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Title:

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Date:

2020-09-01

Citation:

Cheng, C. C., Scott, A., Sundararajan, V., Yan, W. & Yong, J. (2020). An Examination of Public Hospital Productivity and its Persistence: An Index Number Approach. *The Australian Economic Review*, 53 (3), pp.343-359. <https://doi.org/10.1111/1467-8462.12375>.

Persistent Link:

<https://hdl.handle.net/11343/276862>

An examination of public hospital productivity and its persistence: An index number approach

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Acknowledgements. This research was funded by an NHMRC Partnership Grant (Grant ID: 567217) and in collaboration with the Victorian Department of Health and Human Services (formerly the Victorian Department of Health). The views expressed herein are those of the authors and do not reflect the views of the Victorian Department of Health and Human Services.

Abstract.

This paper measures the level and growth of total factor productivity (TFP) of public hospitals in Victoria, Australia, using an index number approach. We further examine the persistence of productivity over time, and the extent to which productivity varies with hospital characteristics such as hospital size. Hospital administrative data from Victoria from 2007/08 to 2011/12 are used. We find substantial variation in TFP across hospitals: large hospitals perform significantly better than small hospitals, both in TFP level and growth. Productivity level is highly persistent over time, but not productivity growth.

Keywords: Hospital productivity; productivity persistence; index number approach.

This is the author manuscript accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/aere.12375](https://doi.org/10.1111/aere.12375).

Introduction

The costs of health care have been rising in most developed economies due primarily to population ageing and advancement in medical technologies. Public financing of hospitals in many countries has struggled to keep pace with demand especially in the face of recent tumultuous global economic situations. Given that the rise in demand for care is outstripping the increase in public finance, improving the productivity and efficiency of hospitals is one of few viable policy options. Consequently, measuring and understanding the productivity of hospitals has become a topic of interest in recent years. In the U.K., for example, alleged negative productivity growth of the UK medical care sector became a major concern that a special parliamentary commission was formed to explore the issue (Atkinson 2005). In the U.S. Medicare payments have been linked to expected improvements in hospital performance on a number of cost and quality dimensions under the Affordable Care Act (Blumenthal et al. 2015; Nyweide et al. 2015; Cutler 2015). In Australia, the efficiency of hospitals has also been in the spotlight following the introduction of a national activity-based funding scheme for all public hospitals from 2012 onward (IHPA 2013).

This paper has a two-fold objective. First, we aim to document the level and changes in the productivity of public hospitals over time in Victoria, Australia, using an index number approach. Second, we aim to uncover what drives the productivity variation across public hospitals in Victoria. Productivity levels are measured as the ratio of aggregate output to aggregate input, both measured by a form of quantity indices. The paper further investigates the persistence of productivity and whether productivity of public hospitals is related to hospital characteristics such as hospital size. For the latter we use standard methodology of panel data regressions, while the investigation of the persistence of productivity makes use of models with lagged dependent variables.

The concept of productivity is designed to capture the capability of production units (e.g., firms in an economy, public hospitals in our context) in converting inputs into outputs. In practice it has been used to measure technological progress, efficiency, and general capability of production units in organising production. There are many notions of productivity; common ones are labour productivity and total factor productivity (TFP). The former measures the level of aggregate output per unit of labour inputs (e.g., dollars of revenue per full-time equivalent (FTE) employee), while TFP, also known as multifactor productivity, broadens the measure of inputs to include all factors of production. This paper will concentrate on the TFP measure.

It is important to distinguish between TFP level and growth (Hulten 2001; Diewert and Nakamura 2006; Diewert and Nakamura 2007). The latter is the rate of change of the TFP level and its measurement involves a standard for comparison in the form of a reference

period or reference production unit. The choice of a reference point is thus an important consideration in the computation of TFP growth; estimates of productivity growth will vary if different reference points are used. Moreover, TFP growth provides little information for understanding the relative performance of different hospitals—hospitals with low TFP level may grow at a fast rate simply because they were starting at a low base.

With a population of about 5 million, Victoria is the second largest state in Australia by population size. The state has about 120 public hospitals during the study period. All citizens in Australia have universal access to care provided by public hospitals, which are jointly funded by the federal and state governments with approximately an equal share. State governments are tasked with managing and regulating public hospitals in their respective state. Victoria is the first state in Australia to adopt a prospective casemix funding system for public hospitals (Duckett 1998). Under this system, hospital admissions are classified into diagnostic related groups (DRGs) and hospitals are funded based on the number and type of patients treated according to a fixed payment schedule. Besides in-patient admissions which constitute the bulk of hospital services, other major activities include outpatient services, subacute and non-acute services, teaching and research, mental health services. These latter services are funded on a cost-recovery or block grant basis in Victoria.

In 2011/12, health care expenditures for Victoria were approximately A\$12 billion, accounting for about a quarter of the state's total operating expenses.¹ Of the state's total health spending, public hospitals take the largest share. Thus the productivity and efficiency of public hospitals have important budgetary implications. However, there have been few studies on hospital productivity in the published as well as grey literature, and little is known about public hospital productivity in Australia. This paper aims to fill that gap. By relating hospital productivity to observed characteristics of hospitals, it also aims to provide a starting point for policymakers and analysts to explore strategies to improve hospital productivity and efficiency.

We use Victorian hospital administrative data for the five-year period from 2007/08 to 2011/12 to construct quantity indices of output and inputs for public hospitals. Well known challenges in measuring outputs and inputs of hospital care (e.g., Triplett 2011; Chansky et al. 2013) are discussed and addressed. We examine the trends of both TFP level and growth of individual hospitals, and find a high degree of variation in TFP across hospitals. Moreover, TFP levels are found to be highly persistent over time, but not TFP

¹ 2011-12 Annual Financial Report, Victorian Department of Treasury and Finance.

growth. Large hospitals were found to perform significantly better than small hospitals, both in TFP level and growth. In other words, hospital productivity is found to be strongly and positively related to hospital size. This result holds whether hospital size is measured by output (in the form of number of admissions) or using an administrative grouping of hospitals according to size and function. Of equal importance is the finding of greatly varying productivity level and growth for hospitals of similar size. On this, it is noteworthy that previous research on UK hospitals has also reported similar findings (Castelli et al. 2015; Aragon Aragon et al. 2017).

In addition to individual hospital performance, we also assess the overall performance of public hospitals in the state by computing an output-weighted index of TFP level and growth of all hospitals. We find that TFP growth on average has been negative for the state. The finding of negative growth is consistent with studies of health care productivity from other countries, e.g., several US studies also find negative productivity growth for the medical care industry as a whole (Triplett and Bosworth 2004; Harper et al. 2010). However, in a later study Romley et al. (2015) reports positive and substantial estimates of productivity growth for US hospitals, although it should be noted that the estimates were obtained after adjusting for changes in quality and patient severity; without these adjustments the productivity growth estimates remain negative.

TFP concepts and computation

Productivity in the form of TFP and its growth can be estimated in a number of ways. In the published literature popular approaches include estimation using econometric models (e.g., stochastic frontier models), or via the method of data envelopment analysis. Alternatively, because the form of TFP as the ratio of output quantity to input quantity resembles an index number, it is natural to estimate it using an index number approach (Hulten 2001).

Underlying all concepts of productivity is a production technology that converts factor inputs into outputs. Under certain regularity conditions, the production technology can be represented in the form of a production function. We consider a production function of an output Y with a Hicks-neutral productivity term. Suppose there are H hospitals and T time periods, indexed respectively by $h = 1, \dots, H$ and $t = 1, \dots, T$. Let Y denote output and X^1, X^2, \dots, X^N denote inputs (e.g., labour, capital, material and other inputs) used in the production. The production function is specified as:

$$Y_{ht} = A_{ht} F(X_{ht}^1, X_{ht}^2, \dots, X_{ht}^N) \quad (1)$$

where A_{ht} is the Hicks-neutral productivity term that captures disembodied technology shifts, i.e., changes in production technology not tied to any specific inputs; in other words, it is a form of technological progress that affects all inputs proportionally.

It is important to note that the production function relates *quantity* of output to *quantity* of inputs. Thus to measure total factor productivity (TFP), i.e., to obtain a measure of the A_{ht} term in equation (1), we can re-arrange equation (1) to obtain:

$$\hat{A}_{ht} = TFP_{ht} = \frac{Qty\ output_{ht}}{Qty\ inputs_{ht}} \quad (2)$$

All measures of productivity take the basic form of a ratio of quantities of outputs to inputs. In practical applications with many inputs and outputs, some form of aggregation is necessary. To arrive at aggregate quantity measures of output and inputs, in principle one could use any set of weights to arrive at weighted sum of inputs and outputs, provided the weights do not change over time (if the interest is in making comparison of TFP over time). For example, if the output is an aggregate quantity of M categories of individual outputs, $Y_{ht}^1, Y_{ht}^2, \dots, Y_{ht}^M$, we can arrive at an aggregate output measure:

$$Qty\ output_{ht} = \sum_{j=1}^M p^j Y_{ht}^j$$

where p^j is the weight assigned to the j th output category and does not vary with time or across hospitals. Similarly, the input quantity can be aggregated if there exists a set of appropriate weights, w^i .

$$Qty\ inputs_{ht} = \sum_{i=1}^N w^i X_{ht}^i$$

In practice, it is common to use the relevant output and input prices as weights in constructing aggregate quantity of outputs and inputs.

Total factor productivity growth (TFPG) is defined as the rate of growth for the corresponding TFP level index, i.e., the productivity growth of a hospital h between two periods, t and s with $s < t$,

$$TFPG_h^{s,t} = \frac{TFP_{ht}}{TFP_{hs}} = \frac{Qty\ output_{ht}/Qty\ inputs_{ht}}{Qty\ output_{hs}/Qty\ inputs_{hs}} \quad (3)$$

As pointed out by Diewert and Nakamura (2005), equation (3) by construction includes a standard of comparison or point of reference in the definition of TFP growth; in this case the productivity level of period s is used as the reference. No such reference is made in the definition of TFP level in equation (2). The distinction becomes important if we make comparisons across hospitals, since a common point of reference will be required for such comparisons to be meaningful.

It is sometimes convenient to express equation (3) as:

$$TFPG_h^{s,t} = \left(\frac{Qty\ output_{ht}}{Qty\ output_{hs}} \right) / \left(\frac{Qty\ input_{ht}}{Qty\ input_{hs}} \right) = output\ growth / input\ growth \quad (4)$$

That is, TFP growth can be equivalently expressed as the ratio of output growth to input growth.

A key requirement in the computation of TFP level and growth is that both the numerator and denominator should only change in response to changes in quantity. The formulation of equation (3) also highlights the data requirements if we are to infer quantity measures from revenue or input cost measures, as will frequently be the case in practice.

Often data on capital, labour and material inputs are extracted from financial accounts, and these are normally denominated in nominal dollar values, i.e., in the form of factor payments or costs. To derive input quantity measures, we rely on the indirect approach (e.g, Eurostat 1995). To obtain a measure of TFP growth according to equation (4), we need to express the aggregate output and total input cost for period- s in period- t dollars; otherwise the measures of input growth and output growth would be conflated by changes in factor and output prices.

For inputs, we express the year- s total costs in year- t factor prices to arrive at the quantity volume of inputs:

$$Qty\ inputs_{h,s|t} = Costs_{h,s|t} = \sum_{i=1}^M w_t^i X_{hs}^i \quad (5)$$

where the subscript “ $s|t$ ” denotes year- s quantities evaluated at year- t prices. As the data are available in the form of factor payments, to obtain the hypothetical value in equation (5), we will need to remove the price change between the earlier year s and end year t . To do so, we use as the deflator the Laspeyres *price* index which measures the change in prices between years s and t weighted with the quantities of earlier year s . If factor i is labour, for example, then the Laspeyres price index of labour for years s and t measures the weighted price growth of various categories of labour between the two years using the earlier year- s labour quantities (e.g., hours worked) of the categories as weights. By using the Laspeyres price index to deflate the input costs, we express input costs of year s in year t prices to provide a Paasche input quantity index. Taking the ratio of these deflated costs for any two years, we obtain an index of real input growth.

Similarly, output data in practice are often available in the form of revenue, i.e., the product of price and quantity of outputs. In our context, however, this differs from the usual case because of the availability of hospital administrative records on patient admissions and emergency department (ED) presentations. Here, we are able to apply the direct approach of constructing the aggregate output quantity from first principles. We construct quantity measures for three types of care services, admitted acute patient care,

ED care, and rehabilitation and mental health care, for each hospital by using unit-record data on quantity. These three types of output are then aggregated using unit costs as weights to arrive at the total output measure.

The TFP level can then be constructed by taking the ratio of total output to total cost, both expressed in constant dollars:

$$TFP_h^{s,t} = Output_{h,s|t} / Cost_{h,s|t} \quad (6)$$

This TFP level measure is in effect a measure of output per dollar of cost, or equivalently, the inverse of average total cost. From equation (6), we obtain the corresponding TFP growth measure:

$$TFPG_h^{s,t} = \frac{Output_{ht} / Cost_{ht}}{Output_{h,s|t} / Cost_{h,s|t}} = \frac{Output_{ht} / Output_{h,s|t}}{Cost_{ht} / Cost_{h,s|t}} = \frac{Real\ output\ growth}{Real\ cost\ growth} \quad (7)$$

2.1 State-wide productivity of public hospitals

It is often desirable to provide an overall perspective of productivity level and growth for all public hospitals in a geographic area. The Victorian state government, as the manager and key funder of public hospitals in Victoria, has a keen interest in tracking the state-wide productivity level and growth, and understanding factors that affect the productivity of all public hospitals. This is particularly important if there are policy changes that can impact on the efficiency of hospitals across the board, e.g., the introduction of safety or quality measures that may affect costs and efficiency.

We compute the state-wide TFP level as the weighted average of TFP level indices of individual hospitals in the data, where the weight for a hospital h is the output of the hospital relative to the total output of all hospitals in the dataset, i.e., $output_{ht} / \sum_j output_{jt}$. Likewise, state-wide TFPG is the weighted average of TFP growth of individual hospitals, where the weights are the same relative-output weights.

The state-wide aggregate index of productivity level is defined as the ratio of aggregate outputs to aggregate inputs of all public hospitals in the dataset. The corresponding growth rate is simply the year-to-year change in the level index. For this measure to be meaningful, a balanced panel of hospitals is necessary, i.e., all hospitals included in the data must be observed every year during the data period. Further, an important and implicit assumption in constructing this aggregate measure is that there exists an aggregate production technology that governs the conversion of inputs into outputs for all public hospitals. This assumption is unlikely to hold in practice since, as will be seen below, hospitals vary greatly in their ability to convert inputs into outputs. Moreover, not all hospitals produce all output types, e.g., some hospitals do not provide ED care. Thus it is not practical to assume that they share a common aggregate production technology.

2.2 Regression analyses of productivity level and growth

To investigate how hospital productivity is related to factors such as size and patient casemix characteristics, we carry out several regressions with TFP level in logarithm as the dependent variable. Both ordinary least squares (OLS) and hospital fixed effects models are estimated. The fixed effects model accounts for unobserved hospital specific effects but cannot accommodate time-invariant factors such as hospital teaching status.

We further investigate the persistence of productivity by estimating regression models with lagged dependent variables on the right-hand side of the regression equation. Separate models were estimated for productivity level and growth, with lagged-one-year TFP and lagged-one-year TFPG as the respective lagged dependent variable. The coefficient of the lagged term, i.e., the autoregressive coefficient, provides a measure of persistence of productivity.

Data

The output and input data used to construct TFP are extracted from datasets maintained by the Victorian Department of Health and Human Services (DHHS). The data cover the five-year period from 2007/08 to 2011/12. For outputs, we construct direct measures using episode-level administrative data, input information is gleaned from the financial statements of public hospitals. After dropping observations with missing input or output values, and removing extreme values (12 observations) and very small hospitals with less than 100 admission episodes a year (8 observations), we have a data set of 470 observations, consisting of 97 hospital campuses observed over five years.

The enumeration of outputs in principle ought to include all activities taking place in hospitals, including admitted acute patient care, ED care, rehabilitative and palliative care, mental health care, and all other activities such as teaching and research. In practice the enumeration depends on data availability of the quantity as well as prices of different categories of outputs. We distinguish the following categories of outputs: (i) Admitted acute patient care, (ii) ED care, (iii) rehabilitative and mental health care. Data on these output components were extracted from administrative datasets, including the Victorian Admitted Episodes Dataset, the Victorian Emergency Minimum Dataset, and relevant administrative datasets on various rehabilitative, palliative and mental health care services. These three types of output account for more than 90 per cent of revenue for most hospitals in our data.

The aggregate input measure is constructed using dollar costs of labour, capital and material inputs. Labour and material costs are obtained from hospital financial data maintained by DHHS. Capital costs are the sum of two components: the opportunity cost

of capital and the obsolescence of capital stock. All costs were deflated using the relevant price indices.

Recall that to deflate factor payments we require the relevant Laspeyres price indices. However, in practice the required Laspeyres price indices may not be readily available. In our case a key price index, the Australian Consumer Price Index (CPI), uses a set of reference quantity weights obtained from the 2009-10 Household Expenditure Survey. The price index therefore neither uses the base year's quantity weights as per the Laspeyres index, nor those of the current year as per the Paasche index. The resulting index is known as the Lowe index (ABS 2011). In applying equations (6) and (7), we make use of the Lowe index as an approximation to the required Laspeyres price index.

Below is a detailed description of how output and input measures are constructed.

3.1 Output quantity measure

Three types of hospital outputs are distinguished: (i) admitted acute patient care, (ii) ED services, (iii) rehabilitation services, palliative care and mental health care services. The first two account for the majority of the output in most hospitals. These three output types were converted into constant dollars and aggregated to arrive at an aggregate output measure. For admitted acute patient care services, we first used casemix or DRG weights (known as WIES weights) to aggregate acute admission episodes. Because the classification of admission episodes into DRGs can change between versions, it is necessary to 'back-cast' latter-year DRG versions to classification of admission episodes of earlier years. For the purpose of keeping the aggregation weights constant, we apply the weights of the latest version (version 18) to admission episodes of all previous years in the data. The back-casting was performed by the DHHS for all admitted patient records in the data. The next step is to convert the aggregated admission episodes into constant dollars using the unit price of WIES (known as WIES price). For this purpose, the price per unit of WIES for 2011-12 was used to establish a dollar value to the weighted episodes corresponding to all years.

For aggregating ED services, we made use of the weights (known as Urgency Related Groups or URGs) constructed by the Independent Hospital Pricing Authority (IHPA). Each ED presentation is assigned an URG based on the triage category, diagnosis and disposition of the presentation. ED services across all years were aggregated using URG version 1.4, and the resulting aggregate was converted into constant dollars using the National Efficient Price determined by IHPA (see IHPA 2012).²

²The document is available online at <http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/nat-price-tech-spec-2012-13>.

For rehabilitation, palliative care and mental health care, the activity levels (in total LOS for each care type) of these services were taken from the respective administrative data records and these services were aggregated using the relevant funding rates for 2011-12 to arrive at a service amount valued at 2011-12 dollars.

Finally, a single aggregate output measure in constant dollars is obtained by adding the three component services discussed above, all valued at 2011-12 dollars. Taking the ratio of these constant-dollar total output for any given two years gives an output growth index in the form of a Paasche output quantity index.

3.2 Labour input quantity measure

Labour cost data were obtained from the financial statements of hospitals. The costs represent all labour-related expenditures incurred by hospitals for health services provision; these include salaries, payroll tax, workers' compensation and superannuation. Note that expenditures on contract workers and visiting medical officers were included in the labour cost calculation, and all labour expenditures related to the provision of non-health services were excluded.

To obtain labour costs in constant 2011-12 dollars, we deflate total labour costs using the price index for "professional health workers wage rates" compiled by the Australian Institute of Health and Welfare.³

One complication with using financial data is that the unit of observations is hospital agency, and some agencies comprise several hospital campuses. Since the unit of analysis is hospital campus, it is necessary to allocate the deflated labour costs to hospital campuses for agencies that comprise multiple campuses. We do this using output share of hospital campuses in an agency for allocating the labour costs of the agency, on the ground that within agency labour costs should be directly related to output.

3.3 Capital input quantity measure

Capital input quantity is measured using constant-dollar costs of capital use, which consists of two components: obsolescence of capital assets and the opportunity costs of capital. The former was taken as the depreciation charged to capital assets and the latter was measured using the long-term Treasury bond rates. The values of depreciation were taken from the financial statements of hospitals and they consist of depreciation of all fixed assets except land. The opportunity costs of capital were computed as the product of

³ see AIHW (2014), Health expenditure Australia 2012-13. Health and welfare expenditure series no. 52. Cat. no. HWE 61. Canberra: AIHW; available online at <http://www.aihw.gov.au/publication-detail/?id=60129548871>.

the 10-year Australian Government Bond rate and gross capital stock values. The former can be obtained from the publications of the Reserve Bank of Australia.⁴

For the construction of capital stock values, we rely on financial information pertaining to balance sheet data on capital assets. The data distinguish three types of capital assets: land, building, and equipment. The last is a catch-all category that includes all fixed assets other than land and buildings. Although the data also contain several sub-categories of machinery and equipment, there is variation in their use across years thus these are not used because their consistency over years could not be assured. We make use of total asset values of building and equipment. Land is not included in the construction of capital stock, although, in principle land should also be considered as a factor of production much like other capital assets. However, it is excluded because land tends not to depreciate but rather appreciate in value and was subjected to re-valuation at irregular intervals, and there were also concerns that revaluation may not be consistently done across hospitals.

The data contain asset valuation at the end of the financial year, net of additions to assets and depreciation of assets that occurred during the year. Using this information, it is possible to derive the asset value at the beginning of the financial year. The total asset value at the beginning of the year was used in the calculation of the opportunity cost of capital.

To aggregate building and equipment into a single capital input measure, we need to deflate these asset values using appropriate price indices. For our purposes, the price index series used was “state territory and local government gross fixed capital formation” index compiled by the Australian Institute of Health and Welfare (AIHW 2014).

As in the case of labour cost computation, a complication arises due to the unit of observations in the data being at the hospital agency level. Some hospital agencies comprise two or more hospital campuses. Hence it is necessary to allocate the constructed capital stock values from hospital agencies to the associated campuses. The allocation weight used here was based on the physical floor area of individual campuses. Unfortunately, the floor area information was only available for the year 2011 when a capital asset census was conducted. This information was used to allocate capital costs of all years, under the assumption that floor areas of hospital campuses do not change much over time.

3.4 Material input quantity measure

Material inputs refer to all intermediate inputs used for the production process. In the context of hospital production they include drugs, medical supplies, foods, domestic services, utilities, repair and maintenance, etc. Information for these items was obtained

⁴ See under interest rates: <http://www.rba.gov.au/statistics/historical-data.html#interest-rates>.

from financial statements. The following intermediate input categories were available: (i) drug supplies; (ii) S100 (drug supplies falling under the Highly Specialised Drugs Program of the Pharmaceutical Benefits Scheme); (iii) medical, surgical supplies and prostheses; (iv) pathology; (v) food supplies (vi) domestic services and supplies; (vii) fuel, light, power and water (utilities); (viii) repair and maintenance; (ix) others.

The nominal monetary values of these material costs were deflated using the appropriate index items in the Consumer Price Index (CPI) collection provided by the Australian Bureau of Statistics. Drug costs, S100 drug supplies, medical, surgical supplies and prostheses, and pathology costs were deflated using the CPI for Pharmaceutical products; food supply costs were deflated using the CPI for Food and non-alcoholic beverages; costs of domestic services and supplies were deflated using the CPI for Domestic and household services; fuel, light, power and water costs were deflated using the CPI for Utilities; repair and maintenance costs were deflated using the CPI for Maintenance and repair of the dwelling; other costs were deflated using the general CPI for all product groups.

The same allocation issue arises because the material costs data were obtained from hospital financial statements which were reported at hospital agency level. To allocate material costs from agencies to hospital campuses, we follow the same allocation rule used in allocating labour costs by using the output shares of hospital campuses in an agency as weights.

Results

The two key components for computing TFP, the aggregate quantity values of outputs and inputs, are computed for each hospital in the data using the process outlined in the preceding section. Table 1 presents some summary statistics of these two quantity measures. Also included is the number of hospital campuses observed each year, which vary between 93 and 95. From the standard deviation values, it is evident that a large degree of variation is present in both input and output quantities. The variation is also increasing over time. On average aggregate output levels were generally about 55 per cent of the levels of aggregate input. The average quantity values of inputs and outputs do not reflect the high degree of heterogeneity between hospitals; in particular hospitals in different groupings show substantial differences in input and output quantities and input-to-output ratios. Figure 1 depicts the input and output quantities by hospital group, where hospitals were grouped by size as 'teaching and large,' 'medium,' 'small,' and 'sub-acute and specialty hospitals,' in accordance to the administrative classification used by DHHS.

Figure 1 plots output against input quantities in scatter plots by hospital group; all observations can be found in the lower half of the 45-degree line, meaning that input quantities are greater than output quantities in all cases. This likely reflects the fact that outputs are valued using WIES weights and prices, which are generally below the actual costs of services, whereas inputs are valued at market prices. In addition, certain output

activities such as research and teaching, are not included in the output computation due to lack of data, although we note that such activities typically account for less than 5 per cent of total output for most hospitals. Noting that the scale for each plot is different, we note that the degree of heterogeneity shown in Figure 1 is very high, particularly for small hospitals whose input quantities were more than three times those of outputs.

Table 2 shows the corresponding rates of growth of inputs and outputs from 2008/09 to 2011/12. During the period input growth clearly outstrips the growth in output on average. The mean and median input growth rates were respectively 3.7 and 3 per cent, while outputs on average were growing at around 1 per cent. This means productivity growth on average would be negative, as will be seen below. Note, however, that because the standard deviations of input and output growth are relatively large in relation to the mean, there is a large degree of variations across hospitals in growth rates, especially of output growth.

Using the aggregate input and output quantity indices, we compute the TFP level index for each hospital campus according to equation (6). TFP growth is simply the year-on-year change of the corresponding TFP level index, as given in equation (7). The computed TFP and TFPG index values are summarised in Table 3. The TFP level index suggests that the aggregate output of public hospitals was about 40 per cent of aggregate costs. Note that this average refers to the average TFP across all hospitals and years; it differs from the ratio of the average aggregate output to average aggregate inputs reported earlier.

Because inputs grew at faster rates than outputs during this period (see Table 2), unsurprisingly the TFPG index during this period was on average negative, although the relatively high standard deviations suggest a high degree of heterogeneity and that some hospitals were experiencing positive productivity growth. However, on average TFPG fell at a mean rate of 2.6 per cent per year during this period; the corresponding median rate of decline was 2.3 per cent. We further note that a high degree of heterogeneity is present in TFP level and growth across different hospital groups, as shown in Table 4, where the unweighted (i.e., hospitals are given equal weights regardless of size) mean hospital TFP level and growth are shown by hospital group.

It can be seen from Table 4 that small hospitals as a group are noticeably different from other hospitals—their TFP level and growth are on average substantially lower than other hospitals. Teaching and large hospitals have the highest average TFP level, while medium hospitals were on average experiencing the highest TFP growth, although the latter was due primarily to a very high positive growth rate in 2011/12.

Table 5 presents an overview of productivity level and growth across all public hospitals in the data by presenting weighted average values of TFP and TFPG of all hospitals, where the weight for a hospital is its relative output share of total output of all hospitals in

the data. Since we capture most public hospitals in the data, these weighted averages provide a measure of the state-wide productivity of public hospitals. Table 5 suggests that, once size is taken into account, TFP level indices have risen to above 56 per cent and the decline in TFPG has moderated to 1.2 per cent per year over the period.

The relationship between productivity and size is illustrated in Figure 2, which shows the relationship using scatter plots with output re-scaled in natural logarithm. The left panel shows a strong log-linear relation between TFP level and output, although it is also evident that there are substantial variations throughout the output range. In particular, within the range of log-output 10 and 12 (equivalent to output level of \$22m and \$162.7m), the best hospitals near the top showed TFP level of close to unity, while a few at the bottom registered TFP level of just above 0.2. Interestingly, there appears to be a peak within this output range, beyond which the TFP level of the largest hospitals begins to fall. A possible explanation could be the non-inclusion of teaching and research activities in the output measure. Since large hospitals tend to engage in these activities more than smaller hospitals, their outputs are likely undervalued due to the non-inclusion.

The right panel of Figure 2 shows the relationship between TFPG and output. Overall, 110 out of 373 observations, or approximately 30 per cent, showed positive annual TFPG. Although there appears no obvious log-linear relation with size, the funnel-shaped pattern suggests that small hospitals exhibited a much higher degree of variability in TFPG than large hospitals. Large hospitals appear to have growth rates clustering around zero, with more observations in the negative half of the graph. In contrast, the growth rates of small hospitals were more widely dispersed, ranging from -40 to +40 per cent per year.

Regression analysis

To further investigate how productivity is related to the size and casemix characteristics of hospitals, we carry out several regressions and report the results in Table 6. The dependent variable is TFP level in logarithm. The table contains the results of five models, the first three are OLS regressions with robust standard errors while the last two (Models 4 and 5) are fixed effects regressions. Model 1 includes only hospital grouping, which is broadly based on size and function, as explanatory variables, while additional casemix characteristics (proportion of admissions via ED and proportion of private-patient days) were added in Model 2. Model 3 is the same as Model 2 but uses the number of admission episodes as a measure of hospital size. For fixed effects estimation, hospital grouping is time invariant hence cannot be included as explanatory variables. Hence Models 4 and 5 use logarithm of output as the size measure, with additional casemix characteristics included in the latter.

The results are consistent with the earlier findings and show that large hospitals are considerably more productive than small hospitals in TFP level. The same result is obtained regardless of whether we use hospital group or admission episodes as the size

variable. Interestingly, with the exception of hospital size and the proportion of older patients (aged 76 or older), other hospital casemix characteristics did not appear to be statistically significant after controlling for hospital fixed effects in Model 5.

Persistence of productivity

To examine the persistence of hospital productivity, we divide hospital-level TFP and TFPG into quintiles for each year and track the movements in quintiles for each hospital over adjacent years. The results, shown in Table 7, reveal very distinct patterns for TFP level and growth. For TFP level, close to 90 per cent of hospitals remained in the same quintile over successive years; movements in quintiles either up or down are rare. In contrast, for TFP growth, only about 20 per cent of hospitals remain in the same quintile over successive years; moving up in quintiles is as common as moving down. In short, there is a high degree of persistence in TFP level but not in growth.

The persistence of TFP level means that the level of productivity for hospitals remains largely unchanged over time—high productivity hospitals remain high while low productivity hospitals remain low. High persistence of TFP level coupled with low persistence of TFP growth implies that TFP differences between hospitals, i.e., the dispersion, will tend to persist over time. The dispersion is also large; the median TFP level of the top quintile is about 4.7 times that of the bottom quintile. The dispersion and persistence of hospital productivity are consistent with findings about firms in manufacturing industries; e.g., Syverson (2004); Hsieh and Klenow (2009).

We further investigate the persistence of productivity by estimating regression models with lagged dependent variables. Separate models were estimated for productivity level and growth, with lagged-one-year TFP and lagged-one-year TFPG as the respective lagged dependent variable. The coefficient of the lagged term, i.e., the autoregressive coefficient, provides another measure of persistence of productivity.

In addition to the lagged dependent variable, other explanatory variables included in the models are number of admission episodes, proportion of admissions via ED and time dummies. For each case of TFP level and growth, three regression models were estimated: OLS, fixed effects and system GMM. It is known that both OLS and fixed effects estimation produce biased estimates due to the problem of dynamic panel bias whereby the lagged dependent variable is correlated with the errors. However, these estimates are useful since they form a bound within which any reasonable estimate of the autoregressive coefficient should fall. To correct for the dynamic panel bias, we estimate the system GMM model by using the Stata command *xtabond2* (Roodman 2009).⁵

⁵ In using *xtabond2* for the system GMM estimation, the lagged dependent variable and lagged number of admission episodes were used as GMM style instruments with the “collapse” option, while for IV style instrument, year dummies and an additional variable, proportion of private patient days, were used with the

Tables 8 and 9 show the estimated results. The autoregressive coefficients of the OLS and fixed effects models are respectively 0.96 and 0.20, both positive and statistically significant. The system GMM estimation gives an estimate of 0.82, which lies between the OLS and fixed effects estimates, but is much closer to the former than the latter. The GMM result shows that TFP levels are strongly persistent. Note that the effect of hospital size (measured as the number of admission episodes) is small and not statistically significant in the GMM model. This is possibly a result of the size variable having low variability over time within hospitals, i.e., hospital size tends not to vary much over time for any given hospital. As a result, the effect of size is likely absorbed by the autoregressive coefficient, resulting in the small and statistically insignificant size coefficient.

Table 9 presents the estimation results for TFP growth. For all three models, the autoregressive coefficients are negative and statistically significant. The GMM estimate is -0.37 and is again closer to the OLS estimate than to that of fixed effects estimation. A negative coefficient suggests that a high TFP growth in one year is likely to be followed by a low growth rate in the next year. This result is unsurprising, since it is easier to attain high growth rates for hospitals starting with a low base; it is uncommon for hospitals to attain high growth rates over successive years.

Conclusions

Hospital expenditures have been growing rapidly in many developed economies, putting increasing pressure on public finances. In this environment, improving the productivity and efficiency of hospitals is an attractive option for policymakers. This paper provides an overview of total factor productivity of public hospitals in Victoria using an index number approach. Productivity is measured at the hospital level by comparing aggregate quantities of outputs to aggregate quantities of inputs. A distinction is made between productivity level and growth. The former measures the production capability of hospitals to convert inputs into outputs, while the latter measures the change in this capability over a reference period. Using the level and growth measures, this paper tracks the changes in productivity of Victorian public hospitals over the period 2007/08–2011/12.

Overall, we find negative productivity growth for public hospitals in the state of Victoria during the study period. This result is consistent with findings on health sector productivity from the U.K. and U.S. Similar to the results reported in Castelli et al. (2015) about UK hospitals, we also find substantial variations in productivity across public hospitals in Victoria. There is also a high degree of heterogeneity in both productivity

“passthru” option. Variables were transformed using forward orthogonal deviations (Arellano and Bover 1995).

level and growth. Average TFP level of hospitals in the top quintile is found to be about 4.7 times that of those in the bottom quintile.

The heterogeneity is closely related to hospital size. Large hospitals are found to consistently outperform small hospitals both in productivity levels and growth. This result holds whether hospital size is measured using the number of admission episodes or by the administrative grouping of hospitals according to size and function. However, even between hospitals of the same size, substantial variation in productivity exists. This is most obvious in TFP growth, where small hospitals exhibited substantially more variability than large hospitals.

We also find strong persistence in hospital productivity levels over time but not in productivity growth. The non-persistence of productivity growth is consistent with the findings of a recent study of UK hospitals (Aragon Aragon 2019). These results taken together imply that productivity differences between high and lower productivity hospitals do not diminish over time unless there are external factors that promote improvements in the production technology.

The findings suggest that the operation of small hospitals would be an area of focus for policymakers. A policy option that deserves investigation is facilitating mergers of small hospitals in close proximity to each other. However, it is worth noting that small hospitals are usually located in geographically remote areas serving specific communities and with specific roles and functions. They are likely to be organised quite differently from large hospitals or from small hospitals in populated areas.

Of equal importance is to understand why hospitals of similar size differ in their productivity levels. An issue deserves further investigation is the extent to which productivity heterogeneity could be attributed to data artefacts, since our data on outputs did not include teaching and research, which are relevant for large hospitals, and outpatient care and thus possibly resulting in underestimation of output for small hospitals. Another area for future research is the link between hospital productivity and economies of scale and scope in hospital operations; these issues are not easily accommodated using the index number approach and which would require a different approach.

It is worth noting that we have not attempted to account for the quality of outputs in this study. There is no consensus on how to adjust for hospital quality in the literature. Castelli et al. (2015) incorporate an ad-hoc QALY-based adjustment term in aggregating outputs for UK hospitals, while Romley et al. (2015) appear to adjust for quality of US hospitals by excluding admission episodes involving patients who died within 30 days of admission or patients who were readmitted within 30 days of discharge. The results were drastically different—Castelli et al. (2015) find quality adjustment to have negligible effects on UK hospital productivity, but Romley et al. (2015) find that US hospital

productivity improved from negative growth to substantial positive growth after making quality adjustment. Neither approach is particularly convincing. We believe a new approach is needed and should be the focus of future research.

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Tables and Figures

Table1: Output and input quantity measures, summary statistics

	Output (\$'000)			Input (\$'000)			N
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	
2007/08	47,645.3	12,261.8	75,079.8	87,369.6	35,355.8	138,257.6	93
2008/09	47,641.1	11,942.5	76,598.2	89,932.5	34,108.1	143,773.2	95
2009/10	50,290.9	12,575.8	80,791.4	96,430.8	35,862.8	152,630.5	93
2010/11	50,897.2	12,019.1	83,348.6	97,657.2	36,439.5	156,270.9	95
2011/12	52,576.6	12,889.5	85,545.7	101,394.9	37,597.7	160,841.5	94
All years	49,811.5	12,295.3	80,058.1	94,565.1	35,740.9	150,044.8	-

Table 2: Output and input growth, summary statistics

	Output growth			Input growth			N
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	
2008/09	1.10%	0.20%	15.00%	4.50%	2.90%	10.40%	93
2009/10	1.40%	1.20%	10.00%	5.30%	5.40%	6.10%	92
2010/11	1.30%	1.80%	10.10%	3.10%	2.80%	5.60%	94
2011/12	0.20%	1.30%	9.90%	2.10%	1.60%	4.80%	94
All years	1.00%	1.10%	11.40%	3.70%	3.00%	7.10%	-

Table 3: Hospital TFP level and growth, summary statistics

	TFP Level			TFP Growth		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
2007/08	0.444	0.463	0.205	-	-	-
2008/09	0.421	0.446	0.204	-3.4%	-3.2%	8.0%
2009/10	0.415	0.422	0.192	-3.7%	-3.5%	8.7%
2010/11	0.406	0.413	0.196	-1.7%	-0.8%	8.4%
2011/12	0.402	0.410	0.200	-1.8%	-1.2%	9.9%
All years	0.418	0.430	0.199	-2.6%	-2.3%	8.8%

Table 4: Hospital TFP level and growth, unweighted mean by hospital grouping

	TFP Level				TFP Growth			
	Teachin g	Mediu m	Small	Sub-acute & Specialty	Teachin g	Mediu m	Small	Sub-acute & Specialty
	& large				& large			
2007/08	0.617	0.529	0.295	0.551	--	--	--	--
2008/09	0.599	0.514	0.272	0.536	-2.7%	-2.6%	4.4%	-2.6%
2009/10	0.588	0.502	0.268	0.518	-1.7%	-2.0%	5.5%	-3.3%
2010/11	0.588	0.495	0.257	0.519	0.1%	-1.7%	3.0%	0.3%
2011/12	0.581	0.502	0.243	0.520	-1.4%	1.8%	4.4%	-0.1%
All years	0.595	0.509	0.267	0.529	-1.4%	-1.1%	4.3%	-1.4%

Table 5: Weighted average TFP level and growth

	TFP	TFPG
2007/08	0.583	-
2008/09	0.566	-2.83%
2009/10	0.555	-1.64%
2010/11	0.557	0.15%
2011/12	0.555	-0.49%
All years	0.563	-1.20%

Note: Weighted average is computed using relative output as weights.

Table 6: Regressions of TFP level

Dep. Var. = TFP	Model	Model	Model	Model	Model
	1	2	3	4	5
	OLS	OLS	OLS	FE	FE
Hospital Grouping					
(Ref: Teaching & large hospitals)					
Medium hospital	-0.195 *	-0.275 *			
	(0.079)	(0.085)			
Small hospital	-0.934 *	-0.917 *			
	(0.091)	(0.097)			
Sub-acute / Sepcialist hospital	-0.151	-0.256 #			
	(0.093)	(0.137)			
Prop. admissions via ED		-0.603 *	-0.554 *		0.013
		(0.234)	(0.157)		(0.032)
Prop. private-patient days		-0.953 *	-0.607		-0.007
		(0.448)	(0.416)		(0.075)
Prop. age 76 years or older					-0.243 *
					(0.065)
Prop. Charlson index 6 or higher					-0.672
					(0.598)
Ln(admission episodes)			0.242 *	0.630 *	0.628 *
			(0.023)	(0.026)	(0.027)
Year dummies					
(Ref: Year 2007/08)					
Year 2008/09	-0.057 *	-0.057 *	-0.054 *	-0.040 *	-0.040 *

		*		*		*		*		*
	(0.014)		(0.017)		(0.013)		(0.007)		(0.007)	
Year 2009/10	-0.058	*	-0.063	*	-0.076	*	-0.087	*	-0.087	*
	(0.028)		(0.029)		(0.023)		(0.007)		(0.008)	
Year 2010/11	-0.082	*	-0.096	*	-0.110	*	-0.112	*	-0.110	*
	(0.029)		(0.032)		(0.025)		(0.007)		(0.008)	
Year 2011/12	-0.111	*	-0.117	*	-0.130	*	-0.133	*	-0.131	*
	(0.032)		(0.035)		(0.028)		(0.007)		(0.008)	
Constant	-0.472	*	-0.110		-2.975	*	-6.915	*	-6.824	*
	(0.045)		(0.114)		(0.277)		(0.248)		(0.252)	
N	470		470		470		470		470	
Adj. R-squared	0.468		0.523		0.659		0.635		0.648	

Note: Figures in parentheses are standard errors.

Significance levels: #10% *5% **1%

Table 7: Quintile movements of TFP level and growth

	TFP quintile			TFPG quintile		
	Unch'ged	Moved up	Moved down	Unch'ged	Moved up	Moved down
From 2007/08 to 2008/09	83	8	1	–	–	–
From 2008/09 to 2009/10	79	3	10	16	35	39
From 2009/10 to 2010/11	84	7	2	22	34	36
From 2010/11 to 2011/12	84	4	6	17	35	41
Total	330	22	19	55	104	116

Table 8: Regressions of TFP with lagged dependent variables

Dep. Var. = TFP	Model L1		Model L2		Model L3	
	OLS		FE		GMM	
TFP lagged 1 year	0.960	**	0.199	**	0.823	**
	(0.009)		(0.047)		(0.220)	
ln(no. of admission episodes)	0.004	**	0.157	**	0.029	
	(0.001)		(0.010)		(0.035)	
Prop. admissions via ED	0.006		0.013		0.008	
	(0.006)		(0.011)		(0.068)	
Year dummies (Ref: 2008/09)						
Year 2009/10	0.002		0.015	**	0.005	
	(0.003)		(0.002)		(0.007)	
Year 2010/11	0.008	**	0.018	**	0.003	
	(0.003)		(0.003)		(0.009)	
Year 2011/12	0.008	*	0.021	**	0.003	
	(0.003)		(0.003)		(0.011)	
Constant	-0.033	**	-1.144	**	0.210	
	(0.007)		(0.096)		(0.229)	
Sargan test of overid. (p-value)	–		–		0.655	
Hansen test of overid. (p-value)	–		–		0.934	
No. of obs.	373		373		373	

Note: Figures in parentheses are robust standard errors.

Significance levels: #10% *5% **1%

Table 9: Regressions of TFPG with lagged dependent variables

Dep. Var. = TFPG	Model G1		Model G2		Model G3	
	OLS		FE		GMM	
TFPG lagged 1 year	-0.364	**	-0.501	**	-0.372	**
	(0.056)		(0.047)		(0.130)	
ln(no. of admission episodes)	0.011	**	0.718	**	0.028	
	(0.003)		(0.058)		(0.020)	
Prop. admissions via ED	-0.043	#	-0.090		-0.087	
	(0.025)		(0.066)		(0.126)	
Year dummies (Ref: 2009/10)						
Year 2010/11	0.017		0.010		0.017	
	(0.012)		(0.009)		(0.011)	
Year 2011/12	0.023	#	0.020	*	0.024	#
	(0.012)		(0.009)		(0.013)	
Constant	1.229	**	-5.369	**	1.085	**
	(0.060)		(0.561)		(0.204)	
Sargan test of overid. (p-value)	-		-		0.102	
Hansen test of overid. (p-value)	-		-		0.369	
No. of obs.	276		276		276	

Note: Figures in parentheses are standard errors.

Significance levels: #10% *5% **1%

Figure 1: Output and input quantity measures, by hospital grouping

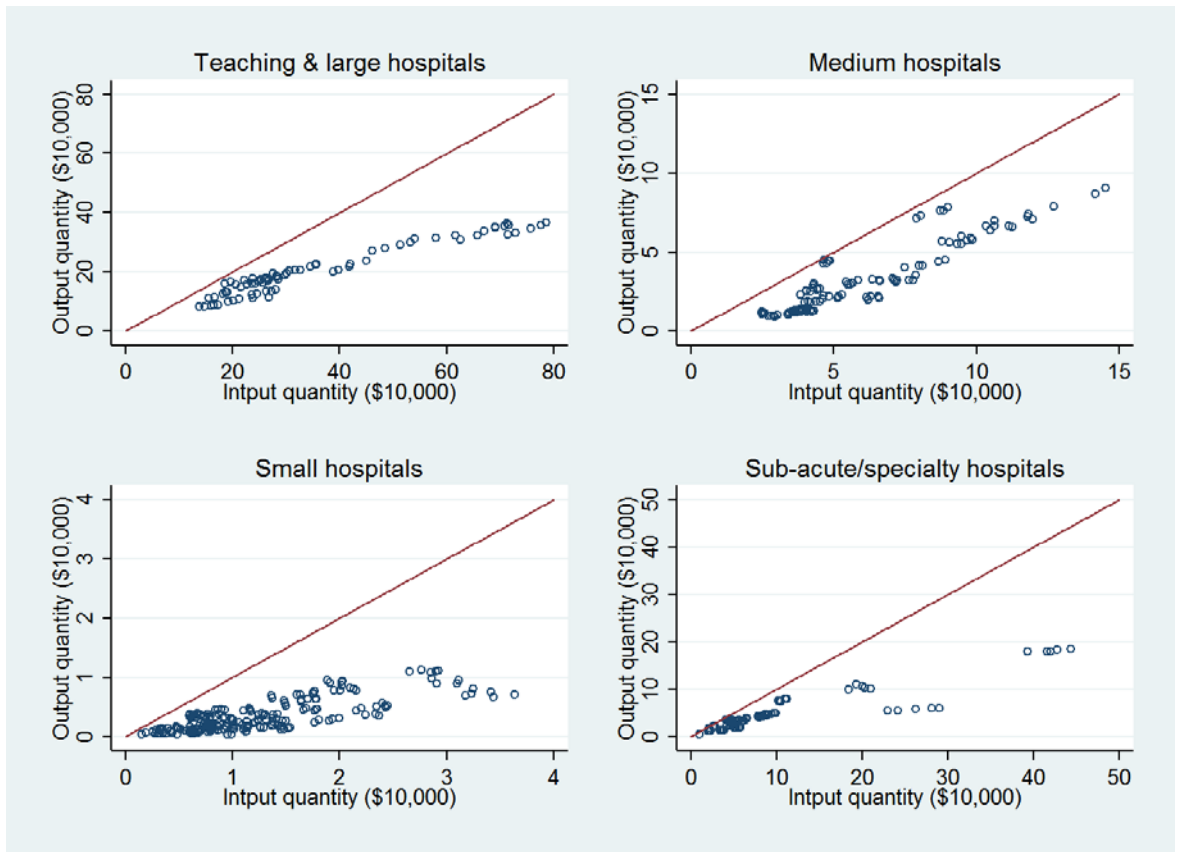


Figure 2: Scatter plots of TFP level and growth against $\ln(\text{output})$

