Public sector productivity

Quality adjusting sector-level data on New Zealand schools

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The New Zealand Productivity Commission (Te Kōmihana Whai Hua o Aotearoa[1]) – an independent Crown Entity – completes in-depth inquiry reports on topics selected by the Government, carries out productivity-related research, and promotes understanding of productivity issues. The Commission's work is guided by the *New Zealand Productivity Commission Act 2010*.

Information on the Commission can be found on www.productivity.govt.nz or by calling +64 4 903 5150.

[1] The Commission that pursues abundance for New Zealand.

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1 Executive summary

Statistics New Zealand has estimated that since 1996 increases in outputs of the public sector have largely been associated with increasing labour inputs. In the education sector, for example, the average annual increase in output of 1.0% between 1996 and 2015 was composed of average annual labour input growth of 2.5% while labour productivity fell on average by 1.5% per annum. These data use standard aggregate productivity methods and are not part of the National Accounts.[2] They involve no explicit quality adjustment. This is important as it is difficult to fully understand productivity data (especially trends over time) without considering the impact of changes in quality.

Yet while important in principle adjusting public sector productivity data for quality changes is complex in practice. As an example, the United Kingdom Office for National Statistics (ONS) has had to revise its approach to quality adjusting education quantity when practices regarding students sitting exams changed.[3] This paper thus estimates a range of quality adjusted productivity measures and discusses the benefits and risks of different approaches (e.g., regarding teacher salaries, students' performance in tests, or impact on earnings). The measures are illustrated with data on schools.

Why education?

A focus on the productivity of the education sector is consistent with a desire to help upskill the economy (Atkinson, 2005) and the Better Public Services programme.[4] This is also a topic of interest to researchers concerned with productivity measurement more generally given the variety of messages that emerge for this sector from different approaches to productivity analysis. While national accounts data show declining labour productivity in the education sector as a whole a number of cross country studies (largely focussing on schools) have suggested that the New Zealand education system performs relatively well internationally (e.g., Afonso and Aubyn, 2005; Sutherland et al., 2007; and Schreyer, 2010). More recent work (Dutu and Sicari, 2016), has however, suggested that New Zealand may have fallen back to the middle of the pack.

This investigation on quality adjustment and school productivity could thus help with interpretation of any evidence of a lagging productivity performance in the public sector,

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[2] As discussed in 3.1, these data are based on the industry classification of output and so include a mixture of organisations in public and private ownership. These figures also include outputs which are traded for economically significant prices (e.g., in markets). Public sector industries (education and training, health and social care, central government administration and local government administration), along with owner occupied housing, make up what Statistics New Zealand refer to as the non-measured sector. Based on a production measure of GDP public sector output as percentage of total industry output was 15.8% in 2015.

[3] This is significant as any quality adjustment makes a substantial difference to measured productivity. From 1997 to 2011, quality-adjusted output growth in the United Kingdom education sector grew at an annual average rate of 2.7%. Of this the quality adjustment accounted for 90%, or an annual rate of growth of 2.5% (Caul, 2014, p. 8).

[4] This programme set out ten specific challenges for the public sector to achieve over a five year period to 2018. Two of these relate to education and are aimed at boosting skills and employment. The targets are: 85% of 18-year-olds will have NCEA Level 2 or an equivalent qualification by 2017; 60% of 25-34 year olds will have achieved qualifications at NZQF Level 4 and above by 2018.

including whether this tells us something about the public services themselves or more about the measures being used.

So what difference could quality adjustment make?

Estimates of labour and multifactor productivity including quality adjustments for New Zealand schools were developed using data at the sector-level (the measures and key results are summarised in Table 1). To illustrate the potential of existing data – and also to allow these measures to be replicated – emphasis was given to using data from publicly available sources.

Table 1 Examples of quality adjustments for schools

Measure	Formal equivalent	Data	Results
Basic labour productivity (Total Student Places / Teacher FTEs)	Q/L	Total student places based on data for student roll by school type. Excludes students in private schools. FTE teachers (headcount for 2001 and earlier) in state and state integrated schools based on education counts data. Teaching staff includes principal, management, teacher, resource teachers, community education, guidance and therapists	Declined by 1.0% on average between 2002 and 2014, with the fastest decline between 2002 and 2008
Basic multifactor productivity (Total Student Places / School Revenue)	Q/(wL+rK+mM)	Total student places as above. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation is based on the full CPI	Declined by 1.7% on average between 2002 and 2014, also with the fastest decline between 2002 and 2008
Labour productivity based on adjusted labour input (Total Student Places / Teacher Salaries)	Q/wL	Total student places as above. Expenditure on teacher salaries (primary and secondary) in state and state integrated schools from education counts. Indexation is based on the full CPI	Declined by an average of 2.0% between 2002 and 2014, although grew by an average of 0.2% between 2008-2014
Labour productivity based on adjusted output (pupil attainment) (Aggregate PISA Points / Teacher FTEs)	pQ/L	Total student places (primary and secondary) weighted by attainment in unweighted averages of the reading, mathematics and science PISA scores. Primary and secondary teacher FTEs	1.1% average decline between 2003 and 2015 (if using only secondary students and FTE teachers the decline was 1.0%)
Labour productivity based on adjusted output (pupil attainment) (Students Achieving Domestic Standard / Teacher FTEs)	pQ/L	Total student places (primary and secondary) weighted by share of students leaving school with NCEA level 2 (or equivalent) or more. Primary and secondary teacher FTEs	0.8% average increase between 2002 and 2014
Multifactor productivity based on adjusted output	pQ/(wL+rK+mM)	Total student places (primary and secondary) weighted by share of students leaving school	0.5% average decrease between

Measure	Formal equivalent	Data	Results
(pupil attainment) (Students Achieving Domestic Standard / School Revenue)		with NCEA level 2 (or equivalent) or more. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation is based on the full CPI	2002 and 2014. This series is most directly comparable to the quality adjusted series used by the ONS
Labour productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real Expected Income / Teacher FTEs)	pQ/L	Data on school levers by three categories of attainment, average weekly incomes for people over 15 in employment for each category from New Zealand Income Survey, average unemployment rate for each category for June year. Primary and secondary teacher FTEs	0.2% average decline between 2002 and 2014 (if only using secondary FTEs the decline was 0.7%)
Labour productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real Expected Income / Teacher Salaries)	pQ/wL	Data on school levers by three categories of attainment, average weekly incomes for people over 15 in employment for each category from New Zealand Income Survey, average unemployment rate for each category for June year. Total (secondary and primary) teacher salaries. Indexation based on the full CPI	Declined by an average of 1.1% between 2002 and 2014
Multifactor productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real Expected Income / School Revenue)	pQ/(wL+rK+mM)	Weighted average real income as above. Wage indexation based on full CPI. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation based on the CPI	Declined by an average of 0.9% between 2002 and 2014

Source: Productivity Commission

These data illustrate both the importance and the difficulty of quality adjusting sector-level productivity data. Policy decisions (e.g., regarding smaller class sizes) are reflected in the basic labour productivity measures. Further, when the measure of labour input is adjusted in an effort to capture quality changes (e.g., through using data on teachers' salaries) this labour productivity performance also worsens. But there are caveats to this. These caveats include questions over the use of salaries as a proxy for quality of inputs – particularly given the nature of public service labour markets (e.g., whether a change in salaries reflects quality or compositional changes) and the importance of missing inputs such as the previous performance of students (needed for measures of value added).

Nonetheless, a similar story emerges from measures that adjust outputs based on attainment in international assessments (such as New Zealand students' PISA scores), where performance has worsened. This reflects a decline in aggregate PISA points (an average annual decline of 0.1%), which itself reflects a larger fall in the average PISA score (an average annual decline of 0.3%). However, there are differences in measured attainment according to international and domestic assessments. Indeed, (labour) productivity based on a measure that adjusted for domestic attainment (e.g., the proportion of students leaving school with at least NCEA level 2 (or equivalent)) increased between 2002 and 2014. A related measure (the series using school revenue as a measure of inputs) was used to compare the results in this paper to those of the Office for National Statistics (ONS) in the United Kingdom (see below).

Finally, measures were adjusted for final outcomes (in this case the performance of school leavers in the labour market). This involved a two-step process:

- First, output was adjusted for the domestic attainment of students.
- The average real expected income for students based on this attainment was then estimated and multiplied by the number of students in each category.

These measures also suggested falling productivity. But these measures can be subject to attribution problems. Indeed, given the improved domestic attainment above, the decline in these measures reflects changes in unemployment and real wage growth following the Global Financial Crisis. With the use of sector-level data it is thus not possible to conclude that changes in these measures are directly attributable to the performance of schools, e.g., they may also reflect differences in the economic context facing different cohorts of school leavers. To estimate the incremental value of school education on earnings it would be necessary to use linked unit record data.

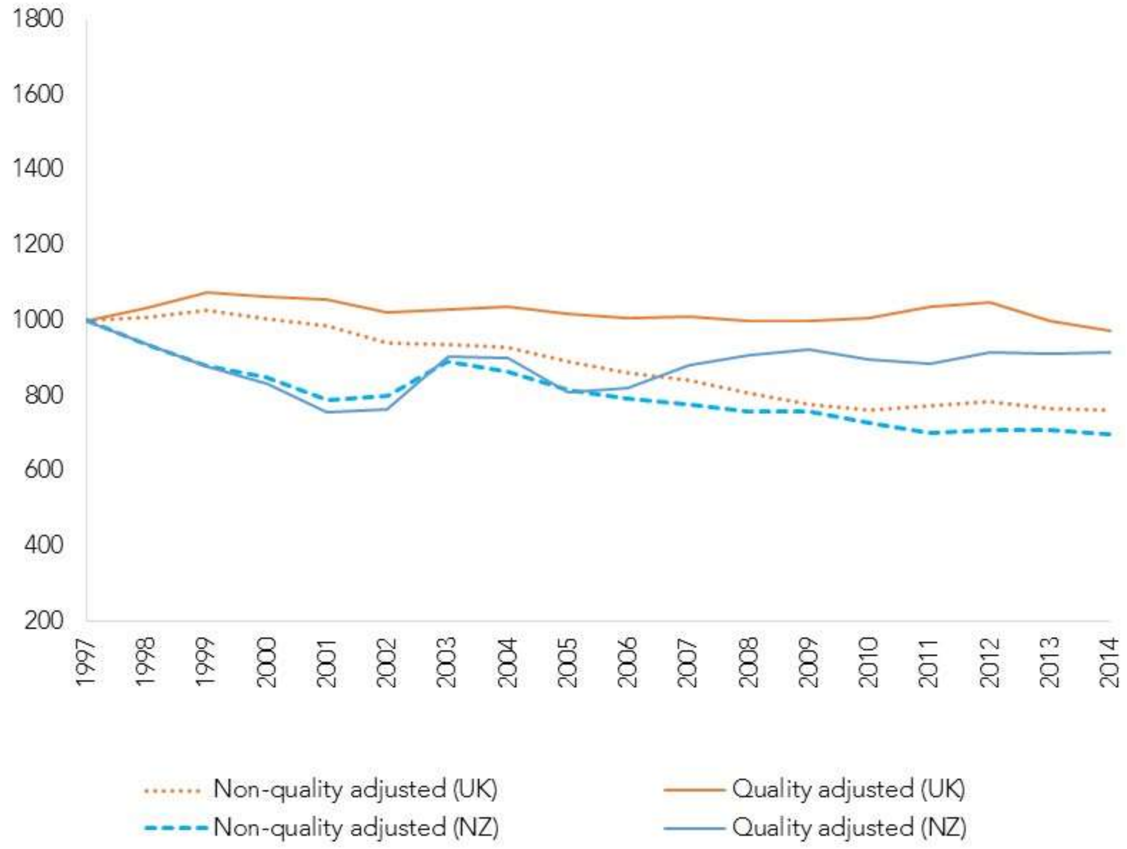
Comparison with ONS estimates of education productivity

One series of results for schools in this paper is benchmarked against a series produced by the ONS in the United Kingdom (Figure 1). In the United Kingdom output is based on the numbers of students adjusted for absences. This is quality adjusted for the Level 2 attainment by students in England, a five year geometric average of average point scores for students at this level in Scotland, and average point scores for GCSEs in Wales. Student numbers are adjusted based on the average point scores in these exams. As discussed in footnote 3, the ONS has had to revise its approach to quality adjusting education quantity when practices regarding students sitting exams changed.

In New Zealand output (numbers of primary and secondary students, not accounting for absences) is adjusted based on the proportion of students completing schooling with NCEA level 2 (or earlier equivalent) or more. In relation to input measures, in New Zealand school revenue is used as the input measure. In the United Kingdom, inputs include labour, goods and services, and consumption of fixed capital, which are all weighted by expenditure share.

It is important to recognise that given differences in public policies, policy contexts, and data availability it is appropriate for there to be some small methodological differences in the two approaches. Findings can thus be expected to differ. Yet similarities in the general magnitude and direction of effect from making broadly similar quality adjustment (based on performance in domestic assessments) can be expected.

Figure 1 **Comparison with ONS estimates of education productivity (1997 to 2014) (1997=1,000)**



Sources: Productivity Commission and Office for National Statistics (2016)

In both countries the unadjusted series show similar trends. They both show a downward shift over time reflecting policy choices regarding smaller class sizes. Making a quality adjustment based on pupil attainment leads to average labour productivity growth around zero in both countries between 1997 and 2014, although in New Zealand a higher proportion of students achieving NCEA level 2 or above since has been reflected in stronger multifactor productivity growth since 2005.

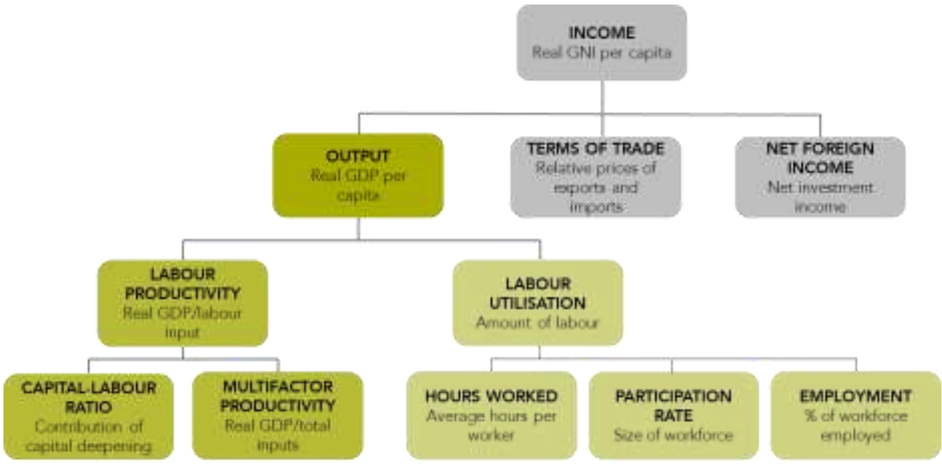
2 Key concepts

This section defines productivity and notes some of the challenges in measuring this in the public sector, particularly given the lack of market clearing prices which can serve as an indicator of consumers' willingness to pay. The section then discusses other differences between the public and private (measured) sectors, and how productivity measures relate to a range of indicators that can be used to evaluate public services.

2.1 What is productivity?

Productivity is a measure of the ability of an economy, industry or organisation to produce goods and services (outputs) using inputs such as labour and capital. It is a volume measure. It shows the ratio of the volume of output to the volume of inputs, e.g., how much output is generated per unit of input (Statistics New Zealand, 2010).

Figure 2 A national accounts perspective on productivity



Source: Conway and Meehan (2013)

A national accounting perspective can be used to illustrate the importance of productivity. Labour productivity shows the output produced from each hour of work. Increasing labour productivity – along with increased hours in work – leads, other things being equal, to more output per person. This is an important component of higher per capita incomes and, in turn, better living standards.

Labour productivity can be expressed in terms of two components: the capital-labour ratio (e.g., capital deepening) and multifactor productivity (MFP). Both labour productivity and MFP increases can come from a range of sources such as new technology; scale, scope and specialisation economies; improvements in firm organisation, management and work practices; and firm turnover.[5]

Productivity, technical efficiency and allocative efficiency

Productivity can also be illustrated with a production possibility frontier. This frontier defines the total output that an economy can produce given its resources. Total output is a function of the production of a number of goods and services. These goods and services can be produced in different quantities (reflecting production trade-offs) to give a range of possible total outputs.

When an economy is on the frontier it is impossible to produce more of one good without producing less of another (all else being equal). However, an economy can move along the frontier (changing the mix of goods produced) by changing the proportion of inputs used in production. Further, over time the frontier itself may also shift outwards due to technical progress. And an economy can become more or less efficient and catch-up to or shift away from the frontier.

It is important for an economy to be as close to its production possibility frontier as possible, otherwise some resources are being wasted. When an economy is below its frontier then opportunities are being missed to increase total output with existing levels of resources. In other words the economy is said to be lacking technical efficiency. Technical efficiency is a measure of how far or close an economy is to its production frontier.

Technical efficiency is closely related to the concept of productivity (the ratio with which inputs can be converted into outputs). Increasing productivity is one way an economy can move closer to its frontier. Indeed, if inputs are fixed this is the only way. However, even if two economies are equally productive (e.g., the same distance from the production frontier) they may have different degrees of allocative efficiency. Allocative efficiency is concerned with the appropriate distribution of resources to different activities (e.g., doing the right thing, not just doing it in the right way). It is thus concerned with allocating resources to where they can be economically most productive (i.e., taking account of relative costs (inputs) and returns (outputs) of different resource allocations).

2.2 Challenges in applying productivity concepts to public services

While there has been considerable work on productivity in the private sector, much less is known about the levels, growth rate and determinants of productivity in the public sector. Given this it can be helpful to define key concepts before seeking to apply them more broadly.

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[5] There is a distinction between embodied and disembodied change. Only disembodied technological changes are included in multi-factor productivity (MFP). Some technological changes become embodied in the volume of inputs and so to avoid double counting them they are not included in MFP. Consider the example of e-mail. This requires some capital deepening (computer servers) and may support and increase in hours of work (e.g., checking e-mails on a smartphone when out of the office). But it may also improve coordination in the workplace – and it is this improved coordination that is a disembodied change and included in MFP.

Prices, willingness to pay and the value of outputs

Given the diversity of outputs produced in an economy, productivity measures require an approach for combining diverse outputs into a single index. Consider the familiar hypothetical example of an economy that produces only guns and butter. Estimating productivity requires a measure that combines the output of both these products. But just how many kilos of butter are equivalent to one gun?

In the private sector prices can be used to make these comparisons. Non-comparable output volumes can be combined into a single index based on their value in the marketplace. This approach is followed as prices are generally assumed to be a good indicator of consumers' valuation of (willingness to pay for) different outputs. It is assumed that if the utility (or benefit) that a consumer receives from a good or service is less than the market price then the consumer will not purchase it. A different consumer may have a different willingness to pay and so instead purchase the good (or purchase different amounts of the good).

Thus in perfect competition different people will consume the product at different levels and the total level of consumption of the good will reflect the overall utility it provides consumers. Indeed, an outcome where different people have different preferences and so consume different amounts of a good could maximise total utility. Perfectly competitive markets allow the price system to allocate goods among consumers so that each person's marginal utility from consumption is equalised. This is a condition for Pareto optimality, as otherwise some of one person's consumption could be reallocated to another person who values that consumption more.

In contrast, public services typically lack, or at best poorly reflect, prices as they are provided free or at subsidised prices at the point of consumption. As a result, it is not possible to say that prices for public services necessarily reflect consumers' willingness to pay, and these prices cannot therefore be used as proxies for the utility (or value) they generate. Further, value judgements may be made that the importance of the consumption of some goods means it should not vary among different consumers (or that it should only vary above a certain "core consumption" level). This can be the case for so called merit goods. An alternative way of valuing public services is therefore needed.

An illustration

Productivity is a measure of the effectiveness of a decision making unit at converting inputs into outputs. As an illustrative example, assume a one output and one input economy in which productivity can be measured as Q/I, where Q is the output volume and I is the input volume. In this case there is no difference between labour and multifactor productivity.

But what if we are interested in productivity growth? There are several ways of conceptualising this: growth in a productivity index, in outputs compared with inputs, and in real revenues with real costs. The approach taken in this paper is an index approach. Thus productivity growth between periods 1 (t1) and 2 (t2) equals $(Q^{t2}/I^{t2})/(Q^{t1}/I^{t1})$.

The next step is to account for the fact that there are likely to be multiple inputs and outputs. One approach is to use input price weights, so labour productivity can be written as Q/wL and multi-factor productivity as Q/(wL+rK+mM), where w is the wage rate, L the labour input, r the rate of return to capital, K the capital input, m the price of intermediate inputs, and M the intermediate inputs. Likewise, where there are two outputs (a and b), Q is equal to $p_aQ_a + p_bQ_b$, where p_a, p_b, Q_a, and Q_b are the prices and quantities of a and b.

In other words, different types of outputs can be combined into a single index by weighting their volumes by their market prices.[6] In using these weights it is necessary to consider whether price weights should be fixed over time (using constant or current prices) and, if fixed, for how long or over what periods (e.g., completed business cycles)?

But there are several challenges in taking a similar approach to measuring public sector productivity where, at best, there are only proxies for market clearing prices. This means two things:

- In the absence of prices some other alternative is required to combine diverse inputs and outputs into single input and output indices (weightings).
- Unless all prices (p, w, r and m) move together, volume and value based measures will give different productivity trend results. This is one dimension of the problem of the need for quality adjustments in measures of public sector productivity.

Other challenges

Even if accurate prices are available, other factors may mean public services require a different approach to measuring productivity from that used for the measured sector. In particular, the process of converting inputs into outputs (the productivity of public sector production) is conditioned by the institutional setting (e.g., regulations, governance structures, etc.). An observed change in productivity may reflect a change in public policy rather than choices made by managers in response to consumer demand.[7] These institutional arrangements also shape the degree of innovation in public sector processes (i.e., they have a dynamic effect). A number of important institutional differences are discussed below. They include differences in the nature of labour inputs (although these can be overstated), observability of outputs and outcomes, accountability requirements, and the roles played by competition and consumer choice.

Nature of labour inputs

Public services tend to be relatively labour intensive. This means they can face the so-called "Baumol cost disease" (Baumol and Bowen, 1966), where wage growth in labour-intensive industries becomes decoupled from productivity growth. This can happen when productivity improvements in a capital-intensive industry leads to wage growth in that industry. Competition

[6] In the measured sector prices can be used in this way as it is assumed that prices are a good indicator for consumers' willingness to pay for different outputs. In a competitive market, the level of consumption of the good will reflect the overall utility it provides consumers. In other words, "outputs can be measured from market transactions where the dollar volume of products reflects how end users value them" (Hanushek and Ettema (2015)).

[7] An example could include a policy to reduce class sizes. In principle these effects can also occur in the market sector where, for example, monopoly power held by some suppliers can lead to outputs and prices that reflect producers' 'policy' choices rather than consumers' marginal valuation under competitive conditions.

for labour between this industry and other more labour-intensive industries can then mean that wages in these other industries also grow. This increases the cost of labour inputs relative to the outputs produced and leads to lower labour productivity. This phenomena can be seen most clearly in the case of some service industries (Productivity Commission, 2016, p. 63).

As well as differences in labour intensity, public and private (measured) sector employment may differ in the form of pecuniary incentives offered. The Productivity Commission (2015, appendix F) distinguished two forms of pecuniary incentives that can operate between a principal and an agent. High-powered incentives are where an agent receives a large share of some risky outcome that is affected by their efforts. With low powered incentives the agent's share of the risky outcome is small. Public sector workers typically have no claim on residual profits or cost savings and so their pecuniary incentives tend to be low powered. Public sector workers are also more likely to have standardised and rigid pay scales – with constraints on pay levels and performance related pay – and greater job security.

It has also been argued that public sector workers may face greater non-pecuniary incentives, such as concern about their reputation, mission orientation, etc. According to this view public sector workers are relatively motivated by non-pecuniary rewards, particularly a shared sense of mission orientation. Yet, as Le Grand (2007, p. 19) noted, "a review of the available literature on the motivation of those who work in the public sector suggests, not that they are exclusively [altruistic] knights or [self-interested] knaves, but, as with most people, a mixture of the two" (Le Grand, 2007, p. 19). And relying on such an ethos may not be enough as 'knightly' people may not "always be motivated to be very efficient" (e.g., recognise the opportunity cost of the resources they consume) and have their own agenda (e.g., "give users what the knights think users need, but not necessarily what the users think they need") (Le Grand, 2007, pp. 20-21).

Further, it would be incorrect to assume that only workers in public services have a concern for the welfare of their customers. Indeed, many essential goods and services are provided outside of the public sector (e.g., food production). And even in cases where essential goods and services are provided in the public sector (e.g., education and health), these services can often also be provided by private providers. Thus it is easy to overstate the uniqueness of the labour input into public services. This means that for productivity measurement many of the techniques that are used to account for labour input in the private sector (e.g., weighting different categories of worker by wage rates when combining them into a single index) can be appropriate for public services.

Observability of outputs and outcomes

An area where there is likely to be a clearer difference between private firms and some (although not all) public services is the ability to set well defined and measurable goals. Compared to private sector firms, which may have goals like increased market share or shareholder value, some public service tasks have relatively complex goals, encompassing, for example, distributional impacts as well as efficiency. And even where goals can be identified at a high level (e.g., investment in human capital), difficulty in observing outputs or outcomes[8] and the role of co-production (e.g., degree to which delivery is self-contained) can mean it is difficult to define measurable indicators of performance.[9] This has implications for the role and form of productivity analysis (Tavich, 2017).

Lonti and Gregory (2007) and Gregory and Lonti (2008) examined the use of performance indicators in selected public sector departments in New Zealand and concluded that "despite the drive to improve managerial performance since the 1990s, indicators tended to address narrow managerial issues rather than 'genuinely meaningful measures'" (p.837). More recently Francis and Horn (2013) argued that New Zealand public service organisations are good at managing immediate issues and transactional functions, but struggle with building strong institutions and the strategic and forward looking parts of the system. This highlights the importance of craft tasks like setting out strategy, leadership and building capability.[10] It also underscores the difficulty of obtaining measures of public sector performance and highlights the risks of focussing on what can be counted, rather than genuinely addressing the effective delivery of public services more comprehensively.

Accountability

A further difference reflects the importance of accountability for inputs in public services. A principle of the state sector reforms in New Zealand in the 1980s was to increase the flexibility with which managers of public services could manage inputs. The principle was that the political executive would specify desired outcomes, contract agency chief executives for outputs to contribute to these outcomes, and agencies would then manage inputs to achieve these outcomes (letting "managers manage"). Nonetheless, the allocation of inputs (e.g., workers) in the public sector rightly remains subject to a number of public law and administrative requirements designed to ensure that public funds are used in a lawful, transparent and accountable manner.

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[8] Different public sector tasks present a variety of challenges. As James Wilson (in Gregory, 1995, p. 172) argued, these tasks can be differentiated according to the observability of their outputs and their outcomes. Consequently four types of task (and examples) can be identified (Gregory, 1995, p. 173). 1. Production tasks: have both observable outputs and observable outcomes. The purpose is to produce things. 2. Craft tasks: produce observable outcomes through unobservable work. Often "the successful achievement of desired outcomes is dependent on the activities of highly trained professionals exercising a large degree of autonomy from day-to-day managerial supervision" (Gregory, 1995, p. 173). 3. Procedural tasks: are characterised by observable work but unobservable outcomes. The purpose is to maintain systems. 4. Coping tasks: neither work nor outcomes are observable. Thus not only does work "often require considerable discretion but it also has ambiguous impacts on the behaviour of 'clients' …. They embody objectives that governments do not really know how to achieve" (Gregory, 1995, p. 173).

[9] As Alford (1993, in Gregory, 1995, p. 175) wrote: "Accomplishing the objectives of a government programme can often call for some of the work to be done by people or organisations other than the producing unit, such as the target group being regulated, or the programmes' clients, or other public sector agencies, or citizens generally." (Gregory, 1995, p. 175). This co-production can involve "getting people to act together even though they do not actually need to agree on why they wish to do so, and can be expected to place differing values on their joint actions" (Gregory (1995), p. 177). Craft and coping tasks are more likely to rely on co-production than production and procedural tasks.

[10] James Q Wilson also discussed the tendency for assignments to be distributed in ways that minimise the chance for key employees to become expert in their tasks, particularly due to the frequent rotation of assignments. He noted the trade-off between having broadly experienced employees and having highly expert ones, and that the bias towards frequent rotation reflects incentives to distribute career-enhancing postings widely rather than just to people most suited for the roles (Wilson, 1989, pp. 171-173).

Yet this emphasis on accountability in public services can come at the expense of a focus on productivity. As the Productivity Commission (2015) noted agencies may manage performance risk through highly specified contracts that describe the inputs to be used, the processes to be followed and the outputs to be produced. This can reduce the incentives and opportunity for innovation, limit the flexibility of providers to respond to changing needs of clients or changes in the environment in which services are provided, and limit the scope for providers to work together and to bundle services in a way that best meets the needs of clients (e.g., service integration).

In principle, however, concerns with accountability and with productivity are not necessarily inconsistent. Consider both the government's purchase and ownership interests in the activities of departments and Crown entities.[11] As Treasury (2011, p. 16) noted:

- As a purchaser of outputs (goods and services), "the Government is likely to require information along the lines of a private sector sales/services contract: provider, quantity, quality, time and place of delivery and cost."
- As owner, "the Government wants to ensure that capital assets are used efficiently and that agencies maintain the capability to provide services efficiently and effectively in future years, in accordance with the Government's objectives."
- Finally, both "as owner and purchaser, Ministers want to procure quality goods and services at the right cost, now and into the future."

Competition and consumer choice (as sources of innovation)

Finally, the mechanism of competition (either in output markets or for the ownership of the firm itself) is often absent in the public sector. Many public services are delivered by agencies that face little competition. And while public agencies can be restructured, merged or disestablished, this tends to be harder to achieve than in the private sector. In contrast, in the private sector this competition can help drive the reallocation of resources between firms, which can, in turn, enhance productivity (Conway, 2016).

Public services are also often characterised by the limited role played by consumer choice. Greater consumer choice can have pros and cons. This choice can drive up quality and efficiency and ensure that the activities and improvements undertaken ultimately reflect the wishes and values of the society (better reflect specific client preferences). In cases where greater choice leads to greater diversity of supply then the provision of services could naturally be less uniform (Productivity Commission, 2015, p. 44), which may or may not be desirable. And some public services may be based on paternalistic value judgements (individual users are not believed to

[11] For example, in relation to the purchasing interest a key principle is that the Crown cannot spend public money except by or under an Act of Parliament. In most cases this authority is achieved through Appropriation Acts presented as part of the Government's budget package (Treasury, 2011, p. 13). Appropriations are limited to a maximum level of spending, to a particular period, and to uses set by the scope statement. Appropriations group outputs purchased by Ministers into output classes that contain different outputs contributing to a common outcome. These outputs are the basis of purchase agreements between Ministers and government agencies (Treasury, 2011, p. 14).

be the best judges of their needs) and so the case for responding to client preferences is attenuated.

Nevertheless, the absence of competition and choice can be overstated, as in practice many public services are usually provided as mixed model systems (e.g., with private as well as public providers). Mixed model systems can generate a number of benefits. From a national-economy perspective a private pillar can, for example, make the welfare state more efficient by increasing the range of tools available for smoothing consumption and spreading risk. By reducing fiscal pressure on the public system this can mean programmes are more affordable for governments in the long run (although this may be undermined by policies like poorly designed funding systems). A mixed model also has important political effects, with a stronger private pillar helping to build consensus that funding the welfare state requires a team effort (Nolan et al., 2012).

Indeed, expanding the roles of competition and choice was seen as a key mechanism for improving the performance of public services in the United Kingdom during the later years of the Blair government. As Le Grand (2006) noted it was argued that the:

> reforms involving choice and competition that the Government of Tony Blair [introduced] into public services such as health and education will make those services not only more responsive and more efficient, but also ... more equitable or socially just.

The benefits from government efforts to extend competition and choice were expected to particularly benefit the less well off, as middle income groups were seen as the major beneficiary of "unreformed no-choice" systems. As Le Grand (2006) wrote: "With their loud voices, sharp elbows and, crucially, their ability to move house if necessary, the middle class get […] more hospital care relative to need, more preventive care, and better schools."

2.3 Productivity and public sector performance metrics

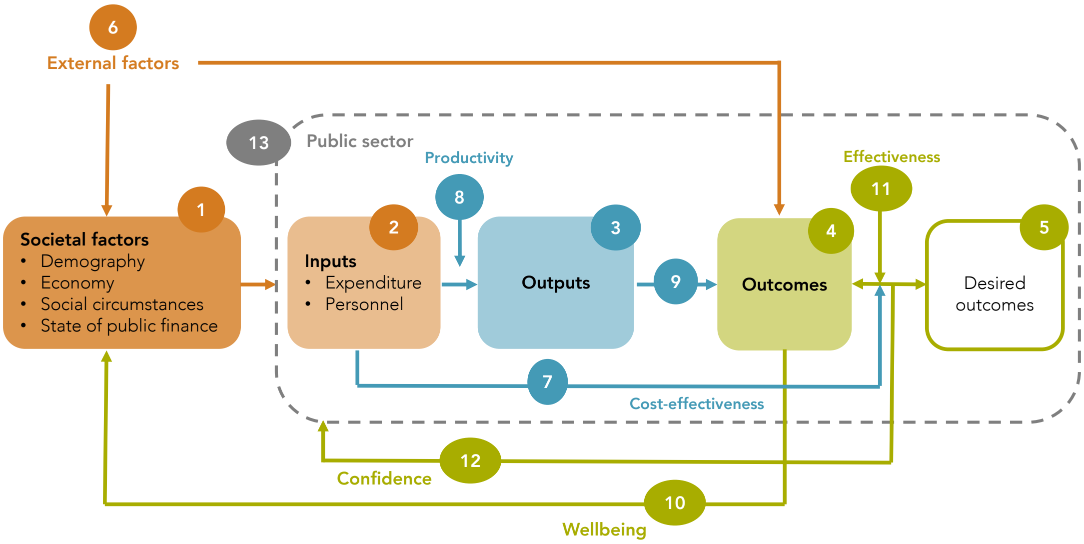
What does the above discussion mean for the role of productivity in performance measurement in government services? In the first place it highlights that productivity is only one possible indicator of the performance of the public sector. This can be illustrated in the model developed by van Dooren et al. (2010), shown in Figure 3.

Productivity (8) lies at the core of the framework and relates the output of goods and services (3) generated by the public sector (13) to the inputs used in the production of those goods and services (2). The next step in the framework highlights the fact that that productivity is not necessarily an end in itself. In fact it is possible for productivity to be improved with no consequent change in outputs (3) or intermediate outcomes (4). In many cases a more comprehensive view of productivity will be required: one that traces the links (9) from outputs to outcomes.

However, for many reasons intermediate outcomes (4) may not necessarily coincide with the desired (final) outcomes (5). For example, external factors (6) may influence the actual outcomes such that they deviate from the desired outcomes, so reducing the effectiveness (11) of the particular policy or activity. It is the relation between the actual outcomes (4) and the inputs (7) that determines the value for money (or cost effectiveness) of the public activity.

A range of societal factors will set the context in which the public sector operates and in part will influence the nature and extent of the activities that the public sector undertakes. An ageing population may, for example, lead to a greater range of services directed to the elderly. At the same time the outcomes resulting from the public sector's activities will themselves result in feedback (10) which shapes the future course of key indicators of social wellbeing, as well as affecting the degree of confidence (12) the citizenry have in the particular public sector activity.

Figure 3 Dimensions of public sector performance



Source: Van Dooren et al. (2010)

This all means that productivity measures (the relationship between outputs and inputs) are just one element of a much broader framework for the assessment of the public sector. They will typically need to be accompanied by or incorporate measures of the quality of a service. Their value depends on the context and the question being addressed.

3 The existing picture

A number of OECD countries are giving increased attention to measuring elements of the non-measured sector (particularly the public sector) or, in some cases, estimates of aggregate public sector productivity. At the forefront of these developments has been the Office for National Statistics (ONS) in the United Kingdom. Progress has also been made by Statistics New Zealand.

For many years the default position in measuring the output of the public sector was to largely assume the growth rate of output was equal to the growth of inputs. This is the inputs equals outputs convention. This approach reflected the absence of prices and directly observed output measures for publicly provided goods and services but effectively assumed away the question of productivity. It implied that the social value of the government outputs was always proportional to the cost of the inputs. There was limited value in such an approach.

Since the early part of this century serious efforts have been made to move beyond the inputs equals outputs convention. In the United Kingdom impetus came as the result of an independent review of the measurement of government output and productivity commissioned in 2003 by the ONS and led by Sir Tony Atkinson. This followed a European Commission requirement that direct measures of output should be incorporated in the national accounts by 2006. The Atkinson report (2005a and 2005b) was positively received by the then National Statistician, Len Cook, and led to the establishment of a Centre for the Measurement of Government Activity (UKCeMGA) within the ONS. UKCeMGA operated between 2005 and 2010 and carried out an extensive programme of development work, including establishing a methodology for estimating productivity growth in key public services.

3.1 The Statistics New Zealand approach

In New Zealand, Statistics New Zealand regularly publishes estimates for education and training and healthcare and social assistance as part of their annual releases of industry-level productivity measures. Details of the methodology are given in Statistics New Zealand (2013) and Tipper (2013). As Tipper (2013) noted education and healthcare were prioritised as these are areas where most progress has been made in defining output measures. Defining output in collective services, such as defence, police or fire services, remains relatively difficult.

Output measures are based on a chain-volume value added, GDP production approach. Value add is defined as output minus intermediate consumption. This approach is designed to overcome the absence of market prices in these sectors. Once activity measures have been defined their growth rates are computed. To the extent there are activities in the subsectors which are not measured, it is assumed that their growth rates are the same as those of the measured activities.

The growth rates of the activities are then combined into a single output index for the subsector using cost weights for the different components of output which reflect their relative importance. Tipper (2013) notes that in the absence of market-clearing prices the international consensus is that it is appropriate to use cost weights, which reflect the value placed on the service by the producer (Dawson et al., 2005). Cost weights are also available for most types of education and healthcare and can be updated annually (Tipper, 2013, p. 9).

In the case of inputs, measures of labour and capital used in the production of the activities are estimated and combined. The labour input is based on hours paid, while the capital input is estimated by applying the user cost of capital to the total capital stock used in the industry. The latter is constructed using the perpetual inventory method (PIM). An exogenously given rate of return of 4% is applied to all industries in the estimation of the user cost of capital (Macgibbon, 2010).

More specifically, in the case of education and training, overall output is constructed by combining preschool education (contributing 8% of value add to the sector), school education (contributing 50%), tertiary education (contributing 33%), adult, community and other education (contributing 8%) (Tipper, 2013, p. 13). The output indicator for each sub-sector is based on cost-weighted number of equivalent full-time students (EFTS). Cost weights are derived from financial data on expenditures for each activity. There is a proportion of the activities that is not measured (including research). Their growth rates are therefore assumed to match those of the measured activities.[12]

3.2 Aggregate labour productivity

The data sources described above can be used to derive measures of labour productivity in the public sector. These can then form the basis of comparisons with labour productivity in the measured sector, as well as comparisons between New Zealand and Australia.

Data from Statistics New Zealand on the relative performance of the measured and public sectors in New Zealand between 1996 and 2014 are summarised in Table 2. Estimates for these sectors are combined to provide a measure of productivity for the total economy. The public sector data are not explicitly adjusted for quality. Nonetheless, these data show:

- For the total economy, New Zealand's lower output growth reflected both a slower rate of growth of labour input and lower overall growth in productivity than in Australia.
- For the measured sector, productivity growth was markedly lower in New Zealand than in Australia. This was a major contributor to the stronger output growth in this sector in Australia.
- For the public sector, in both New Zealand and Australia productivity growth was only 13% of the average growth rate in the measured sector, implying that despite New Zealand's low

[12] For completeness, the Statistics New Zealand approach to constructing health sector output is discussed below (Tipper, 2013, p. 21). Overall output combines hospitals (contributing 45% of value add to the sector), medical and other healthcare services (contributing 34%), and residential care services and social assistance (contributing 21%). The market component of these services is 43% (made up of 2% in hospitals, 30% in medical services and 11% in residential services). The output indicator for hospitals is based on inpatient and day patient events (weighted by the nature of the diagnosis and the length of stay) and emergency department and outpatient services. These are combined using cost weights. Medical and other healthcare services include general practitioners and dentists. There is a proportion of the activities that are not measured (including mental health services). Their growth rates of output are assumed to simply match those of the measured activities.

rate of productivity growth in the public sector, the gap relative to the measured sector is broadly consistent with that in Australia.

Table 2 Average annual rates of growth in labour productivity: New Zealand and Australia (1996-2014)

	Measured sector		Public sector		Total economy	
	New Zealand	Australia	New Zealand	Australia	New Zealand	Australia
Output	2.6	3.5	2.7	3.1	2.5	3.3
Labour input	1.0	1.2	2.5	2.8	1.2	1.5
Labour productivity	1.5	2.3	0.2	0.3	1.3	1.8

Sources: Statistics New Zealand and Australian Bureau of Statistics

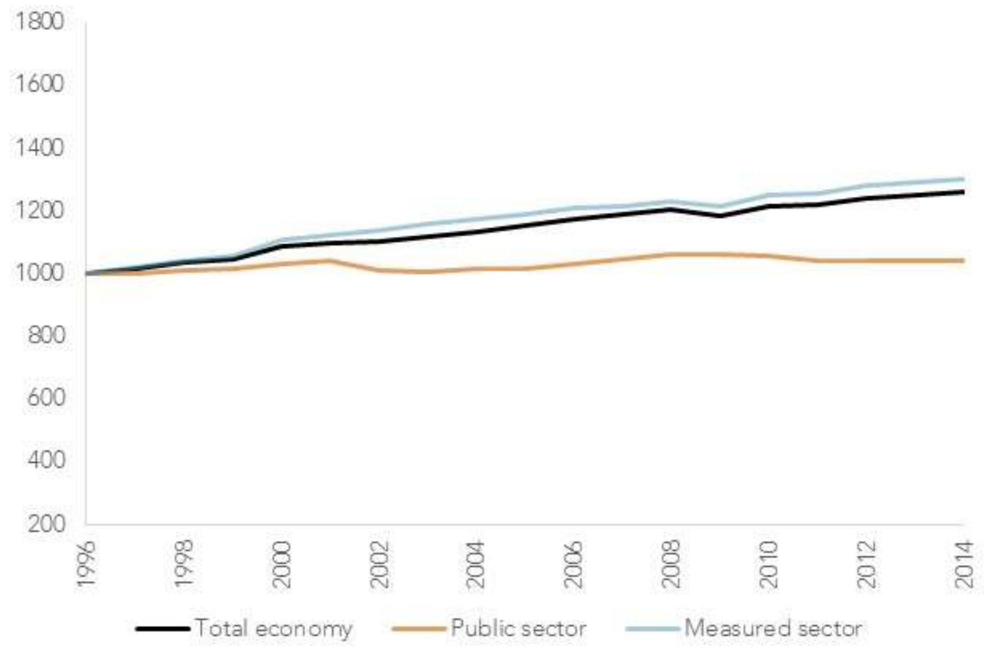
New Zealand is not unusual in having productivity growth in the public sector below that of the measured sector. As well as the example of Australia, in the United Kingdom Pope (2013) reported a measure of public sector productivity for 1997 to 2010 and showed that in virtually every year outputs and inputs grew at the same rate, implying a static level of productivity. In contrast productivity in the measured sector grew at around 2% annually over a comparable period. In contrast, the ONS (2015a) reported that labour productivity in the UK public sector grew at an annual average rate of 1.3% between 2000 and 2012. These ONS estimates, however, include adjustments for quality. For the United States and Canada, Sharpe (2004) reported that the non-business sector (a proxy for the public sector) had relatively slow growth in labour productivity (output per hour) from 1981 to 2003.

Trends over time

As well as the overall picture of labour productivity, these aggregate data can be used to illustrate trends for the public and measured sectors over time. Key trends are depicted in Figure 4. This shows indices of labour productivity for the total economy, measured sector and public sector (with 1996 equal to 1,000). These figures show that a trend for increasing productivity in the measured sector, public sector and total economy was punctuated by a fall in 2008. And while measured sector and total economy productivity partly recovered, productivity growth rates in the public sector have remained below their pre-2008 values.

Table 3 shows the growth rates for labour productivity for the measured and the public sectors. There has been a general slowdown in both the private and the public sectors. Productivity growth rates in the measured sector between 2008 and 2014 were less than one half those of the late 1990s. In the public sector, after a fall in the early part of this century productivity increased until the Global Financial Crisis (GFC). Since the GFC the evidence suggests practically zero productivity growth. Consequently by 2014 the productivity level in the public sector was no higher than it had been in 2001.

Figure 4 Total economy, measured sector and public sector labour productivity indexes (1996-2014) (1996=1,000)



Source: Statistics New Zealand

Table 3 Labour productivity growth rates before and after the Global Financial Crisis

Period	Measured sector	Public sector	Total economy	OECD total economy average
Pre GFC: 2005-2008	1.2	1.4	1.5	1.0
Post GFC: 2011-2014	1.1	0.0	1.2	0.4

Source: Statistics New Zealand

Table 3 compares the period immediately before the GFC (2005-08) with the period after it (2011-2014). The public sector experienced a period of strong productivity growth in the years immediately before the crisis. Indeed, public sector productivity growth in the three years prior to the crisis appeared to exceed that of the measured sector. (However, as Figure 4 shows, for the period 2000-2008 as a whole measured sector productivity growth was much higher.) Yet this was followed by a marked drop in average growth rates in the post-GFC period. It is possible these declines could have reflected, at least in part, labour hoarding which could have been more marked in the public sector. The labour productivity growth rate for the total economy after the GFC was below the rate observed before the GFC.

3.3 Trends for particular public services

As noted above, an estimate of overall public sector productivity growth is an aggregation of four sub-sectors. These are Education and Training; Healthcare and Social Assistance; Local Government Administration; and Central Government Administration, Defence and Public Safety. The education sector covers preschool, school, tertiary, adult, community and other education sub-industries. The health sector covers hospitals, medical and other health-care services, residential-care services and social assistance.

Table 4 Average annual rates of growth in labour productivity within the public sector (1996-2015)

	Education and training	Health and social assistance	Central government	Local Government
Output	1.0	3.9	2.8	2.6
Labour input	2.5	3.0	2.3	0.4
Labour productivity	-1.5	0.9	0.3	2.2
Share of public sector (%)	32.0	38.0	27.0	3.0

Source: Statistics New Zealand

Note:

1. The data for central and local government are for 1996-2014 only.

The two largest sub-sectors are health and social assistance and education and training, accounting for 38 percent and 32 percent of the public sector, respectively. Although the health sector had relatively high growth in labour input over the period, a high level of output growth was associated with labour productivity growth of 0.9 percent. In contrast, high input growth in the education sector was not reflected in output growth, with labour productivity decreasing by an average of 1.5 percent per annum.

Estimates of the output of each of these four industries can be combined and then weighted by GDP shares to form a measure of the output of the public sector. Likewise, a labour input measure for the public sector can be formed by combining the labour inputs of each of the four areas weighted by labour shares. The measure of labour productivity for the public sector can then be found as weighted value added divided by weighted labour input. Reflecting their high weightings, the health and education sectors have a dominant effect on the overall productivity performance of the public sector. Indeed, over the period analysed the negative growth rates of productivity in education almost exactly offset the positive rates of productivity growth in health.

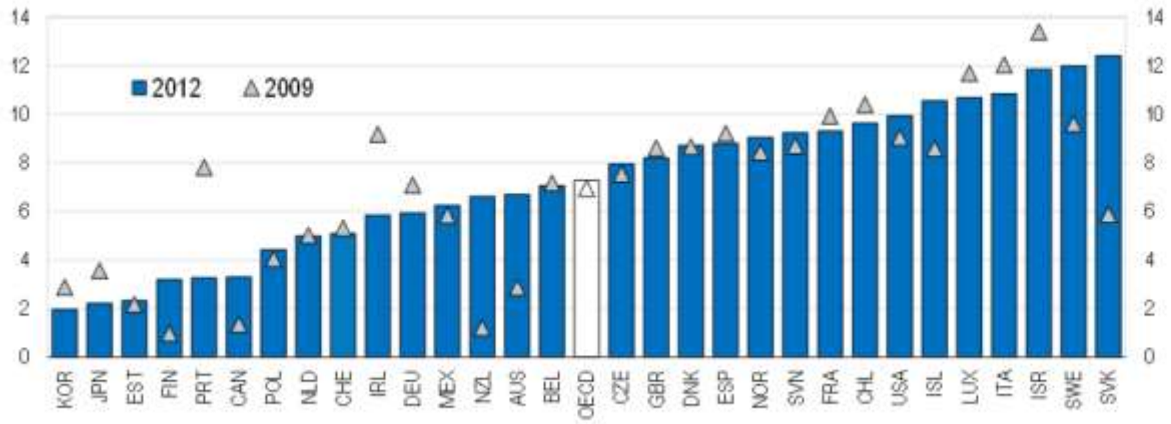
Local government had the strongest labour productivity performance, which reflected relatively low growth in labour input. However, local government accounts for only a relatively small share of the total public sector (an average of 3 percent over the period). For central government, accounting for 27 percent of the total, the labour productivity performance was lower (although still positive), which reflected a similar level of output growth but higher level of labour input growth.

3.4 What other studies tell us

There is a sizeable literature containing detailed comparisons of performance of the education sector.[13] Dutu and Sicari (2016) provide a recent contribution. They argue (p. 7) that an "approach based on spending areas rather than overall public sector efficiency is generally considered more effective when dealing with cross-country data." This is because sectors may have a variety of objectives and differ in the ways in which output can be specified. Further, a focus on a single sector makes it easier to identify performance, as a country's overall performance may mask differences across sectors.

A large number of studies have suggested that the New Zealand education system performs relatively well. For example, Afonso and Aubyn (2005) found that in 2000 New Zealand schools ranked 5th of 17 countries for output efficiency and 8th of 17 for input efficiency. Sutherland et al. (2007) found that New Zealand ranked 6th out of 30 countries for input efficiency. Schreyer (2010) reported that for experimental calculations of educational outputs in 2005 New Zealand was ranked 4th of 33 countries.

Figure 5 Output inefficiency in secondary education (2009 and 2012)



Source: Dutu and Sicari, 2016, p. 12

More recently Dutu and Sicari (2016, p. 10) estimated the efficiency of education spending using a data envelopment analysis (DEA) framework. Their approach drew on previous work by Sutherland et al. (2007). The input measure was based on PPP-measured spending per student in secondary education and the PISA index of economic, social and cultural status (ESCS). The

[13] This literature includes comparative satisfaction surveys, which can indicate the value that users attribute to public services in different jurisdictions. However, Bouckaert and van de Walle (2003) argued that criteria such as 'trust' and 'more satisfaction' do not necessarily imply better governance. Indeed, Boyle (2007) showed that for 15 European countries there was only, for example, a moderate association between expenditure per capita on public services and satisfaction with public administration.

output variable was a synthetic PISA score based on the average country scores for reading, mathematics and science.

These data showed that between 2006-08 and 2009-11 this measure of education sector performance in New Zealand moved closer to (although remaining better than) the OECD average. Output inefficiency had significantly worsened in New Zealand, and the sector's ranking had slipped from 2nd to only just above the OECD average (13th of 30). Likewise, input inefficiency had also significantly worsened with New Zealand falling to just above the OECD average (12th of 30). This deterioration in the ranking can be explained by a weakening of PISA scores coupled with increased spending. By these measures New Zealand had thus fallen from having one of the best performing school systems to having an average performing one.

Data Envelopment Analysis (DEA) techniques (see Appendix C) have also been used to assess the performance of different schools within New Zealand. Factors studied have included ownership type, single-sex/co-educational, location and scale. Alexander and Jaforullah (2005) and Alexander et al. (2007), for example, found scale disadvantages were evident in rural schools, integrated schools generally outperformed state schools and single-sex schools outperformed co-educational ones. Harrison and Rouse (2014) found that higher performance was associated with higher competition (moderated by school size) and that a widening gap in performance was observed between the largest and smallest schools.[14]

3.5 Quality adjustments

The presence or otherwise of quality adjustments can play an important role in the interpretation of productivity data (Maimaiti and O'Mahony, 2011). However, while important, adjusting estimates of public sector productivity for quality can be complex. Further, as Schreyer and Lequiller (2007) noted, information beyond that contained in the national accounts will generally be needed in order to adjust for quality. And as quality is multi-dimensional a single index is unlikely to be adequate.

Some of the challenges in making quality adjustments in the education sector are discussed in detail below and can be illustrated with the case of the United Kingdom. In this country the ONS has had to revise its approach to adjusting education outputs for quality, given an increase in the numbers of students sitting non-GCSE exams (the main United Kingdom exams at age 16). This is not a trivial matter, as any adjustment makes a substantial difference to measured productivity. From 1997 to 2011, measured output growth in the education sector of the United Kingdom grew at an annual average rate of 2.7%. Of this the quality adjustment accounted for 90%, or an annual rate of growth of 2.5% (Caul, 2014, p. 8).

[14] Data Envelopment Analysis (DEA) techniques have also been used to investigate the performance of the New Zealand tertiary education sector. For instance, Smart (2009) and Margaritis and Smart (2011) found that the productivity growth of New Zealand universities between 1997 and 2005 was lower than that of the G8 and newer universities in Australia. They also noted that the introduction of the Performance Based Research Fund (PBRF) stimulated productivity improvements in the New Zealand university sector, as a result of increased research output. Abbott and Doucouliagos (2009) showed that in New Zealand enrolments of overseas students appeared to have had no effect on technical efficiency, which contrasted with the picture from Australian universities. Talukder (2011) found that private providers experienced a larger MFP-growth than that of public providers during 1999-2004, but also experienced a sharper decline in MFP-growth since 2000 through to 2010.

In New Zealand, Tipper (2013) argued that the decision not to make explicit adjustments for quality in the education and health measures reflects the absence of an internationally agreed set of standards and limitations of the data. There is, however, an implicit quality adjustment made. As the measures have been complied at a disaggregated level this allows for changes in the composition of output. Yet this method only captures that part of the total potential changes in quality that are associated with compositional shifts (Sharpe et al., 2007). It fails to capture quality changes at the level of the individual intervention. And when costs are used as weights for groups of activities there is also a presumption that higher costs equate to higher quality. For these reasons Atkinson (2005a) favoured weighting by a measure of the quality of actual outcomes rather than by costs.

The Office for National Statistics approach

The Office for National Statistics (ONS) estimates of public sector productivity growth are built up from estimates of growth rates in nine subsectors. For six of these areas separate estimates of output, inputs and productivity are produced. These are healthcare, education, adult social care, children's social care, public order and safety, and social security administration. A further three areas are treated as collective services and so the inputs equals outputs convention is adopted. These are police, defence, and other services (including general government services, economic affairs, environmental protection, housing and recreation). Productivity is by definition constant for these other services.

Productivity growth for total public services is estimated by combining growth rates for individual subsectors using their relative share of total government expenditure (expenditure weights). For most service areas output is measured by activities performed and services delivered. Quality adjustments are made to outputs in health and education. Inputs are made up of volume measures of labour, goods and services, and capital, and are mostly measured using current expenditure adjusted by a suitable deflator. Particular features of the approaches taken in education are summarised below.[15]

The quantity of education services is the sum, weighted by cost, of full-time equivalent and publicly funded pupil and student numbers for pre-school education, government maintained primary, secondary and special schools, and further education colleges. Student and pupil numbers are adjusted for attendance (Caul, 2014). As the focus is on measuring productivity in publicly-funded education, independent schools and higher education (other than training teachers and some health professionals) are excluded from these estimates (Bridge, 2015).

Quantity is adjusted for the Level 2 attainment by students in England, a five year geometric average of average point scores for students at this level in Scotland, and average point scores

[15] For completeness the ONS approach to quality adjusting healthcare is briefly discussed below. The quantity of healthcare services is constructed by combining hospital and community health services, family health services, GP prescribing and non-NHS output into an activity index with weights given by unit costs. For non-NHS services, which account for approximately 9% of healthcare output, the inputs equals outputs rule is applied. A quality adjustment is then applied to the quantity of healthcare to give healthcare output. The quality adjustment is based on health gain, short-term survival rates, waiting times, results from the National Patient Survey and selected primary care measures (Office for National Statistics, 2013a). Labour inputs are based on full-time equivalent employee numbers. Goods and services and capital consumption are based on current price expenditure divided by appropriate deflators.

for GCSEs in Wales. Output for all countries had previously been based on changes in average point scores at GCSE or equivalent level, but this was no longer appropriate in the face of increases in the number of non-GCSE examinations. Local government labour inputs are based on full-time equivalent teacher and support staff numbers adjusted for hours worked. Central government labour inputs, goods and services and capital consumption are based on current price expenditure divided by appropriate deflators.

Quality adjustments in education

In education, key quality adjustments can relate to inputs (e.g., teacher quality or pupil-staff ratios), outputs (e.g., school inspectors or educational attainment) or outcomes (e.g., impact on human capital or house prices), the latter aiming to capture the impact of school zoning (Howell, 2016). Some of the key challenges in making a quality adjustment for education are shown in Table 5.

As Howell (2016) noted there are a number of studies on teacher quality. This reflects evidence that suggests that teacher quality is the single biggest influence on pupils' educational progress (e.g., Hanushek and Rivkin, 2006). In the United Kingdom, Kimbugwe, Lewis and James (2009) suggested that labour inputs should be quality adjusted in order to recognise improvements in teachers' quality over time. They argued for accounting for quality by measuring the quantity of labour using either actual hours worked, hours paid or FTE number of employees broken down by type of employee.

Class size (pupil-staff ratios) are often cited as an indicator for educational quality. However, the evidence on this link is mixed. To name a few studies, for example, Rivkin et al. (2005), Bowles, Gintis and Osborne (2001) and Collesi et al. (2007) have all drawn different conclusions regarding class size and teaching quality. Class size should be seen as one of many components that may make up teaching quality. There is also a question of at what number of students do any negative effects of congestion start to take effect. Nonetheless, adjustments for class size are relatively simple in their application and are used in a number of countries (Howell, 2016). They do, however, need to be interpreted with caution.

School inspection reports could be useful as a form of quality adjustment as their purpose is to identify and judge characteristics of the education delivered at schools that are valued by the students, educators and parents (Schreyer, 2010). There are also, however, challenges in using inspections as a basis for quality adjustment. Inspections are largely qualitative and may be subject to personal biases of particular inspectors (Schreyer, 2010). The criteria for defining good or bad performance may also change over time. It is also necessary to find some approach to weighting individual inspections so they are comparable over time and across schools, such as through an overall effectiveness score for schools (Department for Education and Skills, 2005).[16]

[16] In the United Kingdom Ofsted has calculated overall effectiveness scores for schools. These incorporate the quality of teaching, pupils' achievement, leadership and management, and personal development, including attitude and behaviour. The score also considered the context of the school and how it performs compared to similar schools (Department for Education and Skills, 2005).

Table 5 Key challenges in quality adjusting data on schools

Concept	Variable(s)	Measure(s)	Quality adjustment(s)	Key challenges
Labour inputs (resources used in production)	Labour	Labour force (employment count, FTEs, hours paid, actual hours worked, quality adjusted hours)	Wage rate method (wage rates of categories)	Combining non-commensurate inputs into an index Informal inputs (such as student attributes)
Total inputs (resources used in production)	Labour, Capital, Intermediate (e.g., teaching aids, electricity usage and building maintenance)	Total real operating allowances	Statistics New Zealand CPI	Implicitly assumes expenditure weights are appropriate
Outputs (what is produced)	Acquisition of skills and qualifications/ Transfer or increase in knowledge	Pupil based: pupil numbers (hours v. EFTS), educational attainment (milestones, credits, degrees) Teaching based: e.g., no of lessons, class size Output index: e.g., pupil based weighted by expenditure	Educational attainment (e.g., exam scores, qualification attainment, international standard scores (e.g., PISA, TIMMS)) School inspections	Combining non-commensurate outputs into an index Attribution (e.g., informal inputs) Teacher quality Grade inflation Teaching to the test
Outcomes (impact on community)	Direct	Human capital	Additional lifetime earnings	Lags and attribution to expected earnings
Outcomes (impact on community)	Indirect	Social network	Housing value approach	Neighbourhood effects

Source: Howell (2016)

The evolution of internationally comparable standardised test scores has led to their increased use in adjusting educational volumes for quality. Test scores and adult literacy have been shown to be a better proxy for education than years of schooling. The “direct output measurement” approach adjusts student numbers (or pupil hours) for measures of attainment as reflected in test scores. For example, Leigh and Ryan (2008) used long-run series on test scores to assess school productivity in Australia. They found that both numeracy and literacy scores declined, and when combined with a rising expenditure per student there was a significant decline in this measure of school productivity. Test scores have also been used to estimate the indirect effect of public services on economic growth. Hanushek et al. (2010) used PISA scores to model the long-run economic impact of attainment levels of students in OECD countries.

Another approach draws on a human capital framework, in which education is viewed as an investment. The payoff to this investment comes in the form of higher expected future earnings, which capture at least one dimension of the outcomes of the education process. Examples include:

- Murray (2007): uses both test scores and expected earnings to derive a quality adjusted measure of the output of Scottish schools.
- O'Mahony and Stevens (2009): use the number of fulltime equivalent students enrolled as their basic output measure to compare productivity growth in the education sectors of the United States and the United Kingdom. This is augmented with earnings outcomes for each educational/qualification level conditioned on the probability of employment. Further adjustment is made to capture quality changes that arise within educational levels due to innovations in teaching methods or curricula. The authors also adjust earnings based on age cohorts.
- Barslund and O'Mahony (2012): use future prospective earnings as a measure of the value of additional education. O'Mahony et al. (2012) apply this to measuring output growth in the post-compulsory education sector in Europe.
- Hanushek (2010) focuses on earnings as a way of estimating the value of teacher quality.

There are, of course, limitations to using expected earnings as a measure of the value of education. The method can be influenced by selection bias, where students enrolling in additional education are self-selecting (i.e., they do not constitute a random sample). Second, the historical earnings profiles for different levels of qualification are typically used as the basis for future earnings but the past is not always a good predictor of the future. Third, any earnings premium is often attributed to education when some part of this may have been due to a person's innate abilities, their family backgrounds, health status or the influence of their peers, employer provided training, and so on (Hanushek, 2015).

A novel approach to assessing the quality of school education adopted by Black (1998) was to analyse the difference in prices for equivalent houses in the same neighbourhood in Boston but belonging to different school zones. In similar work for Christchurch, New Zealand, Gibson and Boe-Gibson (2014) found that a one standard deviation in higher pass rates in NCEA examinations was associated with a 6.4% higher house price index in that zone, all else being equal. However, as Howell (2016) notes, this approach needs to account for any potential neighbourhood effects which also affect house prices and a school may enjoy a better reputation or status despite not being of better quality than comparator schools (e.g., when measured against student test scores).

A final, more general, issue noted by Atkinson (2005a) reflects any interdependence between the value of public sector outputs and economic growth. Atkinson (2005a) argues that, reflecting the rise in the real value of private assets and incomes, the output of public services (e.g., education, firefighting, postal services, health, etc.) becomes more valuable with the passing of time. For example, the benefit of saving a house from a fire rises with the value of the house and its contents. Atkinson (2005a) thus argued that cost weights need to incorporate the effect of these changes in value.

3.6 Quality adjustments in this paper

The quality of a product or service may vary over time as it is refined and developed or as the producers' operating environment changes. These changes can affect productivity trends. Yet as important as quality adjustments are, there is no international consensus on the appropriate way to account for them in public services (Statistics New Zealand, 2010; Tipper, 2013).[17] Schreyer (2010) outlines three approaches to adjusting for quality changes in education.

- Since different types of education call for different approaches to teaching, an analysis of productivity can be done by stratifying different educational products. This amounts to an implicit form of quality adjustment and is the approach taken by Statistics New Zealand.
- An explicit quality adjustment can be made by, for example, adjusting labour inputs by wage rates or outputs by examination scores or attainment levels (O'Mahony and Stevens, 2009).
- Indirect outcome measures such as future earnings can be used as a proxy for the underlying quality of the education. As noted above, some studies have used prices of houses adjacent to schools with different performance ratings as an indicator of school quality (Black, 1998; Gibson and Boe-Gibson, 2014; Cannon et al., 2015).[18]

No single measure can capture the full richness of the productivity story. In this paper a number of explicit quality adjustments have thus been used.

Table 6 summarises the measures used in this paper. To illustrate the potential of existing data and to also allow these measures to be replicated emphasis was given to using sector-level data from publicly available sources. The advantage of sector-level data is that it can be potentially comprehensive, although these data do not address the distribution of outcomes across decision making units. Sources have included Statistics New Zealand, the Ministry of Education, and the Treasury. Statistics New Zealand provided some additional data from the New Zealand Income Survey and Ministry of Education provided data for earlier years for some selected variables. Where data are available results are shown for 1997 to 2015. In some cases data were only available to 2014 or (only available in a consistent way) from 2002. The overall summary of all measures is thus restricted to 2002 to 2014.

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[17] Accounting for quality adjustment can also be difficult in the measured sector – e.g. where innovation is associated with better quality products at initially higher, but then potentially falling, prices.

[18] Evidence for New Zealand comes from a study of house prices in pre-earthquake Christchurch by Gibson and Boe-Gibson (2014). They find that house prices in school zones where the schools have higher NCEA pass rates attract a price premium. For example a 7 percentage point rise in NCEA level 1 pass rates is associated with an increase in mean house prices of $16,000 (in 2005 dollars). This effect is after controlling for 12 characteristics of the house, and 21 characteristics of the mesh block in which the house is located. Other studies for New Zealand that estimate the effect of zoning but not school quality explicitly include McClay and Harrison (2003), Gibson et al. (2007) and Rehm and Filippova (2008).

Table 6 Summary of measures used in this paper

Measure	Formal equivalent	Data
Basic labour productivity (Total Student Places / Teacher FTEs)	Q/L	Total student places based on data for student roll by school type. Excludes students in private schools. FTE teachers (headcount for 2001 and earlier) in state and state integrated schools based on education counts data. Teaching staff includes principal, management, teacher, resource teachers, community education, guidance and therapists
Basic multifactor productivity (Total Student Places / School Revenue)	Q/(wL+rK+mM)	Total student places as above. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation is based on the full CPI
Labour productivity based on adjusted labour input (Total Student Places / Teacher Salaries)	Q/wL	Total student places as above. Expenditure on teacher salaries (primary and secondary) in state and state integrated schools from education counts. Indexation is based on the full CPI
Labour productivity based on adjusted output (pupil attainment) (Aggregate PISA Points / Teacher FTEs)	pQ/L	Total student places (primary and secondary) weighted by attainment in unweighted averages of the reading, mathematics and science PISA scores. Primary and secondary teacher FTEs
Labour productivity based on adjusted output (pupil attainment) (Students Achieving Domestic Standard / Teacher FTEs)	pQ/L	Total student places (primary and secondary) weighted by share of students leaving school with NCEA level 2 (or equivalent) or more. Primary and secondary teacher FTEs
Multifactor productivity based on adjusted output (pupil attainment) (Students Achieving Domestic Standard / School Revenue)	pQ/(wL+rK+mM)	Total student places (primary and secondary) weighted by share of students leaving school with NCEA level 2 (or equivalent) or more. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation is based on the full CPI
Labour productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real	pQ/L	Data on school levers by three categories of attainment, average weekly incomes for people over 15 in employment for each category from New Zealand Income Survey, average

Measure	Formal equivalent	Data
Expected Income / Teacher FTEs)		unemployment rate for each category for June year. Primary and secondary teacher FTEs
Labour productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real Expected Income / Teacher Salaries)	pQ/wL	Data on school levers by three categories of attainment, average weekly incomes for people over 15 in employment for each category from New Zealand Income Survey, average unemployment rate for each category for June year. Total (secondary and primary) teacher salaries. Indexation based on the full CPI
Multifactor productivity based on adjusted output (earnings) (Total Student Places Weighted by Average Real Expected Income / School Revenue)	pQ/(wL+rK+mM)	Weighted average real income as above. Wage indexation based on full CPI. School revenue based on Core Crown Expenditure from Treasury Budget documents and percentage of non-government revenue from Ministry of Education. Core Crown Expenditure covers roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes. Indexation based on the CPI

Source: Productivity Commission

4 School productivity

This section presents estimates of productivity of the New Zealand school sector. It starts with a number of basic measures using labour and capital input quantities. These basic measures are then systematically adjusted to apply quality adjustments. An adjustment is first made on the input side. Then outputs are adjusted for student attainment, and finally an adjustment for outcomes (earnings) is considered.

4.1 Basic measures

Unadjusted inputs and outputs

Data on the inputs into the school sector are shown in Table 7. Teacher FTEs are used as the labour input and school revenue is used as an indicator of total inputs. For the basic measures any changes in the composition of the labour input are not accounted for. Revenue is based on Core Crown expenses and the percentage share of revenue from Government. Revenue is deflated to real terms using the full CPI (the choice of deflator is discussed below). The outcome indicator used is student places provided. No adjustments are made for variations in student attendance.

Table 7 Basic input and output data for schools (1997-2015)

Year	Teacher FTEs	Core crown expenses ($m)	% Funding from government	Revenue (real, 2006 base, full CPI)	Student places provided [4]
1997	38,698[1]	2,447[2]	87.7%	4,948	711,848
1998	39,283[1]	2,673[2]	88.1%	5,194	724,579
1999	40,173[1]	2,779[2]	88.7%	5,359	727,298
2000	40,153[1]	3,043[2]	87.8%	5,789	729,689
2001	41,445[1]	3,113[2]	86.7%	5,789	733,807
2002	41,599	2,888	85.9%	5,184	747,910
2003	42,915	3,018	85.4%	5,279	761,709
2004	43,930	3,269	85.5%	5,559	764,654
2005	44,634	3,488	86.4%	5,724	762,790
2006	45,490	3,680	86.6%	5,815	760,745
2007	45,809	3,823	86.1%	5,970	759,878
2008	46,287	4,023	86.6%	6,022	758,094
2009	47,214	4,382	88.4%	6,278	760,859
2010	47,709	4,594	88.0%	6,459	764,398

Year	Teacher FTEs	Core crown expenses ($m)	% Funding from government	Revenue (real, 2006 base, full CPI)	Student places provided (4)
2011	47,594	4,782	88.3%	6,380	762,682
2012	47,399	4,856	88.4%	6,432	759,960
2013	47,141	4,993	88.3%	6,547	762,400
2014	48,043	4,958	88.4%	6,355	767,258
2015	48,453	5,215	88.1%	6,598	776,815

Sources: Ministry of Education (2017), Full Time Teacher Equivalent by Designation and Gender in State and State Integrated Schools as at April; Ministry of Education (various years), Education Statistics of New Zealand; Treasury (various years), Budget Economic and Fiscal Update: Core Crown Expenses Tables; Ministry of Education (2017), Student Roll by School Type as at 1 July, 1996-2016

Notes:

1. Teacher numbers for 2001 and earlier are based on headcount figures. These are converted to FTE figured based on the ratio of headcount to FTE figures in 2002. Figures are for State and State Integrated Schools. Teacher categories include Principal, Management, Teacher, Resource Teachers, Community Education, Guidance and Therapists.
2. Note that from 2002 the Core Crown expenditure data are reported under new International Financial Reporting Standards and so are not strictly comparable with earlier years. Core Crown Expenditure figures do not include school transport, special needs support, professional development and schooling improvement. Figures cover roll-based operations funding to schools, teacher and management salaries, support costs and supplementary funding programmes.
3. Non-government funding includes local funds (62.6% of non-government revenue in 2015), international students (15.0%), investments (5.7%), hostels (4.2%) and other revenue (12.6%).
4. Excludes students from private schools.

Choice of a deflator

For school revenue data (and the salary data used later in this paper) it is necessary to use a deflator to account for the effect of price changes. However, the choice of deflator has a material impact on results and requires explanation. One approach (that taken by the Office for National Statistics) would be to calculate a Paasche deflator from components of expenditure (ONS, 2017).[19]

A Paasche deflator divides spending on a basket of goods and services in the current period (e.g., the sum of price multipled by quantity for each product) by how much the same basket would cost in a base period. A Paasche deflator was calculated for the revenue and salary based measures in this paper. This was based on average nominal teacher salaries and nominal average revenue per student as proxies for prices. However, it was not possible to produce a useful volume index as at this aggregate level removing price effects simply led to measures equivalent to unadjusted measures (e.g., removing the price effect from total salary growth

[19] As Goodridge (2007) noted "the Paasche calculates the expenditure needed to buy current year quantities, and is expressed as a percentage of what the expenditure would have been in the base period if the quantity consumed had been at current levels." More formally this can be expressed as: $(\Sigma(P^{tn})*(Q^{tn}))/(\Sigma(P^{t0})*(Q^{tn}))$, where P^{tn} and Q^{tn} are prices and quantities at time n, and P^{t0} is the price in the base period.

resulted in an index equivalent to growth in teacher FTEs). This would require a more disaggregated approach than that taken in this paper.

Nonetheless this showed that the average annual 4.4% increase in nominal total teacher salaries reflected an average annual 3.2% increase in average teacher salaries and 1.2% increase in teacher FTEs between 2002 and 2015. Likewise the average annual growth in nominal school revenue was 4.4% between 2002 and 2015 (4.0% between 1997 and 2015), with a price effect of 4.2% (3.6% for the longer period) and an increase in student numbers of 0.3% (0.4% from 1997).

These figures can be compared with the growth in the CPI and the CPI level 2 subgroup for primary and secondary education. This subgroup reflects consumers' spending on schooling and the CPI reflects price movements more generally. Between 2002 and 2015 the CPI grew by an average of 2.2% (2.0% between 1997 and 2015) while the subgroup grew by an average of 5.2% (4.8% between 1997 and 2015).

Thus although nominal total teacher salaries grew at an annual average of 4.4%, this is less than the annual average growth in the level 2 CPI subgroup (of 5.2%). The result is that if salaries are deflated by the subgroup then real salaries will appear to have fallen, and productivity estimates will be higher than otherwise. For instance using the subgroup as the deflator would mean:

- Salary-based measures would grow faster than unadjusted productivity measures, even though the growth in total salaries (4.4% nominal, or 2.1% real when deflated by the full CPI) has been much faster than the growth in teacher FTEs (1.2%) or price growth more generally (the CPI at 2.2%). (To illustrate Appendix A contains a summary of the measures in this paper using the subgroup as a deflator.) Higher salary growth should (all else being constant) lead to lower productivity growth so the results of these two measures would be inconsistent.
- Similar issues arise in relation to school revenue, where nominal school revenue (average annual growth of 4.0% between 1997 and 2015) has risen much faster than student numbers (average annual growth of 0.4% for the same period).

Consequently the full CPI is used to deflate teacher salaries and school revenue in this paper.[20] The full CPI provides a "common numeraire" as the basis for all real comparisons – so it indicates a common average real basket of goods that the funds in question cold alternatively buy. Nonetheless, the sensitivity of final productivity comparisons to the deflator choice is a reason for caution in interpreting schools' productivity trends.

Results

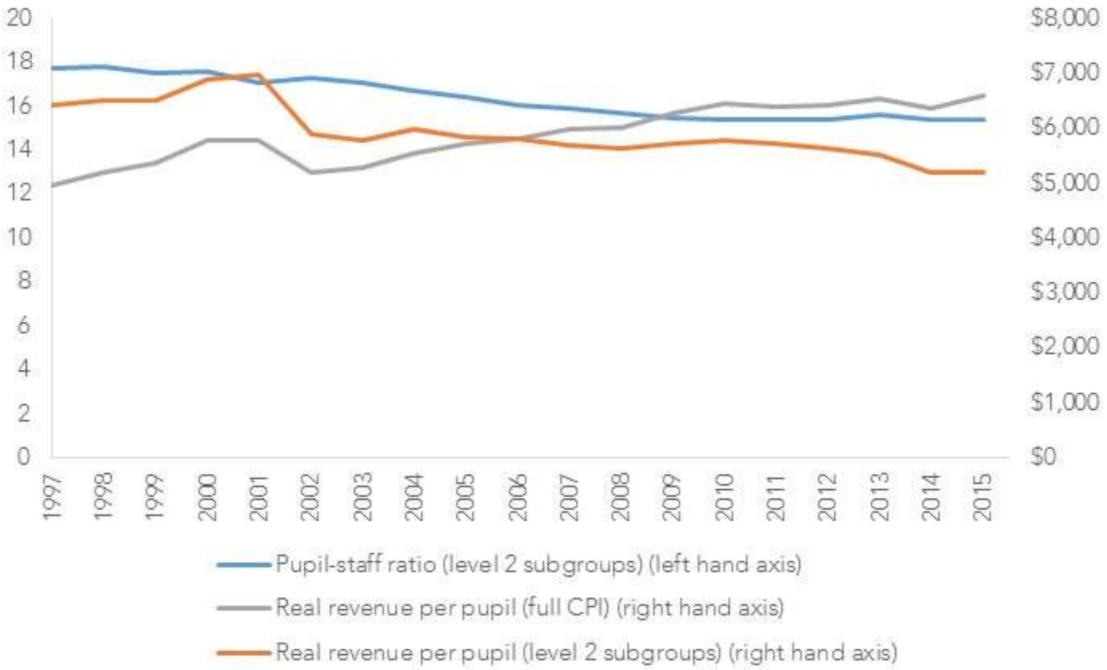
The change in these basic inputs and outputs are shown in two measures in Figure 6. This plots the pupil-staff ratio in the school sector and the real revenue per pupil from 1997 to 2015. Further, along with an increase in staff members per student the cost per student (when indexed

[20] Another possible deflator is the education and training subgroup of Statistics New Zealand's Purchasing Price Index (PPI). Yet this index only covers the "productive sector" and measures changes in the prices of outputs that generate operating income and inputs that incur operating expense. It does not include prices for items related to capitalised expenditure, non-operating income, financing costs, or employee compensation. The education and training subgroup is not published at a further disaggregated level (e.g., for primary and secondary schools).

by the CPI) has risen (i.e., productivity as measured by students per dollar spent on salaries has fallen). These basic measures should be interpreted with some caution and, indeed, should be considered in the light of adjustments made later in this paper. They do, nonetheless, raise a number of testable propositions:

- The first is that if the ratio of staff to pupil numbers is accepted as a basic measure of labour productivity (see Figure 6), then this productivity metric has worsened.
- Likewise, if we focus on the ratio of revenue to pupil numbers as a basic measure (the inverse) of multi-factor productivity, then this metric has weakened too. Yet note that this result does depend on the deflator used (e.g., a subgroup of the CPI versus the full CPI).

Figure 6 School pupil-staff ratio and real revenue per pupil (2006 dollars) (1997-2015)



Sources: Ministry of Education (2017), Full Time Teacher Equivalent by Designation and Gender in State and State Integrated Schools as at April; Ministry of Education (various years), Education Statistics of New Zealand; Treasury (various years), Budget Economic and Fiscal Update: Core Crown Expenses Tables; Ministry of Education (various years), New Zealand Schools: Ngā Kura o Aotearoa; Ministry of Education (2017), Student Roll by School Type as at 1 July, 1996-2016

Note:

1. From 2002 the Core Crown expenditure data are reported under new International Financial Reporting Standards and so are not strictly comparable with earlier years.

Table 8 Summary of basic measures of productivity growth in the school sector

	No. of places provided per staff FTE	No. of places provided per $m revenue
1997-2000	-0.3	-5.1
2000-2008	-1.4	-0.5
2008-2015	-0.3	-1.3
1997-2015	-0.8	-1.6

Source: Productivity Commission

Note:

1. Indexation based on the CPI.

4.2 Adjusting labour input for composition

This section discusses the first adjustment to the basic measures above. As noted earlier a set of basic measures were based on staff FTE numbers. But as well as the overall numbers of staff FTEs the skill composition of staff can also be of relevance. Within the overall number there can also be changes in sub-categories such as specialist teachers and teacher aides. It is thus useful to account for any possible changes in the composition of the labour input.

This can be done in a number of ways. One is by directly measuring the experience and qualifications of staff members. A simpler (less data intensive) approach taken in this section is to use changes in salaries as a proxy for quality. This is based on a view that variations in the hours of work (e.g., full and part time) and the composition of the labour force are reflected in the salaries paid. Salary data are also available for a relatively long series.

As real salaries (indexed to the CPI) have grown faster than staff numbers this measure of labour productivity declined faster than the basic measure. This could reflect a number of things. There may have been a productivity-reducing change in the composition of the teaching staff in New Zealand (this is unlikely to reflect a switch away from teaching staff as Ministry of Education data show that teacher FTEs accounted for 85% of total staff FTEs in 2004 and 87% in 2015). Alternatively it could reflect the price index used to account for inflation in this paper. These measures also take a restricted view of productivity, and fail to consider how any change in wage rates (for example) may translate into changing outcomes. This is where further work such as using individual longitudinal micro data to better understand the impact of teacher quality could be of value.[21]

[21] Chetty et al. (2014) address key aspects of teacher quality: do test scores reflect the causal impact of teachers or are they biased by student sorting? And do those teachers who achieve increases in student test scores lead to higher lifetime outcomes for those students – or are they simply better at teaching to gain higher test scores with no corresponding lasting benefit? For the first question they find that higher quality teachers do in fact contribute to better test scores with little or no bias. To address the second question the authors use more than one million

Table 9 Student numbers over real salaries (2006 dollars) (2002-2014) (2002=1,000)

	Real salaries total ($ million) [1]	Index of labour productivity (total salaries)	Real average salary ($)	Index of labour productivity (average salaries)
2002	2,296	1,000	55,188	1,000
2003	2,421	965	56,408	995
2004	2,552	918	58,098	970
2005	2,640	885	59,144	950
2006	2,707	860	59,498	941
2007	2,748	846	59,979	931
2008	2,981	777	64,405	865
2009	3,024	770	64,059	873
2010	3,092	758	64,815	869
2011	3,024	773	63,541	884
2012	3,019	772	63,685	880
2013	3,001	780	63,654	884
2014	2,987	788	62,184	910
2015	3,012	791	62,168	921
		Average annual growth rates (%)		
2002-2015		-1.8		-0.6

Sources: Ministry of Education (2017), Teacher Salary Funding to Schools, 2002-2015; Ministry of Education (2017), Full Time Teacher Equivalent by Designation and Gender in State and State Integrated Schools as at April; Ministry of Education (2017), Student Roll by School Type as at 1 July, 1996-2016

Note:

1. Salaries are for state and integrated schools. Real salaries are in 2006 constant terms using the full CPI.

4.3 Adjusting output for pupil attainment

The following section illustrates a second adjustment to the basic measures. The output measure (numbers of pupils) is adjusted for pupil attainment. One measure of attainment is the performance of New Zealand students in two international testing regimes: the Programme for

individual student school records and teacher assignments, together with matched tax data on earnings and total income. Controlling variables included college attendance, college quality, neighbourhood quality, teenage births and parent characteristics. They found that students assigned to high performing teachers were more likely to attend college, have higher incomes and fewer teenage births.

International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMMS).

Table 10 Measures based on outcomes adjusted for PISA scores (2003-2015) (2003=1,000)

Year	Average PISA score	Index of PISA points per teacher FTEs	Index of PISA points per $M school revenue
2003	522.5	1,000	1000
2006	524.3	944	911
2009	524.0	909	843
2012	509.3	881	800
2015	505.7	874	774

Sources: OECD (2017), Pisa International Data Explorer; Ministry of Education (2017), Student Roll by School Type as at 1 July, 1996-2016; Treasury (various years), Budget Economic and Fiscal Update: Core Crown Expenses Tables

Notes:

1. For 2006 to 2015 the PISA scores are the unweighted averages of the reading, mathematics and science scores. For 2003 the PISA scores are the unweighted average of maths and reading.
2. Aggregate PISA points are the product of total student numbers (primary and secondary) and the average PISA score.
3. Dollars are indexed using CPI.

Table 11 Measures based on outcomes adjusted for TIMMS scores (2002-2014) (2002=1,000)

Year	TIMMS score	Index of TIMMS points per teacher FTEs	Index of TIMMS points per $M real school revenue
2002	496.0	1,000	1000
2006	492.0	948	914
2010	486.0	874	812
2014	491.0	882	834

Sources: Caygill, Singh, and Hanlar (2016), TIMSS 2014/15: Mathematics Year 5 – Trends over 20 years in TIMSS; Student Roll by School Type as at 1 July, 1996-2016; Treasury (various years), Budget Economic and Fiscal Update: Core Crown Expenses Tables

Notes:

1. The TIMSS scores are for mathematics in Year 5.
2. Aggregate TIMSS points are the product of student numbers and the average TIMSS score.
3. Dollars are indexed using CPI.

The first adjustment is for attainment measured in the OECD's PISA test scores. The results for the unweighted average scores of reading, mathematics and science for 15 year olds are shown in Table 10 for every year for which the testing was administered. The scores have been used to form an aggregate number of student PISA points (multiplying the average score by the total number of student places), which provides an adjusted measure of output. The decline in the average PISA score (an average annual decline of 0.3%) is larger than the decline in aggregate PISA points (an average annual decline of 0.1%) as the number of students has increased slightly (an average annual increase of 0.2%) over the period. The ratio of this adjusted output can be divided by inputs (teacher FTEs and school revenue) as indicators of labour and multi-factor productivity respectively. These ratios, along with changes in their index levels (where the 2003 level is equal to 1,000), are shown in Table 10.

A similar exercise can be repeated with the TIMMS data. The TIMMS scores refer to the average score for mathematics in Year 5 and so are based on performance at primary school. The aggregate student TIMMS points is, as with PISA-based adjustments, based on the average TIMMS score multiplied by the total number of student places. The ratio of this adjusted output to two inputs (staff FTEs) and (revenue) can then be calculated as indicators of labour and multi-factor productivity. These ratios, along with changes in their index levels (where the 2002 level is equal to 1,000), are shown in Table 11.

There are several important caveats to bear in mind when using attainment measures like test scores to adjust outputs. In particular:

- The PISA and TIMMs attainment scores are used to adjust total school education output, but these indicators relate to specific elements within the school education system. They may not be representative of attainment across the broader school curriculum or pupil age ranges.
- There is the issue of attribution. In particular, how much of the attainment is due to the education system, rather than characteristics of the student's background, upbringing, parental engagement, early childhood nutrition, neighbourhood, etc. Indeed, the OECD has estimated that almost 20 percent of the variance in the 2012 PISA mathematics scores for New Zealand can be explained by the students' socio-economic background. This is one of the highest levels in the OECD (OECD, 2014).
- A related issue is the inherent quality of the student intake. There are also questions of timing, as the attainment in a test at, say, age 15 reflects not only the learning in the current year but the cumulative effect of the learning acquired throughout previous years of schooling.
- Further, while both the PISA and TIMMs test scores provide a useful picture on overall student attainment, they cannot illustrate the progress that individual students make from one assessment to the next. Tracking performance in this way would provide a measure of value add (Jensen, 2010).

It could be possible to disentangle some of these issues through the use of micro-data, such as New Zealand's Integrated Data Infrastructure (IDI).

4.4 Adjusting for outcomes (earnings)

A further adjustment is to account for the possible impact of education on key outcomes, such as earnings. This human capital approach to assessing the contribution of education has been widely used. It is based on a view that output of the education system adds to an individual's stock of human capital (Jorgenson and Fraumeni,1992), and has been used in studies of the returns to education (e.g., Maani and Maloney, 2004) and to adjust for quality (e.g., O'Mahony and Stevens, 2009). At the same time there are a number of potential drawbacks of this approach (e.g., Hanushek, 2015; Burgess, 2016).

As in the case of student attainment, it is important to recognise that outcomes such as earnings reflect more than just the education system (e.g., labour market conditions, technological change, and learning in other environments). There may also be a selection bias where students with favourable backgrounds are likely to elect to gain additional qualifications and to be successful in the labour market (Schreyer, 2010). And the school system influences a wide range of outcomes beyond earnings, both for the individual and for society more generally. Nevertheless, a benefit of using earnings as an outcome measure is that it can be seen as a proxy for a price in a market, and so creates some comparability with productivity measurement in the measured sector. A measure of future *real* earnings also recognises that the real return to a given student's education may change over time.

The adjustments made in this section follow an OECD approach developed by Murray (2007) and applied to Scotland. This involved two stages:

- First, school leavers were separated into three attainment categories. The categories are shown in Table 12. Note that as the school attainment measures have evolved over time the definitions of the categories have also changed. The goal has been to develop categories that provide broadly consistent measures of performance across all of the years studied. (This measure of domestic attainment is used as the output measure in the comparison with the Office for National Statistics approach (discussed in section 5).)

- Second, for each of the three categories the average weekly income (earnings plus transfers) for wage and salary earners 15 years of age and older were drawn from the New Zealand Income Survey. These were converted to an expected real income by adjusting for unemployment rates and inflation (the full CPI). A detailed breakdown of the data for each of the three attainment categories is given in Table B.1 in Appendix A. The average weekly income was multiplied by the employment rate (one minus the unemployment rate) to give an adjusted income. The average real expected income for each category was then multiplied by the number of people in that category to give an attainment weighted real income total. This income measure forms the output measure for the productivity calculations.

There are a number of important caveats to bear in mind with these estimates. The results apply to people with wage or salary income or who are self-employed, i.e., they do not cover people not in the labour force. Furthermore, it is assumed that previous levels of income are a good indicator of levels of income in the future. Further, these results are partly driven by the increase in the proportion of students leaving school with NCEA level 2 (or equivalent) or above (increasing from 66% in 1997 to 87% in 2015). Increased shares of school leavers with higher qualifications could reflect a number of factors: improved methods of teaching, improved innate capability of students, or "grade inflation." Again this is an area where further work such as using individual longitudinal micro data to better understand the impact of teacher quality could be of value (see footnote 21).

Table 12 Definitions of attainment categories for the New Zealand Income Survey

Year	Category 1	Category 2	Category 3	Not included
1997 to 2008	Higher school qualification	Sixth form qualification	No qualification	Other school qualification
2009 to 2012	Higher school / NCEA level 3	Sixth form / NCEA level 2	No qualification / School Certificate / NCEA level 1	Other school qualification
2013	NCEA level 3 or equivalent	NCEA level 2 or equivalent	No qualification / NCEA level 1 or equivalent	Other school qualification
2014	Upper secondary school qualification	Lower secondary school qualification	No qualification	School qualification not specified

Source: Productivity Commission

Table 13 Student numbers in attainment categories (1997-2014) (1997=1,000)

Year	Category 1	Category 2	Category 3	% in Category 1 and 2	Index of % in Category 1 and 2 (1)
1997	21,135	12,012	17,046	66%	1,000
1998	21,979	12,356	17,531	66%	1,002
1999	21,458	14,427	18,515	66%	999
2000	20,423	14,949	19,261	65%	980
2001	19,765	14,264	19,488	64%	963
2002	20,304	12,941	19,296	63%	958
2003	22,660	13,235	17,576	67%	1,017
2004	22,373	15,923	17,338	69%	1,042
2005	23,882	13,815	19,757	66%	994
2006	25,382	13,711	17,802	69%	1,040
2007	26,863	15,445	14,255	75%	1,133
2008	28,041	13,513	11,080	79%	1,195
2009	29,219	12,992	10,282	80%	1,218
2010	33,330	14,226	10,904	81%	1,232
2011	35,783	13,804	9,978	83%	1,261
2012	36,087	12,127	8,414	85%	1,289
2013	36,731	12,599	8,702	85%	1,287
2014	36,509	12,594	7,466	87%	1,314

Source: Productivity Commission

Note:

1. This is the output index used for the comparison with the Office for National Statistics approach in section 5.

Table 14 Productivity indexes based on earnings adjusted school attainment (1997-2014) (1997=1,000)

Year	Attainment weighted real average weekly income ($)	Index of income weighted output per teacher FTE	Index of income weighted output per school revenue
1997	502.8	1000	1000
1998	513.1	1005	954
1999	545.7	1046	979
2000	534.1	1024	884
2001	548.5	1019	904
2002	573.9	1062	1038
2003	589.6	1057	1029
2004	591.1	1036	977
2005	615.2	1061	990
2006	636.2	1076	1012
2007	684.2	1150	1062
2008	662.4	1101	1022
2009	657.0	1071	968
2010	608.4	981	865
2011	619.6	1002	894
2012	635.0	1031	912
2013	624.9	1020	878
2014	650.6	1042	937

Sources: Productivity Commission calculations; Student Roll by School Type as at 1 July, 1996-2016; Treasury (various years), Budget Economic and Fiscal Update: Core Crown Expenses Tables

Note:

1. Weekly income and school revenue are indexed to 2006 using the CPI.

4.5 Bringing measures together

These data illustrate both the importance and the difficulty of quality adjusting sector-level productivity data. Policy decisions (e.g., regarding smaller class sizes) are reflected in the basic labour productivity measures. Further, when the measure of labour input is adjusted in an effort to capture quality changes (e.g., through using data on teachers' salaries) this labour productivity performance also worsens. But there are caveats to this. These caveats include questions over the use of salaries as a proxy for quality of inputs – particularly given the nature of public service labour markets (e.g., whether a change in salaries reflects quality or compositional changes) and the importance of missing inputs such as the previous performance of students (needed for measures of value added).

Table 15 Summary of measures (CPI deflator)

Year	Q/L	Q/wL	pQ/L(1)	pQ/L(2)	pQ/wL	Q/(wL+rK+mM)	pQ/(wL+rK+mM)
2002	1,000	1,000		1,000	1,000	1,000	1,000
2003	986	965	1,000	996	974	982	992
2004	967	918		975	927	933	941
2005	949	885		999	933	906	954
2006	928	860	944	1,014	941	892	975
2007	919	846		1,083	996	868	1,023
2008	907	777		1,037	889	861	985
2009	893	770	909	1,009	869	826	933
2010	890	758		924	787	803	834
2011	890	773		944	820	813	862
2012	891	772	881	971	842	806	879
2013	899	780		961	833	792	846
2014	888	788		982	871	816	902
2015	891	791	874			786	
				Average Annual Growth Rates			
2002-2008	-1.6%	-4.1%		0.6%	-1.9%	-2.5%	-0.3%
2008-2014	-0.4%	0.2%		-0.9%	-0.3%	-0.9%	-1.4%
2002-2014	-1.0%	-2.0%	-1.1%	-0.2%	-1.1%	-1.7%	-0.9%

Source: Productivity Commission

Notes:

1. Two other measures based on domestic attainment (with no adjustment for expected real wages) are shown in Table 16.
2. Q/L equals student numbers/teacher FTEs.
3. Q/wL equals student numbers/teacher salaries.
4. pQ/L(1) equals student numbers weighted by attainment in PISA scores/teacher FTEs.
5. pQ/L(2) equals income weighted output/teacher FTEs.
6. pQ/wL equals income weighted output/teacher salaries.
7. Q/(wL+rK+mM) equals student numbers/school revenue.
8. pQ/(wL+rK+mM) equals income weighted output/school revenue.

Nonetheless, a similar story emerges from measures that adjust outputs based on attainment in international assessments (such as New Zealand students' PISA scores), where performance has worsened. This reflects a decline in aggregate PISA points (an average annual decline of 0.1%), which itself reflects a larger fall in the average PISA score (an average annual decline of 0.3%). However, there are differences in measured attainment according to international and domestic assessments. Indeed, (labour) productivity based on a measure that adjusted for domestic attainment (e.g., the proportion of students leaving school with NCEA level 2 (or equivalent)) increased between 2002 and 2014. A related measure (the series using school revenue as a measure of inputs) was used to compare the results in this paper to those of the Office for National Statistics in the United Kingdom.

Finally, measures were adjusted for final outcomes (in this case the performance of school leavers in the labour market). This involved a two-step process:

- First, output was adjusted for the domestic attainment of students.
- The average real expected income for students based on this attainment was then estimated and multiplied by the number of students in each category.

These measures also suggested falling productivity. But these measures can be subject to attribution problems. Indeed, given the improved domestic attainment above, the decline in these measures reflected changes in unemployment and real wage growth following the Global Financial Crisis. With the use of sector-level data it is thus not possible to conclude that changes in these measures are directly attributable to the performance of schools, e.g., they may also reflect differences in the economic context facing different cohorts of school leavers. To estimate the incremental value of school education on earnings it would be necessary to use linked unit record data.

5 Comparison with ONS estimates of education productivity

This section compares some of the results in this paper against a similar series produced by the Office for National Statistics (ONS) in the United Kingdom. As discussed the ONS has been at the forefront of developments in measuring public sector productivity and so a comparison of approaches could be instructive.

In the United Kingdom output is based on the numbers of students adjusted for absences. This is quality adjusted for the Level 2 attainment by students in England, a five year geometric average of average point scores for students at this level in Scotland, and average point scores for GCSEs in Wales. Student numbers are adjusted based on the average point scores in these exams. As discussed in footnote 3, the ONS has had to revise its approach to quality adjusting education quantity when practices regarding students sitting exams changed.

In New Zealand output (numbers of primary and secondary students, not accounting for absences) is adjusted based on the proportion of students completing schooling with NCEA level 2 (or earlier equivalent) or more. In relation to input measures used, in New Zealand school revenue is used as the input measure. In the United Kingdom, inputs include labour, goods and services, and consumption of fixed capital, which are all weighted by expenditure share.

It is important to recognise that given differences in public policies, policy contexts, and data availability it is appropriate for there to be some small methodological differences in the two approaches. Findings can thus be expected to differ. Yet similarities in the general magnitude and direction of effect from making broadly similar quality adjustment (based on performance in domestic assessments) could be expected.

The results in Figure 7 show that in both countries the unadjusted series show a downward shift over time, reflecting policy choices for smaller class sizes. But in both cases making a quality adjustment based on pupil attainment leads to improved (lower rate of decline in) productivity. In New Zealand the average unadjusted annual productivity growth for 1997 to 2014 was -2.1%, while in the United Kingdom it was -1.6%. In contrast, the average adjusted productivity growth over this period was -0.5% in New Zealand and -0.2% in the United Kingdom. However, a higher proportion of students achieving NCEA level 2 or above (or equivalent) in New Zealand has been reflected in strong multifactor productivity growth for the adjusted series since 2005.

Table 16 Comparison with ONS estimates of education productivity (1997 to 2014) (1997=1,000)

Year	ONS NAQ(1)	ONS QA(1)	NZ Multifactor Productivity NQA(1), (2)	NZ Multifactor Productivity QA(1), (2)	NZ Labour Productivity NQA(1), (3)	NZ Labour Productivity QA(1), (3)
1997	1000	1000	1,000	1000	1000	1000
1998	1009	1035	936	938	1004	1006
1999	1028	1076	879	878	986	985
2000	1007	1066	851	835	990	971
2001	986	1055	788	759	963	927
2002	941	1023	799	765	976	935
2003	938	1030	892	906	962	978
2004	928	1037	864	901	944	984
2005	890	1020	815	810	926	920
2006	862	1008	791	823	905	942
2007	842	1010	780	883	897	1016
2008	809	1001	759	907	885	1058
2009	777	999	758	923	872	1062
2010	761	1006	729	898	869	1070
2011	774	1039	702	885	869	1095
2012	785	1050	710	915	869	1121
2013	765	999	710	913	878	1130
2014	763	973	698	918	866	1139
			Average annual growth rates			
1997-2014	-1.6%	-0.2%	-2.1%	-0.5%	-0.8%	0.8%
2000-2014	-1.7%	-0.4%	-1.1%	1.5%	-1.0%	1.7%
2008-2014	-1.0%	-0.5%	-1.4%	0.2%	-0.4%	1.2%

Sources: Productivity Commission and Office for National Statistics

Notes:

1. NQ = Not Quality Adjusted; QA = Quality Adjusted.
2. Unadjusted multifactor productivity is measured as an index of student numbers over school revenue. Adjusted is measured as an index of students leaving school with NCEA level 2 (or equivalent) or greater over school revenue. School revenue is deflated using the full CPI. This is the series contained in Figure 7.
3. Unadjusted labour productivity is measured as an index of student numbers over teacher FTEs. Adjusted is measured as an index of students leaving school with NCEA level 2 (or equivalent) or greater over teacher FTEs.

Figure 7 Comparison with ONS estimates of education productivity (1997 to 2014) (1997=1,000)

Sources: Productivity Commission and Office for National Statistics (2016)

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Appendix A Summary of results with alternative deflator

Table A.1 Summary of measures (CPI level 2 subgroup (primary and secondary education) deflator)

Year	Q/L	Q/wL	pQ/L(1)	pQ/L(2)	pQ/wL	Q/(wL+rK+mM)	pQ/(wL+rK+mM)
2002	1,000	1,000		1,000	1,000	1,000	1,000
2003	986	1,000	1,000	996	1,010	1,018	1,196
2004	967	969		975	978	984	1,200
2005	949	983		999	1,035	1,006	1,203
2006	928	976	944	1,014	1,067	1,011	1,275
2007	919	1,008		1,083	1,188	1,035	1,384
2008	907	941		1,037	1,077	1,043	1,375
2009	893	959	909	1,009	1,083	1,030	1,377
2010	890	959		924	996	1,016	1,253
2011	890	977		944	1,036	1,027	1,251
2012	891	999	881	971	1,090	1,044	1,299
2013	899	1,050		961	1,122	1,066	1,304
2014	888	1,090		982	1,206	1,129	1,381
2015	891	1,142	874			1,134	
				Average Annual Growth Rates			
2002-2008	-1.6%	-1.0%		0.6%	1.2%	0.7%	5.4%
2008-2014	-0.4%	2.5%		-0.9%	1.9%	1.3%	0.1%
2002-2014	-1.0%	0.7%	-1.1%	-0.2%	1.6%	1.0%	2.7%

Source: Productivity Commission

Notes:

1. Q/L equals student numbers/teacher FTEs.
2. Q/wL equals student numbers/teacher salaries.
3. pQ/L(1) equals student numbers weighted by attainment in PISA scores/teacher FTEs.
4. pQ/L(2) equals income weighted output/teacher FTEs.
5. pQ/wL equals income weighted output/teacher salaries.
6. Q/(wL+rK+mM) equals student numbers/school revenue.
7. pQ/(wL+rK+mM) equals income weighted output/school revenue.

Appendix B Additional data on real expected income by attainment level

Table B.1 Real expected income by school attainment level

Year	Average Weekly Income	Unemployment Rate	Expected Weekly Nominal Income	Real Expected Income (2006 base)
		Category 1		
1997	402	3.9	386	470
1998	441	4.4	422	505
1999	456	4.9	434	522
2000	431	4.2	413	487
2001	463	3.7	446	509
2002	492	3.4	475	528
2003	516	3.4	498	546
2004	521	3.1	505	540
2005	597	2.4	583	606
2006	645	2.5	629	629
2007	768	2.5	749	734
2008	732	2.5	714	673
2009	740	3.3	715	662
2010	703	4.5	672	611
2011	760	4.1	729	630
2012	810	4.6	773	661
2013	767	4.7	731	622
2014	790	4.1	758	634
		Category 2		
1997	498	6	467	568
1998	485	7.2	450	539
1999	547	7.0	509	612
2000	547	6.4	512	604
2001	578	5.8	545	622
2002	621	5.7	586	651
2003	650	5.2	616	675

Year	Average Weekly Income	Unemployment Rate	Expected Weekly Nominal Income	Real Expected Income (2006 base)
2004	662	4.4	633	677
2005	671	4.2	643	668
2006	706	4.3	676	676
2007	711	4.3	680	667
2008	730	4.5	698	657
2009	774	5.8	729	675
2010	736	8.1	676	615
2011	776	8.5	710	614
2012	730	8.2	670	574
2013	806	8.9	735	625
2014	911	7.8	840	703
		Category 3		
1997	460	11.3	408	497
1998	484	12.8	422	505
1999	499	12.9	435	522
2000	505	11.0	450	530
2001	518	9.6	468	535
2002	562	8.7	513	571
2003	578	8.1	531	582
2004	582	7.2	540	578
2005	607	6.6	567	590
2006	656	6.0	616	616
2007	662	6.3	621	608
2008	726	6.3	681	641
2009	733	8.4	671	621
2010	727	10.7	649	591
2011	762	10.3	684	591
2012	793	10.2	712	610
2013	832	9.7	751	638
2014	845	9.0	769	643

Source: Productivity Commission

Note:

1. Dollars are indexed to 2006 using the full CPI.

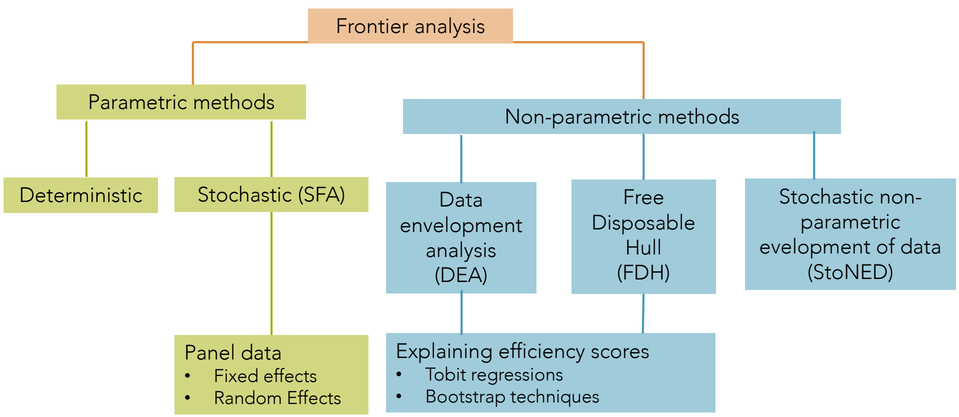
Appendix C Background on frontier approaches

This paper highlighted the growing attention being paid to the estimation of measures of public sector productivity using national accounting approaches. The advantage of these approaches is they are potentially comprehensive. A limitation is that as aggregate measures they do not address the distribution of outcomes across decision making units within a sector. In contrast, micro-data approaches can provide a relatively rich picture of public sector productivity and help illustrate important policy questions (such as diffusion and convergence). But these approaches are data and resource intensive and each study only provides a partial view of changes in aggregate public sector productivity or across the whole education sector.

Nonetheless, the use of individual firm level data from the private sector is proving a rich source of insights for understanding the distribution of productivity across firms (Conway, 2016). This can help answer questions such as what factors explain the performance of some firms. Is it that they are above some minimum size? Do innovation and productivity improvements persist? And how do they diffuse among firms? Do the lower productivity firms eventually attain higher levels of productivity, or do they leave the sector or are taken over by the leading firms?

Based on this experience additional insights into public sector productivity could be gained from more attention to the performance of individual units. Figure C.1 provides an overview of some key methodologies for estimating public sector productivity using individual unit data.

Figure C.1 Methodologies for the measurement of efficiency and productivity



Source: Afonso (2009)

DMUs

As noted above, micro-data can help identify which decision making units (DMU) are at or close to the efficiency frontier, which ones are lagging and some of the key characteristics of leaders and laggards. Frontier studies start with the concept of a DMU. The DMU can refer to an individual, firm, public agency (e.g., a school or hospital), region or country. Examples of research on all these levels of DMU can be found (see Gattoufi et al., 2004). The efficiency frontier (or reference set) is the locus of those DMUs whose input levels are the lowest for any given level of output. This frontier is the reference point against which the efficiency of DMUs can be assessed.[22] Tulkens (2013) specifies that the reference set should contain as its elements:

- All of the observed production plans in the data set (where a production plan is a vector of inputs and outputs);
- Unobserved plans below the frontier (of output); and
- In the case of DEA (see below) any other plan that is a convex combination of some plans satisfying the first two conditions.

Non-parametric approaches

Defining the DMUs and reference set (efficiency frontier)

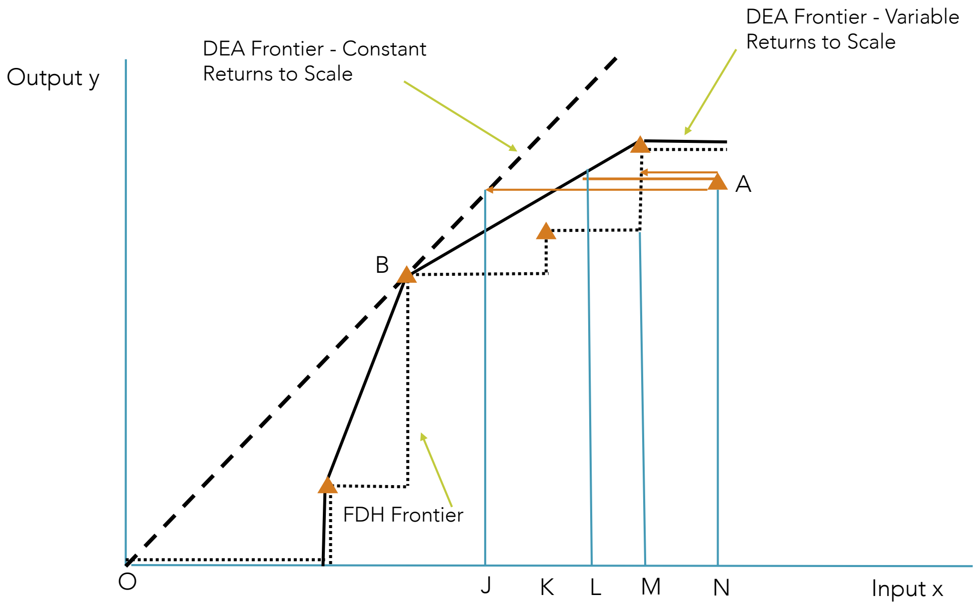
There are two widely used non-parametric approaches for defining the efficiency frontier. These are Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). DEA is a linear programming method which has been increasingly applied to analyse the efficiency of government services as it does not require prices for inputs and outputs (Seiford, 1994). It calculates the efficiency of a DMU relative to the best practice of the sample group. Furthermore, in common with FDH and other mathematical programming approaches it does not require the specification of a particular functional form. As noted by the Steering Committee (1997) it can handle multiple inputs and outputs.

These two approaches create different frontiers and it is important to understand the differences between them. FDH satisfies the first two of the three conditions set out above while DEA satisfies all three conditions. In effect FDH is the non-convex counterpart of DEA, which is arguably more restrictive in requiring that the convexity condition be met. Thus, the DEA approach provides a comprehensive baseline for evaluating performance, but it relies (at least partly) on a hypothetical frontier. The frontiers obtained with each of the two methods are shown in Figure B.2, which for simplicity is drawn for a single output and a single input.

The set defined by FDH lies within the set defined by DEA with variable returns to scale. This, in turn, lies within the set defined by DEA with non-increasing returns to scale. Finally, this is contained within the set defined by the DEA with constant returns to scale. Thus DEA (with either constant or variable returns to scale) and FDH define three distinct production sets and as a consequence potentially three different efficiency measures for any given DMU.

[22] For an accessible introduction to frontier modelling see Coelli (1995) and Mawson et al. (2003). Djellal and Gallouj (2008) and Crowhurst et al. (2015) also provide a simple concise summary.

Figure C.2 DEA and FDH efficiency frontiers



Sources: Becker (2008) and Tulkens (1993)

Estimating the distance to the efficiency frontier

The distance to the frontier of any given sample observation obviously depends on which frontier is chosen. Consider for example the DMU located at point A. There are three possibilities:

$$\frac{OJ}{ON} = DEA\,with\,\text{constant}\,returns\,to\,scale$$

$$\frac{OL}{ON} = DEA\,with\,\text{variable}\,returns\,to\,scale$$

$$\frac{OM}{ON} = FDH$$

The difference between the DEA frontier with constant returns to scale and the DEA frontier with variable returns can be used to define the extent of scale efficiency and the technical efficiency independently of non-scale factors. Referring again to Figure B.2, the technical inefficiency of the DMU called A can be decomposed as:

$$\frac{OJ}{ON} = \frac{OJ}{OK} * \frac{OK}{ON}$$

In other words, overall inefficiency is equal to scale inefficiency multiplied by non-scale technical inefficiency.

Valid comparisons across DMUs can only be made where they are all operating in a similar environment. Differences in the performance of schools, for example, could reflect the socio-economic status of their catchment as much as the efficiency of the management. However, it is possible to correct for external influences in a number of ways:

- By limiting the selection of DMUs to those from similar environments.
- By adding a variable to the analysis where the characteristic is a continuous variable.
- By using a two stage process which establishes an econometric relationship between the efficiency scores and a set of exogenous characteristics.

Parametric methods

Non-parametric methods make no allowance for measurement errors or other random shocks. As a result, any observation falling inside the frontier is treated as technically inefficient. This section discusses stochastic or parametric frontier models.

Estimating the production function and error terms

Following Coelli et al. (2005) the concepts can be illustrated for the simple case of a Cobb-Douglas production function where output, y, is generated from inputs, x. For convenience the illustration is restricted to a single input. The analysis can be extended to the case of multiple inputs with the vector product $x'\beta$. The deterministic component for the *i* DMU is then given by:

$$\ln y_i = \alpha + \beta \ln x_i$$

This can be converted to a stochastic frontier production function by the addition of a random error term, v_i, and a term to capture technical inefficiency (u_i). The random noise and inefficiency terms are random variables assumed to be statistically independent.

$$\ln y = \alpha + \beta \ln x_i + v_i - u_i \text{, or}$$

$$y_i = \underbrace{\exp(\alpha + \beta \ln x_i)}_{\text{Deterministic Component}} * \underbrace{\exp(v_i)}_{\text{Random Noise}} * \underbrace{\exp(-u_i)}_{\text{Technical Inefficiency}}$$

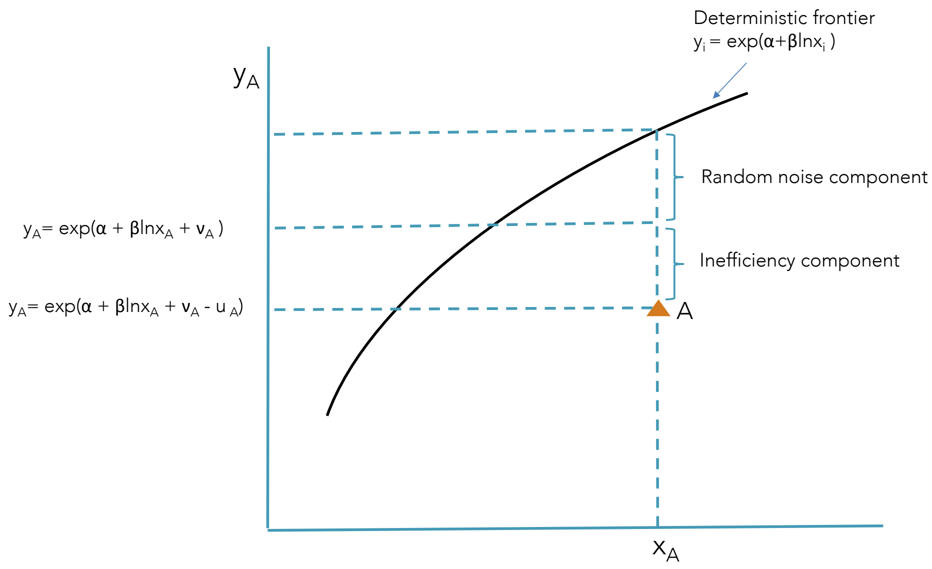
This is shown in Figure B.3 for a DMU whose observed position (y_A, x_A) is at the point denoted A. The distance to the frontier is made up of the random noise and the inefficiency components.

An output oriented measure of *technical efficiency* can then be defined as the ratio of the distance of the observed output point (A) to the stochastic frontier at that input level (x_A):

$$\text{Technical efficiency for A } (TE_A) = \frac{y_A}{\exp(\beta x_A + v_A)} = \frac{\exp(\beta x_A + v_A - u_A)}{\exp(\beta x_A + v_A)} = \exp(-u_A)$$

This measures the output of the DMU at point A relative to that which a fully efficient DMU could produce employing the same level of input, x_A.

Figure C.3 Stochastic production frontier



Source: Coelli et al. (2005)

The strength of stochastic frontier analysis (SFA) lies in its ability to distinguish random noise from systematic inefficiency. But to achieve this comes at the cost of requiring a specific functional form. To predict the level of inefficiency it is necessary to first estimate the parameters of the production frontier (for details of estimation procedures see Coelli et al. (2005)).

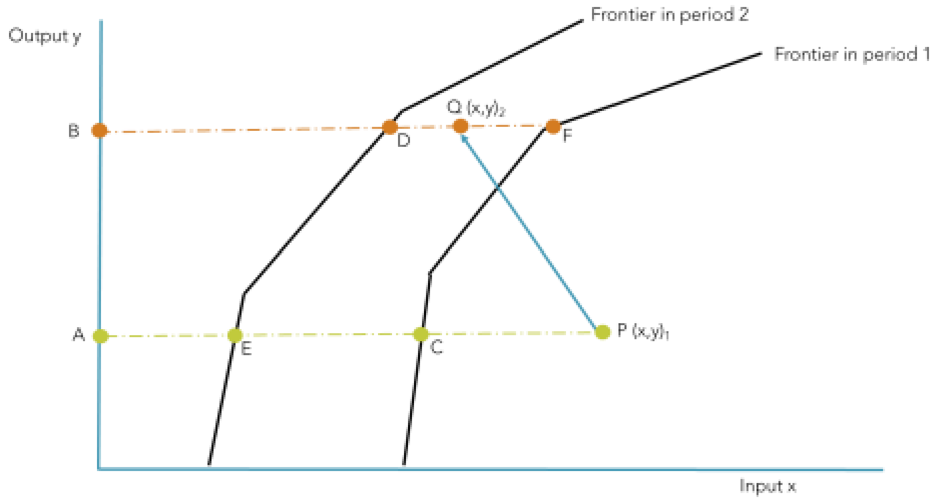
Critical to successful estimation are the assumptions concerning the nature of the error terms. Inefficiency is identified on the basis of an assumption about the error structure which is not testable. Specifically, the random error term, *v*, is assumed to be distributed without skewness. If this assumption is violated Skinner (1994) shows that it will lead to a false finding of higher levels of inefficiency.

Calculating distance from and movements towards frontier

A stylised version of a SFA frontier is shown in Figure B.4. The position of each DMU is compared relative to the frontier and the extent to which the frontier shifts can be defined. Improvements in efficiency over time can result from some DMU's adopting new practices that shift the frontier outward, while others catch up (Cullen and Ergas, 2014). This is explained briefly below; for the underlying analytics see Färe et al. (1994).

The frontier is depicted for two periods, 1 and 2. In period 1 the unit of interest lies inside the frontier at point P, and in period 2 has moved to point Q. In period 1, the unit's position relative to the frontier can be described by AC/AP. This ratio will be less than one for all points lying inside the frontier, while for those on the frontier the ratio would, by definition, be equal to one. Likewise in period 2, the corresponding ratio would be BD/BQ.

Figure B.4 Measuring efficiency relative to a frontier



Source: Afonso (2009)

It is then possible to ask to what extent has the unit moved closer to the frontier. This provides a measure of so called catch-up and is given by:

$$\frac{BD}{BQ} / \frac{AC}{AP}$$

This captures the change in relative efficiency by measuring whether production is getting closer (catching up) or further from the frontier. Now consider shifts in the frontier. In the first instance the shift can be measured at the output level of the DMU denoted by point P:

$$\varphi_1 = \frac{AC}{AE} = \frac{AC / AP}{AE / AP} = \frac{Efficiency\, wrt\ period 1\ frontier}{Efficiency\, wrt\ period 2\ frontier}$$

Likewise the shift of the frontier can equally be defined relative to the point Q as:

$$\varphi_2 = \frac{BF}{BD} = \frac{BF / BQ}{BD / BQ} = \frac{Efficiency\, wrt\ period 1\ frontier}{Efficiency\, wrt\ period 2\ frontier}$$

One approach to dealing with these two measures of the shift in the frontier is to take an average, in this case the geometric mean, given by $(\varphi_1 \varphi_2)^{1/2}$.

Defining an index of productivity

The distance measures can now be used to define an index of productivity. Following Färe et al. (1994), a Malmquist MFP Index (M) can be written as:

$$M = \left(\frac{BD}{BQ} * \frac{AP}{AC} \right) * \left[\frac{AC}{AE} * \frac{BF}{BD} \right]^{1/2}$$

The term in square brackets is the geometric mean of the shift in technology between the two periods, i.e., the extent of technical change. The ratio outside the square brackets is the input oriented measure of technical efficiency or catching up. In summary, the MFP index can be decomposed into an element of technical efficiency which captures the diffusion of technology and an element measuring technological change or innovation. In its simplest terms the Malmquist measure for productivity change can be viewed as:

$$M = (Diffusion) * (Innovation)$$

How does this result relate to that of growth accounting? Färe et al. (1994) illustrate the case for a Cobb-Douglas production function of the standard form:

$$y_t = A_t \prod_i x_{it}^{\beta_i}$$

and show that M is simply the ratio of the Solow efficiency parameters (A_t) or:

$$M = \frac{A_{t+1}}{A_t}$$

This result, however, depends critically on the assumption that the actual output levels lie on the frontier, so the growth accounting measure of multi factor productivity is simply capturing the technological shift. When observed outputs lie on the frontier the distance functions are by definition equal to one. As a consequence the diffusion term is unity and M measures just the innovation or technological change effect. In other words, a standard growth accounting measure of MFP derived from a Cobb-Douglas production function will be biased if there is any inefficiency such that some observed outputs fall inside the frontier. Indeed, Coelli (2002) stresses that the Malmquist MFP index will only properly measure productivity changes if the underlying technology used to generate the input distance functions for M display constant returns to scale.

Conclusion

Observations of the inputs and outputs of DMUs can be used to define a frontier. This efficiency frontier (or reference set) is the locus of those DMUs whose input levels are the lowest for any given level of output. This frontier is the reference point against which the efficiency of a DMU can be assessed. Two useful techniques for defining a frontier are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Considerations when choosing between them include:

- Cases with less heterogeneous samples are more suited to DEA. SFA is more suitable for more heterogeneous samples. DEA is more sensitive to heterogeneity in the sample (influenced by outliers) and will tend to give lower average efficiency scores (although not consistently so). The regression approach of SFA means outliers are given less weight.

- Cases where output supplied is subject to variable and/or unpredictable client demand are less suited to DEA. Unpredictability of client demand can introduce a source of variance in outputs and make the input-output relationship for a DEA stochastic. SFA is better suited to coping with unpredictable demand.
- Both methods can deal with cases where operating environments are influenced by exogenous variables. Where these variables could be an important consideration a DEA approach of restricting the comparison set (to DMUs that have similar or less favourable operating environments) is likely to be less suitable. Other DEA approaches or an SFA approach based on regression analysis would be better.
- SFA requires the parameters of the production function and the random error term to be estimated. DEA is more suitable for cases where these parameters cannot be feasibly estimated, such as where there are a limited number of observations available for robust regression analysis.