither does there appear to be any clear consensus in the empirical literature as to which of these SFA models is most appropriate (Hollingsworth 2003, 2008). Furthermore, among the few studies that do consider different SFA models, there are mixed conclusions regarding the sensitivity of the results (see, for example, Bryce, Engberg and Wholey 2000, and Rosko 1999).

In the absence of such statistical tests or consensus amongst practitioners, this paper presents results for a number of these models.

To fill this information gap, the selection of a preferred model and benchmarking of results can be undertaken on the basis of judgements about the likely nature of the unobserved state-specific effects and how they may interact with the other inputs and the technical inefficiency term.

If the unobserved state-specific effects are thought to be uncorrelated with the regressors (inputs), one of the various random effects SFA models estimated in the literature may be more appropriate. In addition, if the unobserved state-specific effects are thought to behave as white noise or are easily accounted for through the inclusion of suitable environmental variables, the random effects models estimated in this paper may be more appropriate.[8]

However, if the unobserved state-specific effects are thought to be correlated with other inputs, a fixed effects SFA model may be more appropriate (either a time invariant model if technical inefficiency is thought to be fixed over time or a time varying model if technical inefficiency is thought to vary over time).

Without practical understanding of what gives rise to the unobservable state-specific effects, it is difficult to ascertain *a priori* which of these assumptions is more likely to be appropriate for Australian public acute care hospital systems. That said, it is difficult to conceptualise unobservable state-specific factors affecting public hospital systems that are unlikely to be correlated with the inputs used by hospitals in delivering health services as assumed by a random effects model, especially over time. In this case, the unobservable state-specific effects would be expected to affect the relationship between observed outputs and inputs being estimated and productivity measures. Furthermore, these unobservable state-specific effects are unlikely to be white noise across jurisdictions and over time.

If the above assessment of the assumptions underpinning these models holds in reality, this would incline us, *a priori*, to place greater weight on the time-varying fixed effects model.

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[8] However, if the unobserved state-specific effects are not thought to behave as white noise and are not easily accounted for through the inclusion of suitable environmental variables, a random effects model reflecting these characteristics (termed a 'true' random effects model) may be more appropriate.

6 Data

Outputs

The output measure used in this paper is the number of casemix-adjusted separations from each State and Territory's public acute care hospital system and is sourced from the *Report on Government Services* (SCRGSP 2008).

Inputs

Each model estimated uses the same three inputs: physical measures of labour, capital and medical supplies.

Labour is measured as FTE employment in public acute care hospitals and is sourced from AIHW (2008).[9] To ensure strict comparability with the other data used, FTE employment in each jurisdiction was multiplied by the relevant inpatient fraction — the proportion of total hospital expenditure related to the provision of care for admitted patients (AIHW 2008, p. 301).

Real capital services cover buildings and equipment less interest payments, but not land, and is measured as depreciation plus an 8 per cent opportunity cost of the funds employed (based on the asset value) deflated by a state, territory and local government gross fixed capital formation price index. The capital services data are sourced from the *Report on Government Services* (SCRGSP 2008) and the deflator used from AIHW (2007).

Real medical supplies is measured as nominal expenditure on medical supplies and drug supplies deflated by final household consumption expenditure on medicines, aids and appliances. The medical and drug supplies data used are sourced from AIHW (2008) and the deflator used from AIHW (2007).

All variables are expressed per 1000 residents to account for differences in size between jurisdictions (ABS 2008).

The resulting dataset consists of a balanced panel dataset spanning 10 years (1996-97 to 2005-06) with one output and three inputs for each of the eight Australian State and Territory public acute care hospital systems (New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania,

[9] Initially, we considered sourcing the data used in this study from the *National Hospital Cost Data Collection* (DHA 2007), as it also contained data that would have enabled public hospital productivity to be explored by type of procedure. However, further investigation revealed that this data was unsuitable for this purpose (Gabbitas and Jeffs 2007). In particular, it did not collect data on homogeneous input use (ie it often combined the use of labour with other inputs).

the Northern Territory and the Australian Capital Territory).[10] This dataset is summarised in table 2.

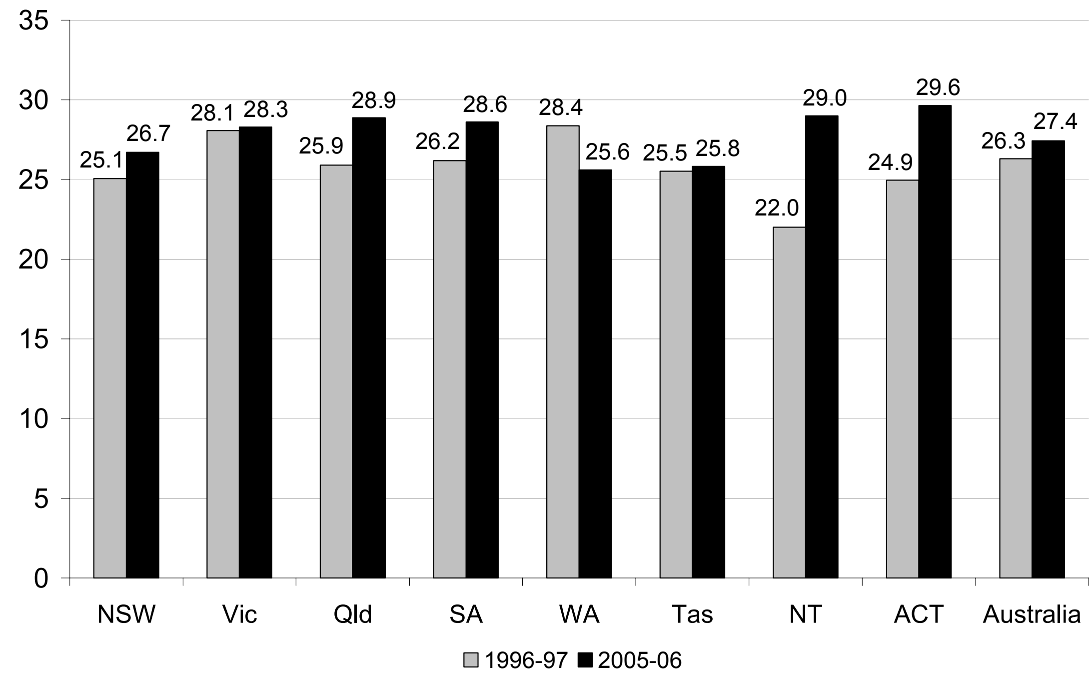
Since the three inputs included in the models estimated do not cover all inputs used by public hospitals, the sum of the estimated coefficients should not be interpreted as an indication of increasing, constant or decreasing returns to scale.

What the data indicate

The average level of labour productivity — defined here as casemix-adjusted separations per FTE employee — in public hospitals varies across States and Territories (figure 5 and table 3). In 1996-97, labour productivity was highest in Western Australia with 28 casemix-adjusted separations per FTE employee (after adjusting for the inpatient fraction) and lowest in the Northern Territory with 22 casemix-adjusted separations per FTE employee. In 2005-06, labour productivity was highest in the Australian Capital Territory with 30 casemix-adjusted separations per FTE employee and lowest in Western Australia with 26 casemix-adjusted separations per FTE employee.

Figure 5 **Public hospital system labour productivity, 1996-97 and 2005-06**

Casemix-adjusted separations per inpatient-adjusted FTE employee[a]



[a] Inpatient-adjusted FTE employee is FTE staff multiplied by the admitted patient cost proportion.

Source: Estimates based on AIHW (2008) and SCRGSP (2008).

[10] The capital data series used was only available until 2005-06.

7 Results

As outlined in section 5, this paper presents results for a range of random and fixed effects SFA models. This effectively provides a form of sensitivity test on the results to different model specifications, and, as such, an indication of the reliability of the results from which policy conclusions can be drawn.

Random effects models

Table 4 presents the SFA results for the time invariant and time varying random effects models, while tables 5 and 6 present the technical efficiency scores and the implied inefficiency gaps by state.

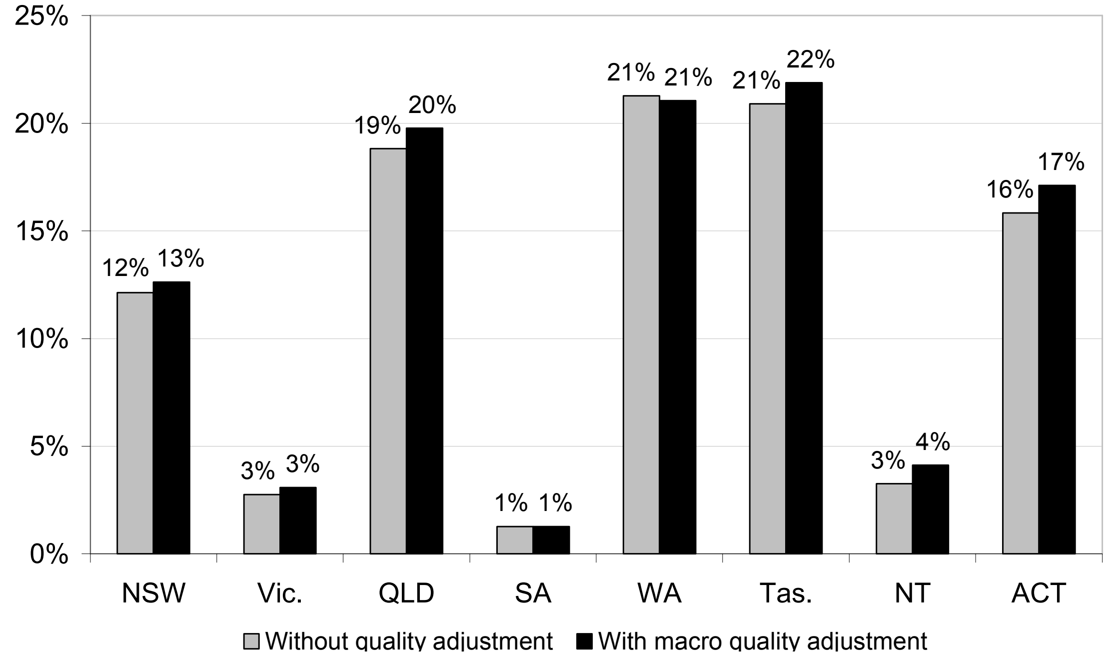
Time invariant model

The experimental results from the time invariant version of this model estimated over the period 1996-97 to 2005-06 indicate substantial variation in the implied inefficiency gaps across State and Territory public hospital systems (table 5 and figure 6). The estimated slope coefficients on labour, capital and medical supplies are all positive and statistically significant (table 4). The experimental results indicate three broad groupings:

- The first group consists of South Australia, Victoria and the Northern Territory, which lie closest to the estimated frontier. The implied inefficiency gaps for these states range from 1 to 3 per cent.
- The second group consists of New South Wales and the Australian Capital Territory, with implied inefficiency gaps of 12 and 16 per cent, respectively.
- The third group consists of the remaining states — in order, Queensland, Tasmania and Western Australia — with implied inefficiency gaps of between 19 and 21 per cent.

Figure 6 **Implied inefficiency gaps by State and Territory, 1996-97 to 2005-06**[a]

Time invariant random effects SFA models



a The macro quality adjustment involves multiplying output (casemix-adjusted separations) by the ratio of the growth in State and Territory life expectancy at birth relative to that in 1996-97.

The results for the third group of states seem large and could possibly be outliers, notwithstanding the fact that there will be some measured technical inefficiency associated with each State having some excess capacity to deal with emergencies and unforeseen peaks in demand.[11] The issue in interpreting these results is therefore whether they are influenced by some omitted variable bias, or whether the modelled inefficiency differences represent underlying differences.

The arithmetic mean across all States and Territories is 12 per cent and the geometric mean is 8 per cent. That is, the experimental analysis taken at face value suggests that, on average over the period, the level of output undertaken across all States and Territories could have been increased by approximately 10 per cent using the same inputs (or the same output could have been produced using approximately 10 per cent fewer inputs).[12] These results fall towards the lower end of those from other Australian studies (table 1).

[11] Spare capacity to handle emergencies and unforseen demand is akin to reserve plant margin in electricity generation.

[12] A 10 per cent measure of output-orientated technical inefficiency may not be equivalent to a 10 per cent reduction in inputs while maintaining the same level of output, as the

However, technical inefficiency is unlikely to remain constant over time in the real world. This would suggest that a time varying model is likely to be more appropriate than a time invariant one (Greene 2005).

Time varying model

The time varying random effects model suggests that the trend in technical inefficiency is fairly steady over the period 1996-97 to 2005-06, with gradual and consistent increases in technical inefficiency over the sample period (table 6). In this model, the relativities between states remain unchanged by model assumption (see above).

Both the time invariant and time varying random effects models suggest implied inefficiency gaps of roughly 12 per cent for Australia as a whole averaged over the period.

Fixed effects models

The implied inefficiency gaps for the time invariant and time varying fixed effects models are also somewhat consistent, in that they both suggest *average* implied inefficiency gaps in the range of 9 to 12 per cent for the system as a whole over the period (tables 8 and 9). However, the time varying fixed effects model provides a different story of technical inefficiency across states and over time, when compared with the time varying random effects model. Whereas the latter suggests a consistent gradual decline in technical efficiency across all states over the period, the former indicates a degree of variability for all states over the same period.

Taken at face value, the time varying fixed effects results indicate wider variability in the performance of State and Territory public hospitals systems over the sample period than does the time varying random effects model. For some jurisdictions, this variability does not appear to be systematic and sometimes varies sharply from one year to another (eg Tasmania, South Australia and the Australian Capital Territory). This year-to-year variability in the performance of particular jurisdictions may indicate the possibility of time varying unobserved state-specific factors that are not adequately controlled for in the time varying fixed effects model. On the other hand, for the Northern Territory in the time varying fixed effects model, the trend in productivity growth over the entire period is higher than indicated by the time varying random effects model.

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relationship between output- and input-orientated technical efficiency is, in theory, asymmetric and will depend on the degree of curvature in the estimated production frontier.

Sensitivity test

An earlier version of this paper (Gabbitas and Jeffs 2007) tested the effects of adjusting public hospital output to account for changes in output quality (proxied by the macro-health indicator of changes in State and Territory life expectancy at birth) using this variant of the model. Adjusting for quality in this way did not change the estimated results in any material way (figure 6).

There may be a degree of sensitivity in the technical inefficiency estimates in such models. Gabbitas and Jeffs (2007), for example, found that small adjustments to measured output in a random effects SFA model to take into account changes in output quality led, for some jurisdictions, to changes in technical inefficiency that did not align with the quality adjustments made. Unambiguous improvements in output quality using the same quantities of inputs can give rise to a slight rotation in the SFA frontier and, with it, marginally higher estimates of technical inefficiency (all other things equal).

Overall indications of results

The four models estimated indicate broad scope for productivity improvements in the order of 10 per cent for Australia's public hospitals overall. That said, the results collectively demonstrate a degree of variability in the estimates of technical inefficiency across states and over time.

However, the extent to which the average implied inefficiency gap for the system as a whole applies to individual jurisdictions, or to the performance of individual jurisdictions over time, is less clear.

Improving productivity measurement of public hospitals

The data used in this paper indicate substantial variation in the use of capital per casemix-adjusted separation across jurisdictions. Because of the difficulty in measuring capital stocks, it is unclear if these differences reflect actual differences in the use of capital inputs or statistical differences arising from the estimation techniques. As the techniques used in this paper to estimate technical inefficiency depend on accurate measures of inputs and outputs, variability in data series arising from differential application of estimation methods could flow through to bias the estimates of productivity gaps. Presenting data in this framework provides a new opportunity to examine the information in a broader economic context.

The provision of consistent disaggregated data for the procedures undertaken within individual public hospitals would assist to better identify and understand the drivers of productivity change in public hospitals. This would enable productivity to be assessed at different levels within individual public hospitals and across the public hospital system. This would assist in understanding the effects of health-related policy decisions by enabling comparisons of service delivery across hospitals within a jurisdiction, across jurisdictions (both for individual hospitals and for the hospital system as a whole) and, potentially, across the wider health system.

8 Summing up

This paper explores productivity in Australian State and Territory public acute care hospital systems. The results presented here are experimental and need to be treated with caution. On the surface of it, the available data indicate significant differences in the level and growth of labour productivity across jurisdictions in Australia between 1996-97 and 2005-06.

A range of random and fixed effects models from the SFA literature are estimated for Australian State and Territory public acute care hospital systems. However, the absence of well-established and reliable statistical tests in the SFA literature make it difficult for us to ascertain which, if any, of the SFA models estimated is most appropriate in explaining productivity differences across States and Territories and which are not.

That said, the results presented suggest that there is scope to improve productivity in public acute care hospitals, based on information for the period 1996-97 to 2005-06. If the *observed* differences in productivity reflect productivity potential, productivity improvements in the order of 10 per cent may be achievable in *aggregate* for Australian public acute care hospitals. This estimate falls within a range of possibilities suggested by previous studies, albeit at the lower end.

The extent to which the overarching finding that there is scope for improvement in public acute care hospital system productivity applies to individual jurisdictions, or to the performance of individual jurisdictions over time, is less clear. Some models suggest that system-wide efficiency is higher in Victoria, South Australia and the Northern Territory with scope for improvement being greatest in other jurisdictions. Other models indicate a more complex story with the performance of individual jurisdictions varying in non-systematic ways over time. The results also highlight the need to better understand the factors underpinning the drivers of public acute care hospital system performance, particularly if the results are used to assess the scope for improvement in individual jurisdictions.

Further work is clearly needed in this area to help inform policymakers and to improve our understanding of the complex interplay of factors involved in assessing the historical changes in productivity and the scope for productivity improvement in pubic hospital systems. Moreover, additional work is needed to assess how productivity in Australian public hospitals contributes to, and interacts with, the delivery of health services more generally. Developments that are likely to contribute to an improved understanding of health sector productivity could include: disaggregation of data from state-wide aggregates to individual DRG line items across jurisdictions on a consistent basis; reassessment and improvements of component data series, particularly capital stocks; and measures to directly include quality estimates with clear micro links to the nature of acute care hospital services and their contribution to overall health outcomes.

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Table 1 **Estimates of inefficiency in Australian studies of public and private hospitals**

Study	*Sample*	*Factor inputs*[a]	*Estimation technique*[bc]		*Implied inefficiency*[d]
Public hospitals					
SCRCSSP (1997)	109 public hospitals (Victoria) (1994-95)	MFP (labour, other)	DEA	Model 1	23%
		MFP (labour, other)	DEA	Model 2	12%
		MFP (labour, other)	DEA	Model 3	49%
		MFP (labour, other)	DEA	Model 4	11%
		MFP (labour, other)	DEA	Model 5	89%
Yong & Harris (1999)	35 public hospitals (Victoria) (1994-95)	Labour	SFA	Model 1	3%
		Labour	SFA	Model 2	5%
Wang & Mahmood (2000a)	112 public hospitals (NSW) (1997-98)	TFP	DEA	Model 1	25%
		TFP	DEA	Model 2	37%
Wang & Mahmood (2000b)	114 public hospitals (NSW) (1997-98)	MFP (labour, capital)	SFA	Model 1	10%
		MFP (labour, capital)	SFA	Model 2	12%
Mortimer (2002)	38 public hospitals (Victoria) (1993)	MFP (labour, capital)	DEA	Model 1	19%
		MFP (labour, capital)	SFA	Model 2	20%
Paul (2002)	223 public hospitals (NSW) (1995-96)	TFP	SFA	Model 1	35%
Mangano (2003)	116 public hospitals (Victoria) (1992-93 to 1995-96)	TFP	SFA	Model 1	33%
Queensland Department of Health (2004)	74 public hospitals (Qld) (2000-01 to 2002-03)	TFP	DEA	Model 1	9%
Private hospitals					
Webster, Kennedy & Johnson (1998)	301 private hospitals (Australia) (1991-92 to 1994-95)	TFP	DEA	Model 1	37%
		TFP	SFA	Model 2	35%
		TFP	SFA	Model 3	22%

[a] Measurements for total factor productivity (TFP) include all inputs (labour, capital and other inputs); multi-factor productivity (MFP) generally refers to labour and capital. However, the term MFP is used here to also describe the studies which include labour and other non-capital inputs as the factors of production. [b] The estimation techniques referred to in this table are data envelopment analysis (DEA) and stochastic frontier analysis (SFA).[c] Some of the empirical studies use various estimation methods and sensitivity analysis by changing model specifications such as inputs/outputs and analysis of the size and location of hospitals. For simplicity, various modelling results have been represented as model 1, 2 etc. [d] The inferred inefficiency score in the source has been expressed as a share of the technical efficiency score to indicate the potential for improvement.

Source: PC (2006, p. 172).

Table 2 **Summary of Australian State and Territory public acute care hospital systems, 1996-97 to 2005-06**

Output/input[a]	*Mean*	*Minimum*	*Maximum*	*Standard deviation*
Casemix-adjusted separations	0.20	0.15	0.29	0.03
FTE employment	7.26	4.90	9.99	1.04
Real capital services	0.08	0.03	0.15	0.03
Real medical supplies	0.09	0.05	0.14	0.02

[a] Output and inputs are expressed per 1000 residents and have been adjusted by the inpatient fraction.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 3 **Labour productivity rankings by State and Territory, 1996-97 to 2005-06**

Public acute care hospitals

	Labour productivity[a]			
State	*Level 1996-97*	*Level 2005-06*	*Growth rate 1996-97 to 2005-06*	*SFA*[b]
NSW	6	6	5	4
Vic.	2	5	7	2
Qld	4	3	3	6
SA	3	4	4	1
WA	1	8	8	8
Tas.	5	7	6	7
NT	8	2	1	3
ACT	7	1	2	5

1 is the most efficient and 8 is the least efficient. [a] Casemix-adjusted separations per FTE employee. [b] Ranking of the technical efficiency scores from the time invariant random effects SFA model.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 4 **Estimated stochastic production function for State and Territory public hospital systems, 1996-97 to 2005-06**

Random effects SFA models

	Time invariant		Time varying	
	Coefficient[a]	z-statistic	Coefficient[a]	z-statistic
Constant	-1.44***	-9.54	-1.38***	-3.73
Labour	0.27***	3.85	0.26	1.11
Capital	0.05*	1.75	0.04	1.36
Medical supplies	0.19***	4.16	0.22***	3.08
No. of observations	80		80	
Maximum likelihood	125.42		126.02	

*** significant at 1 per cent. ** significant at 5 per cent. * significant at 10 per cent. [a] As the variables included do not cover all of the inputs used, the sum of the estimated coefficients should not be interpreted as an indication of increasing, constant or decreasing returns to scale in the provision of health services by public hospitals.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 5 **Implied inefficiency gaps by state, 1996-97 to 2005-06**

Time invariant random effects SFA model

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Ave*
Technical efficiency score	0.89	0.97	0.84	0.99	0.82	0.83	0.97	0.86	0.90
Implied inefficiency gap	12%	3%	19%	1%	21%	21%	3%	16%	12%

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 6 **Implied inefficiency gaps by State and year, 1996-97 to 2005-06**

Time varying random effects SFA model

Year	*NSW*	*Vic.*	*QLD*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Ave*
1996-97	11%	3%	18%	1%	20%	20%	3%	15%	11%
1997-98	12%	3%	18%	1%	20%	20%	3%	15%	11%
1998-99	12%	3%	18%	1%	20%	20%	3%	15%	12%
1999-00	12%	3%	19%	1%	21%	21%	3%	15%	12%
2000-01	12%	3%	19%	1%	21%	21%	3%	16%	12%
2001-02	12%	3%	19%	1%	21%	21%	3%	16%	12%
2002-03	13%	3%	20%	1%	22%	22%	3%	16%	12%
2003-04	13%	3%	20%	1%	22%	22%	3%	17%	13%
2004-05	13%	3%	20%	1%	23%	23%	3%	17%	13%
2005-06	13%	3%	21%	1%	23%	23%	3%	17%	13%
Average	12%	3%	19%	1%	21%	21%	3%	16%	12%

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 7 Estimated stochastic production function for State and Territory public hospital systems, 1996-97 to 2005-06

Fixed effects SFA models

	Time invariant		Time varying	
	Coefficient[a]	t-statistic	Coefficient[a]	z-statistic
Labour	0.23***	3.45	0.36***	25.43
Capital	0.04	1.57	0.02	1.53
Medical supplies	0.21***	6.14	0.19***	6.13
No. of observations	80		80	
AIC/Maximum likelihood	-6.14		107.93	

*** significant at 1 per cent. ** significant at 5 per cent. * significant at 10 per cent. [a] As the variables included do not cover all of the inputs used, the sum of the estimated coefficients should not be interpreted as an indication of increasing, constant or decreasing returns to scale in the provision of health services by public hospitals.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 8 Implied inefficiency gaps by state, 1996-97 to 2005-06

Time invariant fixed effects SFA model[a]

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Ave*
Technical efficiency score	0.89	0.97	0.84	1.00	0.82	0.82	0.98	0.86	0.90
Implied inefficiency gap	13%	3%	20%	0%	22%	22%	3%	17%	12%

[a] Using casemix-adjusted separations as output.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).

Table 9 **Implied inefficiency gaps by State and year, 1996-97 to 2005-06**

Time varying fixed effects SFA model[a]

Year	*NSW*	*Vic.*	*QLD*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Ave*
1996-97	6%	10%	5%	8%	3%	7%	20%	17%	10%
1997-98	5%	9%	5%	9%	7%	10%	20%	18%	10%
1998-99	5%	5%	6%	8%	9%	3%	13%	13%	8%
1999-00	7%	5%	7%	8%	6%	15%	13%	8%	9%
2000-01	8%	5%	8%	9%	7%	12%	11%	7%	8%
2001-02	10%	9%	10%	14%	12%	11%	12%	9%	11%
2002-03	12%	8%	11%	6%	11%	7%	7%	11%	9%
2003-04	9%	9%	9%	6%	11%	8%	4%	5%	8%
2004-05	8%	9%	8%	5%	10%	9%	4%	5%	7%
2005-06	9%	10%	12%	7%	10%	7%	4%	3%	8%
Average	8%	8%	8%	8%	9%	9%	11%	9%	9%

[a] Using casemix-adjusted separations as output.

Source: Estimates based on AIHW (2007, 2008), SCRGSP (2008) and ABS (2008).