MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

How useful are our productivity measures?: Literature review

October 2018

New Zealand Government

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Ministry of Business, Innovation and Employment (MBIE)

Hikina Whakatutuki – Lifting to make successful

MBIE develops and delivers policy, services, advice and regulation to support economic growth and the prosperity and wellbeing of New Zealanders.

MBIE combines the former Ministries of Economic Development, Science + Innovation, and the Departments of Labour, and Building and Housing.

Author

Sharon Pells

Acknowledgments

Thanks to Daniel Griffiths at Stats NZ, Patrick Nolan at the New Zealand Productivity Commission, and Lynda Sanderson, Corey Allan, Eyal Apatov, Bettina Schaer, Donna Purdue and Gina Williamson at MBIE for their helpful suggestions. Thanks also to members of a MBIE reference group, and attendees of a workshop on 4 December 2017, for their useful feedback.

More information

www.mbie.govt.nz

0800 20 90 20

Information, examples and answers to your questions about the topics covered here can be found on our website www.mbie.govt.nz or by calling us free on 0800 20 90 20.

ISBN (online) 978-1-98-857017-4

October 2018

How useful are our productivity measures?

Key points

MBIE should maintain its focus on lifting productivity because:

– productivity growth is central to lifting incomes

– mismeasurement is estimated to have played a fairly minor role in the global productivity slowdown; the slowdown cannot simply be written off as measurement error

– the measurement challenges are unlikely to explain New Zealand's consistently poor productivity performance.

What is happening with productivity?

Productivity growth has slowed worldwide. One possible explanation is that productivity is increasingly being **mismeasured**, ie 'true' productivity growth may be higher than measured growth.

New Zealand has seen this slowdown too. New Zealand has comparatively low incomes, driven by our **poor productivity performance**.

What is productivity?

– Productivity is a measure of efficiency.

– Productivity is defined as: **'a ratio of a volume measure of output to a volume measure of input'.**

$$\text{Productivity} = \frac{\text{Volume of output}}{\text{Volume of input}}$$

– **Productivity is about production**. Outputs (goods and services) are produced using inputs (like workers' time, effort and skills, and machines). Prices provide a way of adding up and weighting different outputs and different inputs.

– **Productivity is a volume measure**. Volume has a quantity and a quality component.

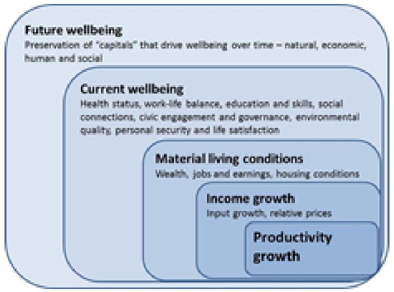
Why is productivity important?

– Lifting productivity means that New Zealand is making more of its limited resources. This increases society's **choices**.

– Productivity growth is linked to **wage growth**.

– Productivity growth is a key driver of long-term per capita **income growth**. This improves material living conditions and contributes to overall wellbeing.

Productivity growth contributes to wellbeing



Source: Author, drawn from OECD (2015) *How's life? Measuring well-being.*

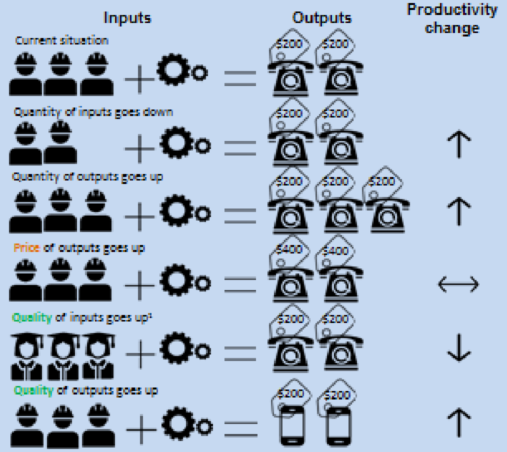
How is productivity measured?

– Measuring productivity involves dividing some measure of the volume of output by some measure of the volume of input.

– In practice, data on output tend to be available as dollar values rather than volumes. Adjusting for price and quality changes therefore plays a key role in measurement. An increase in the quality of output represents an increase in output volume, but pure price increases (inflation) do not.

– Consumers are willing to pay for higher quality goods and services, so prices and quality tend to move together. But this is not always the case. For example, the quality of computers has risen dramatically in recent years, while prices have fallen.

A stylised example of how productivity works



Note: In practice, productivity measures are not adjusted for labour quality
Source: Author

What are the measurement concerns?

Measurement concerns can be grouped into two broad areas.

1. Disentangling price and quality changes is becoming trickier

– It is hard for measurement to keep pace with rapid changes in the quality of ICT and other digital products. The quality of services is also hard to assess.

– The digital economy and services sector are a growing share of the overall economy. This means that the measurement challenges may be growing too. If so, analysing productivity trends will become more difficult.

– Improving price and quality adjustment methods will therefore improve productivity measurement.

2. Productivity covers less and less of what matters

– Productivity measures generally only cover things that are produced and consumers pay for. They exclude the unpaid-for benefits from the digital economy like free apps, Google and Facebook.

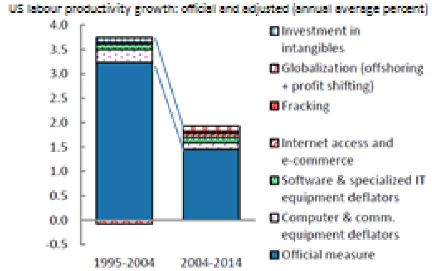
– It is therefore important to recognise what productivity is and isn't, and to improve methods of measuring the benefits from the digital economy.

What is the scale of mismeasurement?

– Mismeasurement is estimated to play a limited role in explaining the global productivity slowdown.

Accounting for mismeasurement doesn't change the story much

US labour productivity growth: official and adjusted (annual average percent)



Sources: Byrne, Fernald, and Reinsdorf (2016); IMF staff calculations.

Conclusions

– Productivity measures *are* still useful. They tell us something unique about how efficiently resources are being used.

– Mismeasurement appears to have played a fairly minor role in the global productivity slowdown.

– Many of the benefits of the digital economy fall outside conventional productivity measurement.

Key points

Productivity is a measure of the efficiency with which inputs (labour, capital and raw materials) are converted into outputs (goods and services). Productivity is commonly defined as 'a ratio of a volume measure of output to a volume measure of input'. Key points to note from this definition are that productivity is a volume measure, where volume has a quantity and a quality component, and that productivity generally only covers things that are produced by firms and that consumers pay for.

Productivity growth has slowed worldwide. Since the mid-2000s, productivity growth has been declining in many countries. This decline has been substantial, long-lasting, and across the board. New Zealand has seen this productivity slowdown too, but the slowdown here pre-dated that in many other countries and was less severe.

There are a number of possible explanations for the productivity slowdown, many of which relate to technology. This report focuses on measurement error as a possible explanation of the slowdown.

The measurement issues can be grouped into two broad areas. Firstly, the challenge of disentangling price and quality changes in outputs and inputs is likely to be growing, due to factors like the growth in the services sector and in the digital economy. Secondly, productivity measures capture less and less of what matters. For example, these measures exclude the unpaid-for benefits to consumers from things like free apps on smartphones, Google and Facebook.

In the light of measurement issues, MBIE considered the question: how useful are our productivity measures? We examined the validity of concerns about measurement. This partly reflects that perceived measurement issues risk productivity being relegated from important policy discussions. We also examined productivity concepts, measurement practices, and the use of productivity measures. The purpose was to deepen our understanding of productivity more generally.

Productivity measures *are* still useful. They tell us something unique about how efficiently resources are being used. In large part, these measures appear to still reflect 'true' productivity.

Measurement error is estimated to account for only a small portion of the productivity slowdown. Estimates vary markedly, and there is considerable uncertainty around the estimates. But overall, studies tend to come to similar conclusions: measurement error has played a relatively minor role in the productivity slowdown.

New Zealand should continue to focus on lifting productivity. New Zealand's consistently poor productivity performance cannot simply be written off as measurement error. Therefore it is important that, in our economic strategy and discourse, we maintain our efforts to raise productivity.

New Zealand should also continue to improve methods to adjust for price and quality changes. Productivity is a key measure of economic performance, and keeping on top of the measurement challenges is increasingly difficult. In broad terms, the aim of adjustment methods is to distinguish between pure price changes (inflation) and changes in quality.

Productivity trends should be interpreted with care. This reflects that the measurement challenges may be growing, due to rapid growth in hard-to-measure sectors like the digital economy and the services sector.

Better measuring the benefits from the digital economy is important too. Many benefits of the digital economy fall outside conventional productivity measurement. One opportunity to better measure these benefits relates to the development of a 'digital nation domain plan'; Stats NZ and MBIE are involved in the development of this plan.

Table of Contents

1. Introduction

Motivation

Over the last 15 years or so, productivity growth has slowed considerably in many countries (van Ark 2016) including New Zealand.

There are a number of possible explanations for the productivity slowdown. One explanation is that productivity is increasingly being mismeasured, due to factors like measurement failing to keep pace with rapid advances in digital and other products and services.

If concerns about measurement are valid and measured productivity growth is lower than 'true' productivity growth, MBIE could be paying too much attention to lifting productivity. Conversely, if the concerns are not valid and MBIE staff are overly worried about mismeasurement, productivity risks being relegated from important policy discussions in which it should be included.

Productivity is a widely known, but not well understood, concept. So improving understanding within MBIE about productivity and its measurement should help MBIE better interpret productivity statistics. This is not just about the measurement issues, but raising the understanding more generally about productivity.

MBIE has some work underway relevant to productivity measurement. In particular, MBIE is working with Stats NZ on the development of a Digital Nation Domain Plan, which considers enduring questions about the digital economy and the data required to address those questions.

Purpose, objectives and audience

In light of concerns about measurement, the central question this report considers is: How useful are our productivity measures?

The specific research questions (around which this report is broadly structured) are:

1. Why is productivity important – why do we care?
2. What is productivity conceptually?
3. What questions can productivity measures help answer, and how are the measures used in practice?
4. How is productivity measured?
5. What are the issues or concerns about productivity and how it is measured?
6. What is the likely scale of mismeasurement? To what extent is the productivity slowdown (in New Zealand) likely to be due to mismeasurement?
7. To what extent are the issues or concerns being addressed, or can they be addressed?
8. What are the implications for MBIE and others?

The ultimate aim is to grow capability within MBIE in terms of an improved understanding about productivity and its measurement.

The prime audience for this work is MBIE's policy teams, business-facing operational teams, and research teams with an interest in productivity. The findings from this report are potentially relevant to a number of other government agencies and organisations within New Zealand with an interest in productivity.

Approach

This report is based on a review of New Zealand and international literature targeted at the research questions above. The review was undertaken in September and October 2017 by MBIE's Strategic Policy branch.

The project included working with an internal MBIE reference group, and with New Zealand experts in productivity and its measurement from Stats NZ, the New Zealand Productivity Commission ('the Productivity Commission') and elsewhere. This report reflects suggestions from the internal reference group and the productivity experts.

A glossary of terms is provided at the end of this report.

2. What productivity is and why it is important

This section provides a definition of productivity and discusses why productivity is important. It also covers some concepts about productivity, starting with some simple firm-level concepts and then building to more complex economy-wide concepts.

Productivity is a *volume* measure, and relates to *production.* Productivity growth drives income growth and thus sustainable long-term improvements in material living standards.

Productivity is the ratio of output to input

Productivity is commonly defined as 'a ratio of a volume measure of output to a volume measure of input' (OECD 2001). We use this definition throughout this report.

$$\text{Productivity} = \frac{\text{Volume of output}}{\text{Volume of input}}$$

Productivity rises when the volume of output increases more rapidly than the volume of input, and falls if the volume of input increases more rapidly than the associated output.

Productivity is a measure of efficiency

Productivity is a measure of the efficiency with which firms, industry, and the economy as a whole, convert inputs (labour, capital and raw materials) into output (Gordon et al 2015).

Efficiency relates to the distance between the quantity of input and output being used, and the quantity of input and output that defines a frontier (Daraio and Simar 2007). Efficiency improvements can be seen as movements towards (or beyond) a frontier. There are three aspects of efficiency:

- **Technical efficiency** is about obtaining the maximum output from a given set of inputs, or using minimum inputs for a given set of outputs. The frontier here is the maximum that is physically achievable in an engineering sense, given current technology (OECD 2001). It is sometimes referred to in an intuitive way as 'doing things right'.
- **Allocative efficiency** is about allocating resources in an optimal way (OECD 2001). The frontier here is the mix of goods that society most desires – 'doing the right things (right now)'.
- **Dynamic efficiency** is about the allocation of resources over time, to push out the current production frontier due to innovation for example (Australian Productivity Commission 2013) – 'doing things better in future'.

Productivity and efficiency are related, but not identical, concepts (Sharpe 1995, cited in Schreyer and Pilat 2001). In the same way that kilojoules are a measure of energy but not the same thing as energy, productivity is a measure of efficiency but not the same thing as efficiency. Productivity measures can indicate whether efficiency is improving, but they do not generally tell us how close to the frontier we are.

Productivity is important because it:

- contributes to improvements in material living conditions by lifting wages and incomes
- reflects technological change, which drives long-run economic growth (Adler et al 2017)
- frees up resources that can be used to produce other, new goods and services (Adler et al 2017)
- recognises that resources are limited.

Productivity is central to income growth and material wellbeing

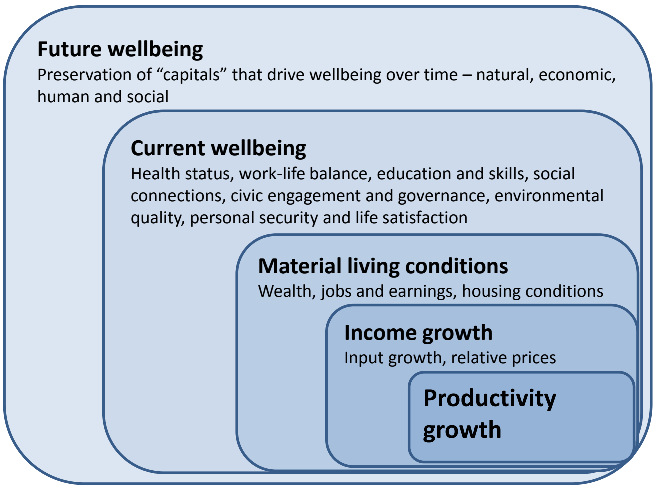
The reason we care about productivity is that improving productivity is about making better use of resources. This provides society with more choices. It means, for example, that (Fox 2007):

- there are more goods and services to consume for the same amount of inputs
- people can have more leisure time to produce the same amount of goods and services
- fewer natural resources are required to produce the same amount of output, meaning preservation of the environment.

Over the long term, increasing productivity is the only way to sustainably increase incomes (Sharpe 2002). This is because the other main source of economic growth – growth in inputs – is unsustainable, as inputs will become increasingly constrained. For example, as the New Zealand population ages, the number of hours worked by New Zealanders (a measure of labour input) will be restricted. Productivity growth, on the other hand, is not constrained by the size of the population or other factors. Productivity growth is sustainable through technological advances. This is why Paul Krugman (1994) famously said: 'Productivity isn't everything, but in the long run it is almost everything'.

Productivity is therefore a means to the end of higher incomes for New Zealanders. Higher incomes in turn contribute to material living conditions – see Figure 1 below. Productivity growth can also enhance some of the non-material influences on wellbeing, including the time available for leisure and the quality of the environment (Conway 2016).

Figure 1: Productivity growth contributes to wellbeing



Source: Author, drawn from OECD (2015b)

Productivity is not the only thing that matters. Productivity growth on its own may do little for inequality or poverty for example (Sharpe 2002). Productivity measures do not capture the potential or contribution of those not in paid employment, and so do not indicate the efficient allocation or uses of labour from a societal perspective.

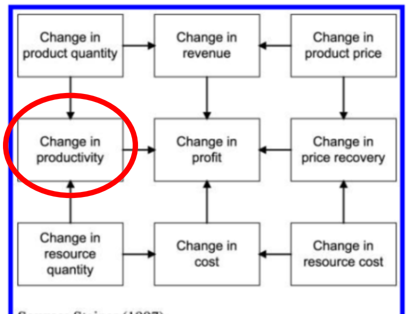
But lifting productivity is highly relevant for New Zealand. While New Zealand has historically been very successful at getting people into work, it has had a consistently poor productivity performance (Conway and Meehan 2013). Reasons for this poor productivity performance include New Zealand's small and insular domestic markets, weak international connections, capital shallowness, and weak investment in knowledge-based capital (Conway 2016). This poor performance contributes to comparatively low incomes in New Zealand.

Productivity contributes to business profitability

From a business perspective, productivity is only one aspect of performance. Profitability is the overriding goal for business success (Tangen 2005). Profitability broadly reflects the ability of a business to generate revenue as compared to costs. Productivity, by contrast, relates the volume of output to the volume of inputs (DIISTRE 2013).[1]

Profitability and productivity are linked – depicted in Figure 2 below (Stainer 1997, cited in Tangen 2005). The placement of profit at the centre of the diagram shows the central role of profitability to businesses. Productivity – in terms of technical efficiency – is closely associated with the elimination of waste and cost reduction. For example, if a smaller quantity of resources (bottom left-hand side) is needed to produce a given level of output, this will reduce costs (bottom middle) and lift productivity (middle left-hand side), thus lifting profits.

Figure 2: Productivity and profitability are linked

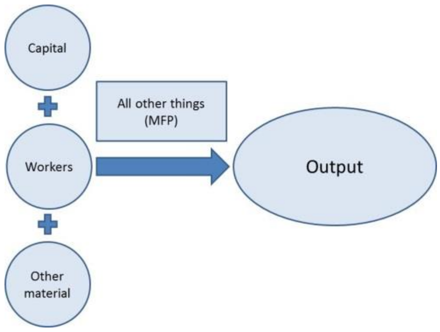


Source: Stainer (1997)

Productivity is most easily understood at the production unit level

The production process can be thought of as a black box with purchased inputs taken in on one side and outputs sold on the other (Diewert and Nalamura 2005). Measures of productivity assess how well the black box is doing at turning inputs into outputs – see Figure 3.

Figure 3: Productivity is about producing outputs from inputs



Source: Author

This process is most easily measured for an individual production unit like a factory which uses a single input to produce a single output (Daraio and Simar 2007).

Therefore in the field of business economics, comparisons of productivity measures for benchmarking purposes tend to relate to specific production processes (OECD 2001). Typically, the relevant measures are expressed in physical units (eg cars per day, passenger-miles per person) and are highly specific. This is useful for factory-to-factory comparisons, but has the disadvantage that the resulting productivity measures are difficult to combine or aggregate. Methods to address these aggregation challenges are discussed in section 4.

[1] Department of Industry, Innovation, Science, Research and Tertiary Education.

The same broad ideas apply at the industry and economy level

The basic principle that productivity is about the relationship between outputs and inputs holds true at every level of detail (Schreyer and Pilat 2001).

Productivity at the industry level will increase if productivity *within* individual firms in the industry increases (for example through improvements in technical efficiency), or if resources move *between* firms towards high-productivity firms. The latter can be due to high-productivity firms entering the industry, existing high-productivity firms growing their market share, or to low-productivity firms shrinking or exiting. If this reallocation process is productivity-enhancing, it represents an improvement in allocative efficiency.

Similarly, economy-wide productivity will increase if productivity *within* each industry rises as outlined above, or if resources move *between* industries towards high-productivity industries (again an improvement in allocative efficiency).

This means that broad productivity measures, like gross domestic product (GDP) per hour worked, can reflect gains in technical, allocative and dynamic efficiency.

The production function underpins productivity measurement

The economic theory behind productivity measurement is based on a production function approach, and goes back to the work of Robert Solow (1957, cited in Schreyer and Pilat 2001).

The production function is an equation that estimates what output will be at some particular time as a function of the economy's stock of capital, its labour force, and multi-factor productivity (MFP) (which relates output to combined inputs). Therefore, output changes because of changes in the economy's capital stock, its labour force, or its level of MFP.

A key point is that if output, the capital stock, and the labour force are known, it is possible to derive MFP. So MFP is measured residually. It is sometimes referred to as the Solow residual.

MFP therefore captures any growth in output above and beyond growth in inputs (Mai and Warmke 2012). It picks up things like advances in scientific knowledge, and the diffusion of knowledge on how things are done, including better management and organisational change – disembodied technological change. In contrast, embodied technological change is that which is embodied in new vintages of *physical* capital, or in people, or in intermediate goods. Embodied technological change is captured in capital and labour inputs.

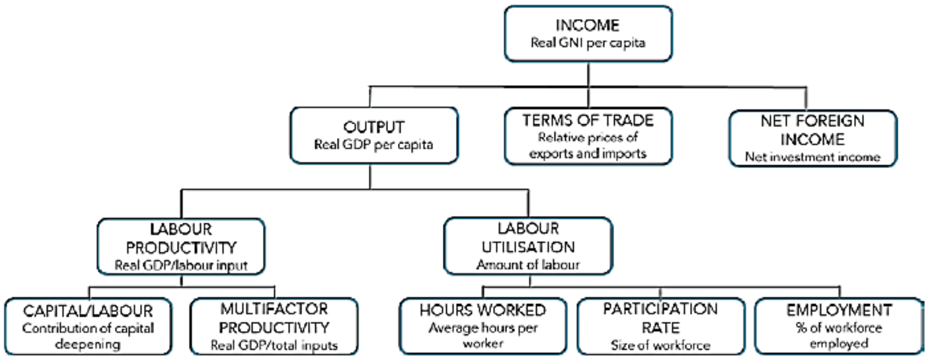
Disembodied technological change is important for economic growth, as ideas and knowledge are not used up in the same way that other inputs are. But MFP only reflects disembodied technological change under certain restrictive assumptions. So in practice, MFP can reflect a range of things beyond technological change. Notably, this can include measurement error. For this reason, Abramovitz (1956, cited in Stats NZ 2014a) referred to MFP as a measure of our ignorance.

The production function also highlights the relationship between wages and productivity. Workers' real wages should equate to the marginal product of labour. In other words, a worker will be paid according to his/her contribution to the firm's output. Real wages are therefore the most direct mechanism through which the benefits of productivity growth are transferred to workers (Sharpe et al 2008). However, a number of factors in the labour market – such as firms' monopsony (buyer's) power, discrimination etc – can weaken the link between wages and productivity (see for example Sin et al 2017).

Growth accounting is based on the production function

The production function forms the basis for the growth accounting framework that is widely used in macroeconomic analyses. Growth accounting specifies a production function that relates a *level* of output to levels of inputs and MFP, and uses this to decompose output *growth* into the growth of inputs and MFP (Jaffe et al 2016). Figure 4 is based on the growth accounting decomposition.

Figure 4: Describing economic growth



Source: Conway and Meehan (2013)

A number of important points emerge from this diagram. Firstly, GDP per capita can be broken down into 1) labour productivity and 2) labour utilisation, highlighting the role of productivity in output growth. Secondly, labour productivity can be broken down into 1) capital deepening (capital per worker) and 2) MFP. Capital deepening is a key way in which to improve labour productivity, as workers have more capital to use in the production process (Conway and Meehan 2013).

Note that growth accounting essentially *describes* economic growth, rather than telling us why growth happens.

The growth accounting framework has some important assumptions (OECD 2001):

- Production processes are well represented by production functions.
- Producers behave efficiently, ie they minimise costs and/or maximise revenues.
- Markets are competitive, and market participants are price-takers.
- There are constant returns to scale, ie as all inputs increase, there will be an equal and proportionate increase in output.

The implications of some of these assumptions are discussed in later sections.

3. How productivity measures are used in practice

This section provides some concrete examples of how productivity measures have been used, and outlines some rules of thumb about how to interpret productivity information.

Productivity measures are used to help answer a wide variety of questions about New Zealand's productivity performance and its drivers and outcomes. Like all measures, productivity measures should be interpreted with care.

Productivity measures can help answer a variety of questions

Figure 5 below provides one way of thinking about the types of questions that productivity measures can help answer.

Figure 5: Productivity is both an input and an outcome

Source: Author

Figure 5 highlights that productivity measures are used:

- as an input or independent variable in research and evaluation (middle and right-hand boxes)
- as an outcome or dependent variable in research and evaluation (left-hand and middle boxes)
- purely descriptively (middle box).

Table 1 below identifies some of the questions that productivity measures can help answer, grouped per the diagram above.

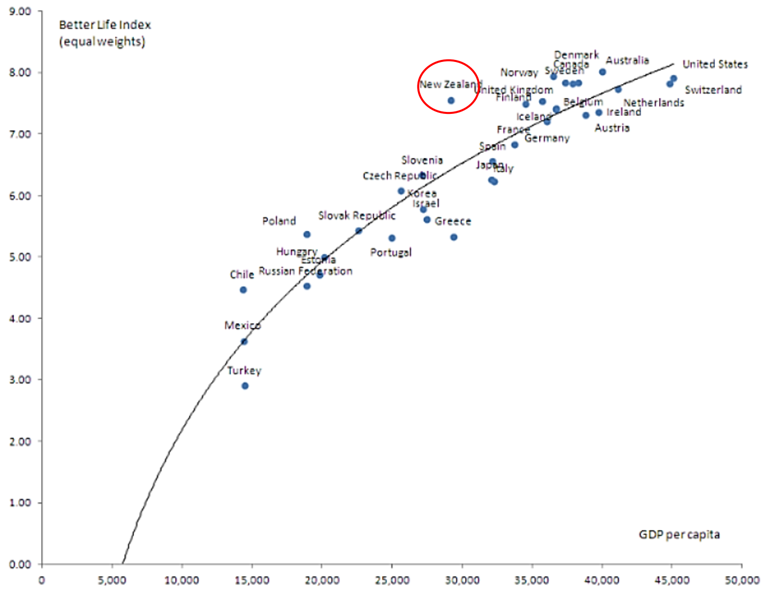
TABLE 1: MAIN QUESTIONS THAT PRODUCTIVITY MEASURES HELP ANSWER			
QUESTION	**KEY MEASURE(S)**	**EXAMPLES**	**COMMENT**
Outcomes from productivity performance			
What contribution does productivity make to economic growth?	• Growth in GDP per capita, and per hour worked	• The Treasury's annual *Budget Economic and Fiscal Update* (see for example the Treasury 2016)	• Economic growth can be decomposed in various ways, with some decompositions including labour productivity growth and others MFP growth
What is the relationship between productivity and outcomes (such as living standards and wellbeing)?	• Growth in GDP per capita, and per hour worked	• Various OECD studies (see for example OECD 2015a)	• Often based on country-level studies
What is the relationship between productivity and wages?	• Various macro and micro labour productivity measures	• The Productivity Commission's work on the labour income share (Conway et al 2015; Fraser 2018) • Motu's study of the gender pay gap (Sin et al 2017)	• Studies based on micro measures can examine the underlying drivers of the productivity-wage relationship, and how the relationship varies between different types of firms and workers

Productivity performance and proximate drivers			
How is the economy tracking (in terms of productivity performance)?	• Growth in GDP per capita, and per hour worked • Stats NZ's official productivity measures	• Stats NZ's annual productivity releases (see for example Stats NZ 2017)	• Used for macroeconomic analyses, including to assess the productive capacity and inflationary pressures of the economy • Can be used both to monitor historic performance and to forecast future performance
How does New Zealand's economic (productivity) performance compare with other countries?	• Various measures, including growth in GDP per capita, and per hour worked	• Various OECD studies including the OECD's regular compendium of productivity indicators (see for example OECD 2017b)	• Prompts further questions/ analysis about *why* performance varies • Should be interpreted with care due to differences in measurement practices and economic structures etc between countries
What contribution to aggregate productivity growth does industry composition make?	• Industry-level labour productivity	• Various Productivity Commission studies (see for example Conway and Meehan 2013; Mason 2013)	• Helps identify the scope to lift economy-wide performance via changes in industry structure
Which industries are performing well (in terms of productivity performance)?	• Industry-level labour productivity and MFP		• Prompts further questions/ analysis about *why* performance varies
What does the distribution of productivity performance (by industry, firm characteristic etc) look like?	• Industry-level and micro measures of labour productivity and MFP	• Various Productivity Commission studies (see for example Conway and Meehan 2013) • Motu's study of the construction sector (Jaffe et al 2016) • Motu's study of the relationship between productivity and changing skill level, including the effects of firm dynamics (Maré et al 2017) • Treasury's study on the contribution of firm dynamics to productivity growth (Law and McLellan 2005)	• Helps identify the scope to lift industry or firm performance
What are the characteristics (such as firm size, firm age, industry, location) of high-productivity firms?			• Relevant from a policy perspective, as some of the characteristics may be influenced by policies
What is the contribution of firm dynamics (such as firm entry, exit and growth) to productivity performance?			• Can help analyse industry-level productivity performance
Underlying drivers of productivity performance			
What internal factors to the firm (such as the firm's management practices, R&D and innovation activity, and export activity) drive productivity performance?	• Micro measures of labour productivity and MFP	• Studies about the effects of intangible investment (Chappell and Jaffe 2016), exporting (Fabling and Sanderson 2013) and personnel practices (Fabling and Grimes 2014) on firm performance	• Relevant from a policy perspective, as some of the factors may be influenced by policies
What external factors to the firm (such as the competitive environment, and spillovers from other firms' activities) drive productivity performance?		• Study about the spillovers from foreign direct investment (FDI) (Doan et al 2015)	
What difference has a policy change (such as a regulatory change, R&D policy, competition policy) made to firm productivity performance?		• Studies of the impacts of business R&D grants (MED 2011; Wakeman and Conway 2017)	• Relevant from a policy perspective in terms of evaluating a policy's performance

Productivity measures are widely used in practice

The figures below illustrate how productivity measures have been used to help answer some of the questions in Table 1 above, and identify some basic insights from such work.

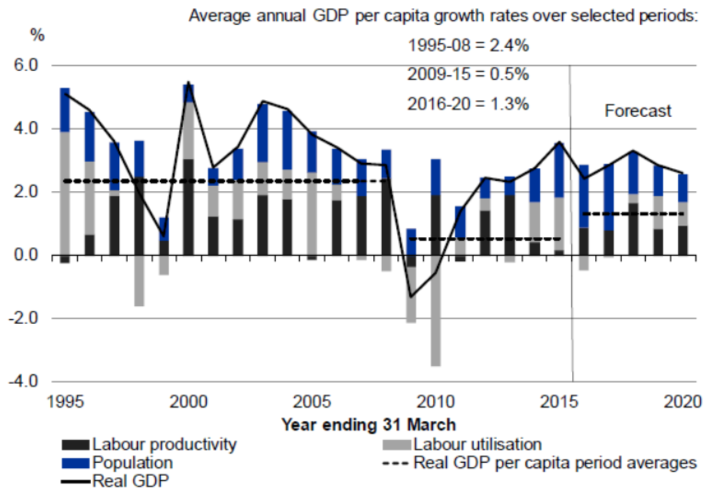
Figure 6: What is the relationship between productivity and wellbeing?



Source: Boarini (2012)

- Developed by the OECD to show the relationship between GDP per capita and the OECD's wellbeing index
- Shows that the relationship is positive – in other words, countries with higher GDP per capita are also those where wellbeing is higher on average. However this relationship becomes weaker as a country's income grows
- Also shows that New Zealand performs comparatively much better on wellbeing than on GDP per capita

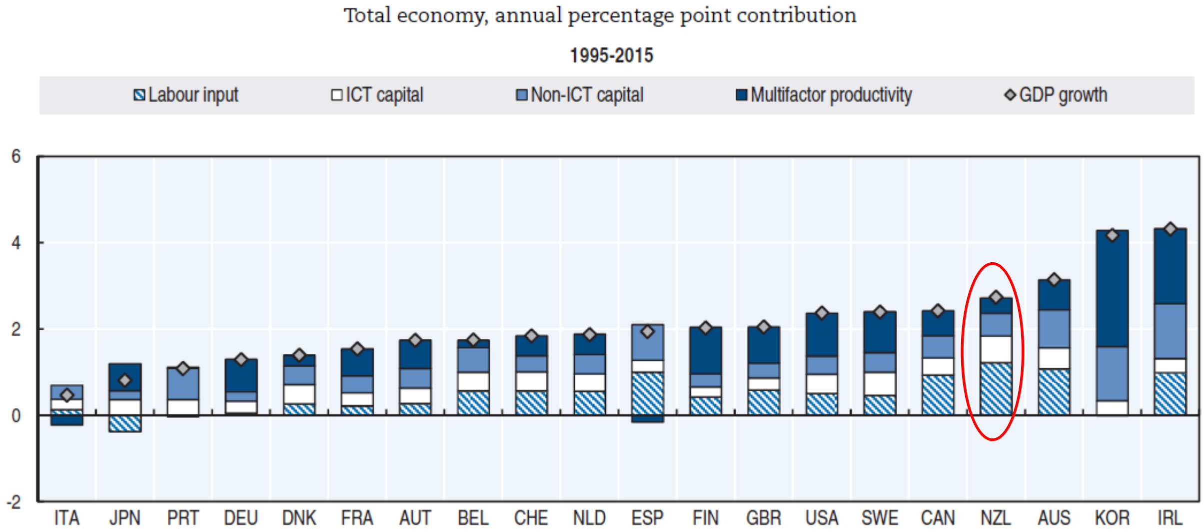
Figure 7: What contribution does productivity growth make to economic growth in New Zealand?



Source: The Treasury (2016)

- Developed by the Treasury to feed into its medium-term outlook for New Zealand
- Illustrates one possible decomposition of GDP growth, including labour productivity growth
- Highlights that a long term view is needed to analyse labour productivity growth (and labour utilisation growth etc), which fluctuate considerably each year

Figure 8: How does New Zealand compare in terms of the contribution of productivity growth to economic growth?

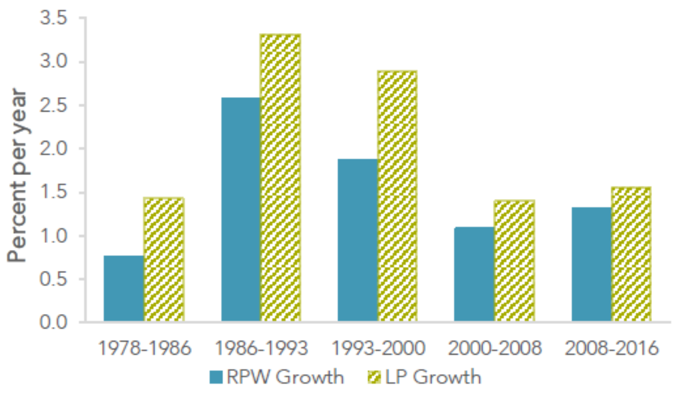


Source: OECD (2017b)

- Developed by the OECD to compare the decomposition of GDP growth across countries
- Illustrates one decomposition of GDP growth, including MFP growth
- Shows that New Zealand was one of the top performing countries in terms of GDP growth over the period, and that (compared with other OECD countries) much of this growth came from growth in labour input rather than from MFP

Figure 9: What is the relationship between productivity growth and wage growth in New Zealand?

Real product wage growth and labour productivity growth in the measured sector

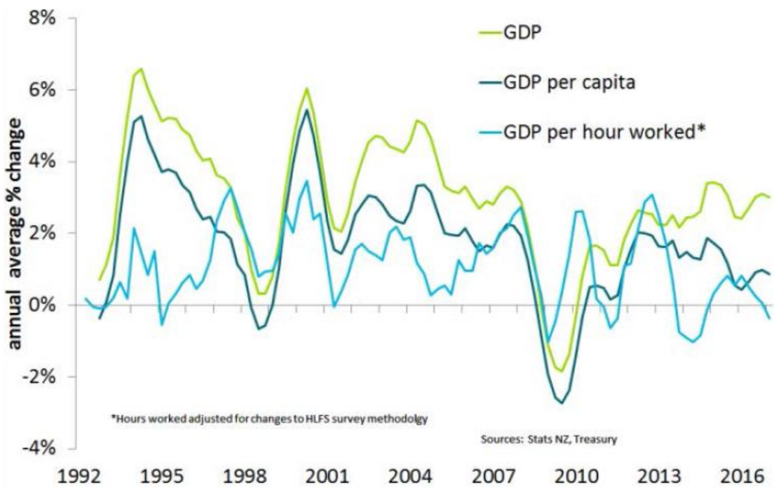


Source: Fraser (2018)

Note that the real product wage is broadly the wage that producers face. It is the average hourly rate of labour compensation (including on-costs such as superannuation, ACC) relative to the price of output.

- Developed by the Productivity Commission to examine whether workers proportionately share in the income gains generated from productivity improvements
- Shows that workers appear to have shared substantially (but not fully) in the productivity gains they have helped to create

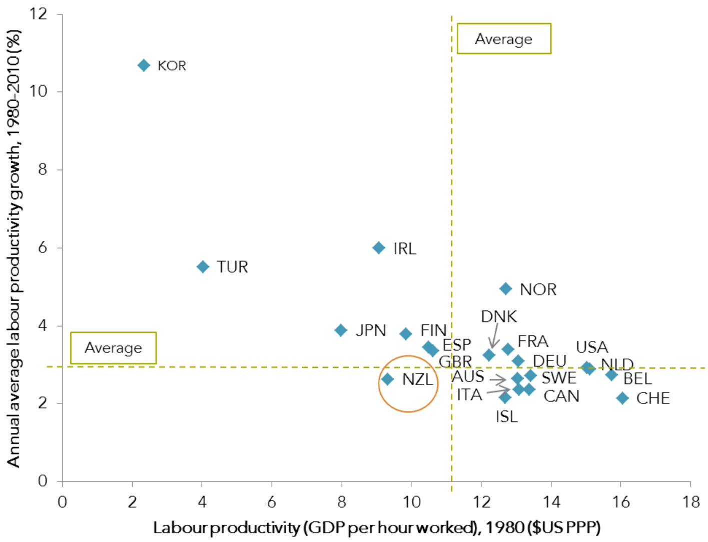
Figure 10: How is the New Zealand economy tracking?



Source: MBIE (2017)

- Used by MBIE as part of one of its Senior Leadership Team quarterly economic updates
- Shows that since 2013, GDP growth was much higher than growth in GDP per capita and in particular GDP per hour worked. This reflects that economic growth over this period has largely come from population growth rather than productivity growth
- Highlights that the measure selected matters, and that labour productivity growth is highly cyclical

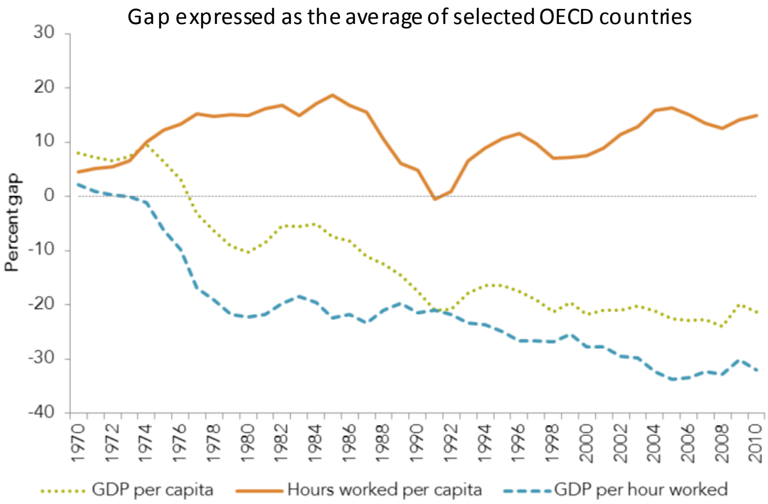
Figure 11: How does New Zealand's labour productivity level and growth compare?



Source: Conway and Meehan (2013)

- Developed by the Productivity Commission to see if New Zealand is catching up to other countries in terms of our productivity performance
- Shows that, despite starting with a comparatively low labour productivity *level* in 1980, New Zealand's labour productivity *growth* over the period 1980 to 2010 was also comparatively low
- We might expect that a developed, open economy behind the productivity frontier (like New Zealand) would converge over time as learnings from other countries diffuse to New Zealand firms. This chart illustrates that there is nothing inevitable about this process

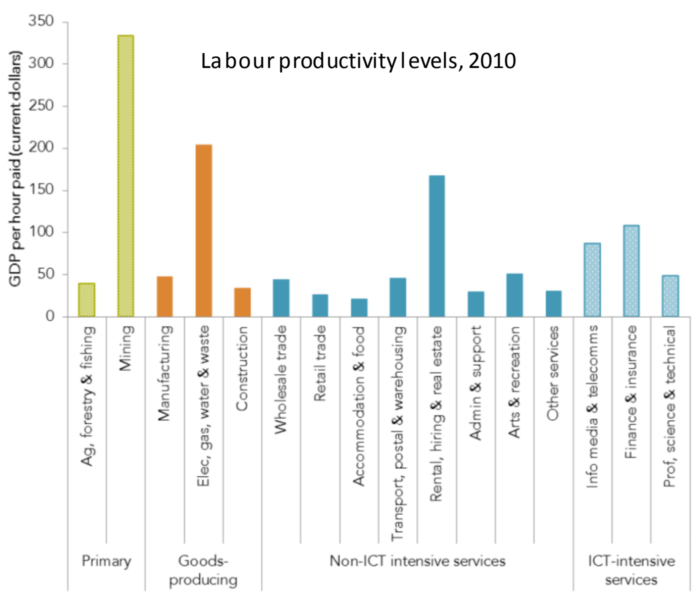
Figure 12: How does New Zealand's productivity performance compare over time?



Source: Conway and Meehan (2013)

- Developed by the Productivity Commission to decompose the sources of New Zealand's comparative performance in GDP per capita
- Shows that the gap in New Zealand's GDP per capita compared with the OECD average has trended downward over time. This gap was mainly due to a comparatively poor performance in labour productivity (GDP per hour worked); labour utilisation (hours worked per capita) was comparatively high in New Zealand over the entire period

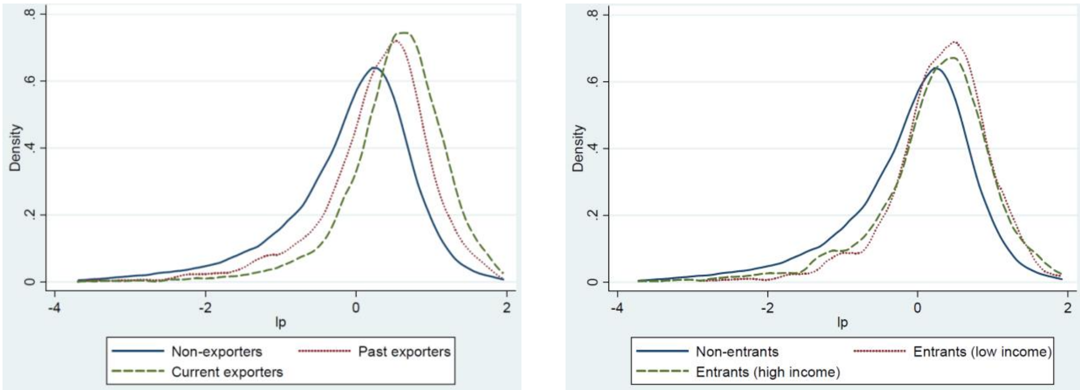
Figure 13: Which New Zealand industries are performing well?



Source: Conway and Meehan (2013)

- Developed by the Productivity Commission to compare the productivity performances of different industries
- Shows considerable variation in labour productivity levels by industry
- Raises further questions about what's driving the variation, such as the capital intensity of each industry (eg the mining industry has the highest level of labour productivity and is very capital-intensive)

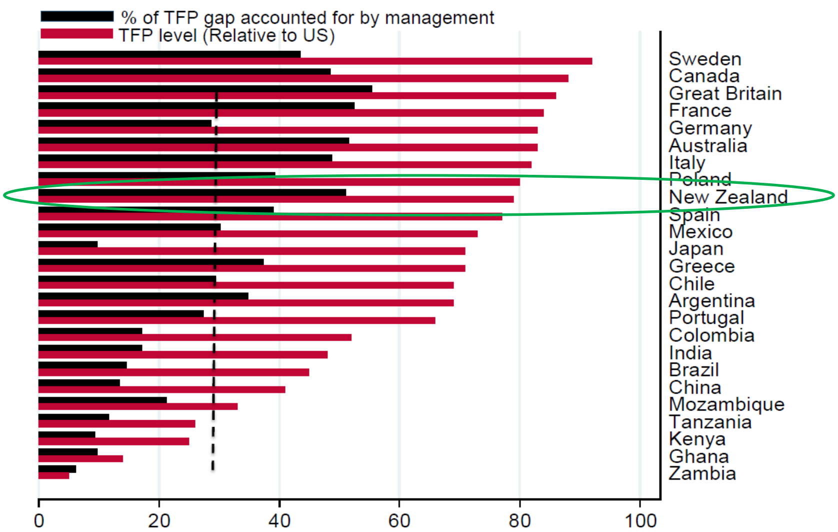
Figure 14: What is the distribution of productivity performance across firms in New Zealand?



Source: Fabling and Sanderson (2013)

- Developed by the authors to examine variations among firms' productivity performances based on their exporting activity
- Shows that firms that are currently exporting tend to have higher productivity than those that have exported in the past but are not currently, who in turn have higher productivity than those that have never exported (left hand panel). Firms that are about to start exporting tend to have higher productivity than those that are not about to enter exporting, but there's not much of a difference between those that are going into high income and those that are going into low income countries (right hand panel)
- Implies that exporters perform better than non-exporters, but most of that difference existed before they started exporting. Thus, the gap is more about self-selection than learning-by-exporting
- Highlights the importance of analysing distributions (as opposed to averages) to better understand productivity performance

Figure 15: What are the effects of management practices on countries' productivity performances?



Source: Bloom et al (2016)

- Developed by the authors as part of a study to examine the effects of management practices on total factor productivity (TFP or MFP)
- Shows that, based on the authors' model, differences in management practices explain around half the TFP gap between New Zealand and the US

There are some rules of thumb for interpreting productivity measures

The examples above illustrate that a number of factors should be taken into account when using and interpreting productivity measures.

- **The right measure depends on the purpose of measurement.**
- **GDP per hour worked** is a relatively simple, straightforward measure of labour productivity which can be used in a number of contexts.
- **Productivity is pro-cyclical.** This has two key implications: firstly, long-term productivity trends should not be extrapolated from short-term trends; secondly, growth rates should be calculated at comparable points in the cycle, preferably from peak to peak (Sharpe 2002).
- **International comparisons should be interpreted with care**. Differences in measurement practices and economic structures etc between countries can make it hard to compare apples with apples. In particular, comparisons can vary considerably depending on the purchasing power parity (PPP) adjustment used.
- **Growth rates are highly relevant to policymakers...** A higher *level* of productivity generates a higher level of income, but higher productivity *growth* results in progressively higher income gains over time (DIISRTE 2013).
- **...and are relevant for comparing industries.** Industries vary considerably in their capital intensities and in the technologies they use, which can lead to wide variations in productivity *levels* by industry. Given that technologies and capital intensities of industries tend to be relatively stable over time, labour productivity *growth* rates can provide a more meaningful comparison across industries than productivity levels.
- **Productivity growth $\approx$ Output growth – Input growth.** It can be shown that the productivity growth rate is approximately the output growth rate minus the input growth rate (see Office for National Statistics 2007). For example, if output growth in a period is five per cent and labour input growth is two per cent, then labour productivity growth is roughly three per cent. This approximation provides a straightforward way of inferring productivity growth.
- **Productivity measures have limitations and are based on assumptions** – see section 4. The limitation of measures to reflect the competitive environment, or firms' market power, implies that understanding the market structure of each product is important for understanding how much quality improvements can be inferred from prices (Office for National Statistics 2016).

4. How productivity is measured

This section discusses how productivity is measured in practice. It considers methods for aggregating different types of outputs and inputs, provides an overview of the approaches taken in macro productivity measures and in micro measures, and outlines some of the benefits and limitations of New Zealand's measures. The specific measures available are discussed in Table 3 at the end of this section and in appendix A.

Prices play a key role in productivity measurement; many of the measurement concerns discussed in section 5 stem from the relationship between prices, quality and volumes. Overall, selecting the right measure depends on the purpose of measurement.

A number of measures are available

As noted earlier, productivity is a ratio of a volume measure of output to a volume measure of input. Measuring productivity therefore involves dividing some measure of the volume of output by some measure of the volume of input.

Productivity measures can be categorised in a number of ways as described below.

Single-factor or multi-factor: Single factor measures relate a measure of output to a single measure of input. MFP – also known as TFP – relates a measure of output to a bundle of inputs (Schreyer and Pilat 2001).

Labour productivity is a single factor measure. It involves dividing output by some measure of the amount of labour used in its production. Labour productivity is a central productivity measure as it is relatively easy to understand and measure, and relates to an important input (people).

However, care is needed in interpreting partial measures (Mai and Warmke 2012). This is because they attribute to one input changes in efficiency that are actually attributable to other ones (Janssen and McLoughlin 2008). For example, substitution from the use of labour to the use of machines may not increase output, but will increase labour productivity (Fox 2007).

So MFP is the preferred conceptual measure as it accounts for the broadest range of inputs and therefore gets closer to a true efficiency measure, but labour productivity measures are often used in practice.

Growth and levels: Growth rates provide a comparison over time with past performance. For example, over the recent (incomplete) cycle 2008–16, average annual labour productivity growth in the measured sector in New Zealand was 0.7 per cent (Stats NZ 2017).

Productivity growth tends to be pro-cyclical. Reasons include that resources can be under-utilised in a downturn, such as machinery lying idle, or workers being used less intensively as firms try to hold on to key staff (labour hoarding). So as output falls, inputs may fall by a relatively smaller amount, thus leading to a deterioration in productivity.

Productivity levels provide a point-in-time comparison across industries within New Zealand, or between New Zealand and other countries. They give insights into the possible scope for further gains (Schreyer and Pilat 2001). For example, New Zealand's labour productivity level for year end March 2016 was $42 per hour worked (2015 US$) compared with $61 per hour worked on average across the OECD (ie there was a 30 per cent gap between New Zealand and the OECD average).[2]

Macro and micro: Macro measures capture productivity at the industry level or at the level of the economy as a whole. Micro measures draw on data about individual firms, as discussed below.

[2] Conference Board Total Economy Database, based on the original OECD countries.

Value added is used to avoid double counting

Aggregation of outputs requires a way of linking one firm's activities with that of another. Figure 16 below illustrates some of the linkages, and shows that one firm's output can be another firm's input. The goods or services that are produced within the firm and that become available for use outside it are called (gross) output (Schreyer 2011). Output is produced using primary inputs (labour and capital) and intermediate inputs. Value added is the value of output less the value of intermediate inputs.

In Figure 16 below, flour is the final output of the miller, but is an intermediate input for the baker. If the output is added up for each producer ($500 + $700 + $1,000 = $2,200) it totals to more than the final amount ($1,000). This is an example of double counting. That is, a pure output-based measure involves double counting.

Value added is the basis for calculating GDP and is often used as the output measure in productivity measurement to avoid double counting. In the example below, a value added approach would correctly identify total production as $500 + $200 +$300 = $1,000.

Figure 16: Simple example of value added

Output	Wheat	Flour	Bread	Total
Value of output	$500	$700	$1,000	$2,200
Value of input	Zero	$500	$700	$1,200
Value added	$500	$200	$300	$1,000

Source: Author

Prices matter in measuring volumes

Aggregation in productivity measurement is challenging because both inputs and outputs vary greatly in nature. Even within the same broad product group, like cars, it is fairly clear that adding up a simple count of the number of minis and BMWs is not a meaningful measure of output volume. This reflects that the volume of output is regarded as having two components (Office for National Statistics 2007):

1. **quantity** – the number of units (of a product)
2. **quality** – the description of the characteristics of each unit.

Quality of output has many dimensions which include design, convenience, and novelty, as well as features such as comfort, durability, and freshness (Gordon et al 2015). These dimensions of quality are valued by consumers, and so tend to be reflected in prices.

Importantly, increasing the quality of a good conceptually equates to a larger volume of the good (Byrne et al 2016). For example, a better computer can be thought of as providing more computer services, or better running shoes as providing more 'running support' services.

The same concept applies to inputs. For labour input, higher quality (skilled) labour represents a higher volume of labour. A key difference, though, is that a higher volume of labour reduces productivity, as labour input appears in the denominator of the productivity ratio.

For example, Maré et al (2017) found that productivity growth in New Zealand over the period 2001-12 was higher than previously thought, once labour was quality-adjusted. This was because lower-skilled (lower quality) workers had been drawn into the labour market over this period. Once the volume of labour input was adjusted to reflect this lower quality, 'true' productivity was estimated to be higher than measured productivity.

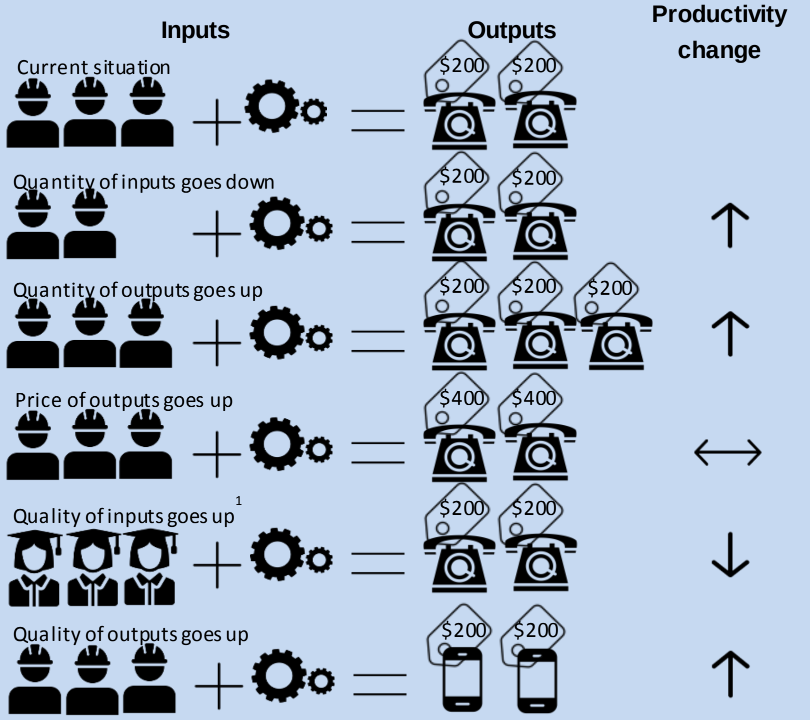
Prices – and the assumption of functioning markets – allow the volume of diverse outputs to be compared and weighted (New Zealand Productivity Commission 2017). This is based on an assumption of functioning markets. When markets are functioning efficiently, the ratio of one market price to another is reflective of the relative appreciation of the two products by those who purchase them (Stiglitz et al 2009). Conceptually, changes in the quality of products should be reflected in price changes. This is because consumers derive higher utility from higher quality products, and in a perfectly competitive market these differences in utilities would be revealed in market prices (Office for National Statistics 2007).

A key issue from a measurement perspective is determining whether an observed price rise reflects general inflation or improvements in quality. The latter should be counted as an increase in volume, while the former should not. Statistical agencies have to make judgements about the extent to which an observed price change is due to changed quality or a change in the price of a product (Corrado et al 2017).

Even within relatively narrow product ranges, it may be difficult to disentangle the price/quality/volume relationship. Gibson (2017) provided an example of the wide range of retail prices for fizzy drinks in New Zealand. In just one store, the highest price for fizzy drinks was $7.99 per litre (small containers of branded product) and the lowest $0.66 per litre (large containers of a supermarket range). These products vary in quality attributes like flavour and convenience, but these numbers do suggest large variations in the price/volume relationship.

Figure 17 below provides a stylised example of how changes in the quantity, quality and price of inputs and outputs affect productivity. For example, in the second row, a lower quantity of labour is used compared with the status quo (first row), so productivity has increased.

Figure 17: A stylised example of how productivity works



Note: In practice, productivity measures are not adjusted for labour quality

Source: Author

In practice, the official productivity measures developed by Stats NZ are based on value added at constant prices for the output component. That is, output prices are deflated to reflect industry-wide price level changes. Three alternative methods are used to obtain constant prices (Stats NZ 2014b) – see appendix A. A key point to note is that these methods essentially aim to account for price *movements*. This means, for example, that the point in the product lifecycle at which new products are picked up is important, as the price of a product can vary considerably over its lifecycle.

The method most commonly used to obtain output at constant prices is to deflate (divide) output by price indices. The price indices are in turn adjusted to reflect quality improvements in output.

Stats NZ compiles a suite of price indices. The most relevant in the context of the productivity statistics are the following.

- **Producers price index (PPI),** which measures changes in prices for the supply (outputs) and use (inputs) of goods and services by New Zealand's productive sector (Stats NZ 2015). One of the surveys used to construct the PPI asks firms about why prices of the products they produce have changed, including changes in the product's quality.
- **Consumers price index (CPI),** which measures changes in the prices of final goods and services based on a basket of goods representative of household consumption. The CPI basket and weights are updated once every three years, and data on prices collected each quarter. Stats NZ uses hedonic modelling (see section 6) to quality adjust computers and some other electronic products and used cars, and makes quality adjustments for other products on an ad hoc basis.
- **The capital goods index,** which provides information on the change in the general price level of fixed capital assets.

There are a number of broad measurement approaches available

Different approaches to measuring productivity draw on the theories outlined in section 2, in particular production function theory. There are several ways to implement these theories empirically. The most common approaches are described below (drawn from Jaffe et al 2016).

1. The **growth accounting approach** specifies a production function that relates a *level* of output to levels of inputs and MFP. This makes it possible to decompose output *growth* into the growth of inputs and MFP. MFP growth is a residual – it captures the part of the growth in output that cannot be explained by growth in inputs. The growth accounting approach is relatively simple to implement. But it relies crucially on several assumptions, including that the production function exhibits constant returns to scale.

2. The **index number approach** measures productivity by dividing an output quantity index by an input quantity index to give a productivity index. Calculating productivity growth rates based on the index obtained is then relatively straightforward. The index number approach can only be used to measure productivity growth, not productivity levels. This is the approach used by most statistical agencies, including Stats NZ.

3. The **production frontier approach** uses an output distance function that measures the distance of a production unit from the production frontier (as discussed in section 2). This function measures how close a level of output is to the maximum level that can be obtained from the same level of inputs if production is efficient. This approach is useful in identifying and quantifying the sources of inefficiency. However, it requires knowledge of the production technology or production frontier of all firms at all time periods covered.

4. The **econometric approach** measures productivity via estimating the parameters of a production function. As in the growth accounting approach, if a production function is specified in growth rate form, the estimated residual captures the residual growth, which is often interpreted as a measure of productivity growth. The main advantage of the econometric approach is that it enables testing the assumptions underlying the growth accounting and index number approaches. However, as with the growth accounting approach, results from the econometric approach are sensitive to the form of the production function.

New Zealand draws on a number of these approaches in its macro and micro productivity measures.

New Zealand's official macro measures follow OECD guidelines

In March 2006, Stats NZ published the first official productivity estimates for New Zealand (New Zealand Productivity Commission 2017).

Stats NZ broadly uses an index number approach for its official macro productivity series. This is the approach recommended by the OECD in its guidelines (see OECD 2001).

Table 2 below provides a simple hypothetical example of how a labour productivity index might be calculated. It illustrates that indices allow for the measurement of changes over time, ie productivity growth, but not productivity levels.

TABLE 2: SIMPLE HYPOTHETICAL EXAMPLE OF A PRODUCTIVITY INDEX

YEAR	LABOUR HOURS	OUTPUT	OUTPUT PER HOUR	GROWTH IN OUTPUT PER HOUR (PER CENT)	PRODUCTIVITY INDEX
2017	50	250	5	...	1000
2018	60	240	4	-20	800
2019	80	480	6	50	1200
2020	80	560	7	16.7	1400

Also important to note is that output is value added at constant prices, based on the same procedures as GDP. This means that the official macro productivity measures are consistent with GDP, and have some of the same benefits and limitations as GDP.

Official productivity measures are available (mainly drawn from Stats NZ 2014a):

- for the 'measured sector' only, ie they exclude government and a few other services
- broken down for 25 industries
- for labour productivity, capital productivity and MFP
- for growth rates (not levels)
- annually from 1978.

These official measures are mainly used to track trends in New Zealand's productivity performance.

Other macro measures are often used in practice

Because of some of the restrictions in scope and timeliness of the official productivity statistics outlined above, other macro measures of labour productivity are often used in practice. The most common ones are GDP per capita, GDP per worker and GDP per hour worked. These measures are drawn from official statistics developed by Stats NZ, but are not directly produced by Stats NZ (except GDP per capita). Instead, they are constructed by individual researchers, and as such there is scope for slight differences in how they are calculated. They have the benefits of covering the entire economy (not just the measured sector) and being available quarterly with minimal lags.

These measures of labour productivity are often used for international comparison purposes. It is also possible to construct measures of labour productivity levels at broad industry level by combining series of hours worked with industry output data.

Micro measures dig beneath the surface

Micro measures draw on data about individual firms. Essentially they use a benchmark relationship between output and inputs, captured by a production function (Fabling and Maré 2015a). Each firm is judged by comparing its ratio of output to inputs with that of a benchmark calculated for firms with the same level of inputs. So MFP as measured in this way is essentially a relative concept.

As production functions are intended to reflect the production technology used by a firm, micro measures are generally used to compare firms within an industry at a point in time. This is in contrast to macro measures, where the focus is on growth rates.

A consequence of the use of industry-specific production functions is that it is not possible to compare the relative efficiency of two groups of firms that operate with completely different technologies (Fabling and Maré 2015a). As industries operate with different technologies, MFP is meaningful only for comparisons within the same industry (Fabling and Maré 2015a).

While a number of different methods are available to calculate firm-level productivity, research in New Zealand has focused on the use of either Cobb Douglas or trans-log production functions. This probably reflects a combination of data availability and researchers' preferences.

Researchers have some flexibility in how they estimate the production function, depending on the particular question they are aiming to address. This lack of a standardised approach means it can be difficult to compare findings across studies, as can differences in sample availability and selection (see for example Fabling and Sanderson 2014). In particular, different approaches are used to control for unobserved differences between firms. In general, the more inputs or characteristics are introduced, or the more refined the econometric specification, the more inter-firm differences are loaded into the benchmark, and the less is attributed to MFP (Fabling and Maré 2015a).

One of the key benefits of micro measures is that they uncover variations among firms in productivity performance, and so help understand the underlying drivers of productivity (Fabling and Maré 2015a). A further benefit of the econometric approach is that it provides an opportunity to relax some of the assumptions used in the macro approach, as the parameters of the production function are estimated directly.

For example, in a recent study of spatial productivity, Maré (2016) relaxed the assumption of perfect competition by taking account of differences in competition levels across locations in New Zealand. This recognised that output price differences arise when competition is imperfect, with firms in less competitive local markets charging higher prices. The author estimated a competition term as a parameter which provides an index of the firm's ability to charge a higher price, and achieve a higher mark-up, by restricting the quantity of output.

In brief, international studies based on micro productivity measures have found enormous and persistent measured productivity difference across firms, even within narrowly defined industries (Syverson 2011). The causes of these differences reflect differences in firms' practices (such as management practices and innovation) and in firms' operating environments (such as competition).

In New Zealand, a recent summary of New Zealand studies which use micro productivity measures has been developed by Allan (2018).

As with macro measures, simple micro measures of productivity, such as labour productivity and capital productivity, are available at the firm level, and labour productivity is comparable across industries for example.

Linking the macro with the micro is hard to do in practice

Macro and micro productivity measures complement each other, as they focus on different things and have different strengths and weaknesses. In theory, it should be possible to reconcile them, as they draw on the same fundamental concepts and broadly use the same data sources.

But in practice, it is difficult to construct this full picture (see Mai and Warmke 2012). So far, there have been no formal attempts to reconcile official macro productivity measures with micro ones.

One of the main sticking points appears to be differences in measurement of inputs, particularly labour input. Stats NZ's Longitudinal Business Database (LBD) does have a 'full-time equivalent' adjusted labour input, but this is done in a fairly basic way due to the absence of hours worked information. Another sticking point is that the national accounts use supply-use balancing when estimating sector-level GDP, to avoid double counting. In contrast, the focus of the LBD is less on double counting and more on how good the firm is at turning inputs into outputs.

Each measure has benefits and limitations

Table 3 below summarises some of the features, benefits and limitations of the main productivity measures available. More information about each of these measures can be found in appendix A.

TABLE 3: MAIN PRODUCTIVITY MEASURES

MEASURE	FEATURES	BENEFITS	LIMITATIONS/CAVEATS
Official macro measures			
Labour productivity growth	• Definition: growth in output per hour of paid work • Based on index number approach • Follows OECD's (2001) guidelines • Output is value added at constant prices, based on the same procedures for GDP • Labour input is hours paid (see appendix A) • Covers measured sector, and can be broken down into 25 industries • Data drawn from firm and household surveys and administrative tax data	• Relatively easy to measure • Relates to an important factor of production – people • In line with international best practice	• Substitution of capital for labour may increase measured labour productivity • Covers measured sector only, and only produced annually and in growth rates
Capital productivity growth	• Definition: growth in output per unit of capital services • Based on index number approach • Follows OECD's (2001) guidelines • Output is value added at constant prices, based on the same procedures as GDP • Capital input is the flow of capital services generated by capital stocks • Covers measured sector, and can be broken down into 25 industries • Data drawn from firm and household surveys and administrative tax data	• In line with international best practice	• Substitution of labour for capital may increase measured capital productivity • Covers measured sector only, and only produced annually and for growth rates

MFP growth	• Definition: output growth that cannot be attributed to growth in labour and capital • Based on index number/growth accounting approach • Follows OECD's (2001) guidelines • Output is value added at constant prices, based on the same procedures for GDP • Input index is based on the volume indexes of labour and capital • Data drawn from firm and household surveys and administrative tax data	• Proxy for technological change • Takes account of substitution • Preferred conceptual measure, as it accounts for the broadest range of inputs • In line with international best practice	• Restrictive assumptions – markets are competitive, constant returns to scale etc • In practice, reflects a range of factors other than technological change, including capital utilisation and measurement error
Other macro measures			
GDP per capita	• Definition: total economic activity / total population • Economic activity is production GDP from national accounts • Total population is from national population estimates	• Timely, both series are produced quarterly with small lags • Uses official Tier 1 data • Covers entire economy • Easy to understand • Internationally comparable	• Poor proxy for labour productivity, as does not take account of labour market participation • Industry breakdowns not available
GDP per worker	• Definition: total economic activity / total employed • Economic activity is production GDP from national accounts • Employment is from Household Labour Force Survey • Can be calculated for broad industry groupings	• See GDP per capita above • A better measure of labour input than GDP per capita, as it reflects employment	• Not standardised, as constructed by individual researchers
GDP per hour worked	• Definition: total economic activity / total hours worked • Economic activity is production GDP from national accounts • Hours worked is from Household Labour Force Survey • Can be calculated for broad industry groupings	• See GDP per capita above • A better measure of labour input than GDP per worker, as it reflects part-time work	• Not standardised, as constructed by individual researchers
Micro measures			
Labour productivity, capital productivity and MFP	• Definitions vary • MFP is based on econometric approach, which in turn is based on a production function • Output is revenue-based gross output or value added • Labour input is headcount or FTE • Capital input is based on the flow of capital services generated by capital stocks • Firm-level data from administrative tax data and surveys in Stats NZ's LBD	• Allows examination of causal drivers of productivity • Approach can be tailored to specific question • Some of the restrictive assumptions in MFP above can be relaxed	• No measure of hours worked for labour input • Difficult to compare studies • Estimated aggregates will not equal official stats • Industry-level output price deflator limits quality adjustment • MFP is relative to other firms, not an absolute measure. It can't be used to compare industries due to differences in technologies
Source: Stats NZ (2014a) and Fabling and Maré (2015a)			

Productivity measures have a number of limitations

Some of the key limitations of New Zealand's productivity measures include the following. Note that some of these points (especially the final two) often apply to other countries too.

- **Labour inputs are not quality-adjusted.** While quality adjustments are made for outputs in the official productivity series, no quality adjustments are made for labour inputs. This means, for example, that if higher skilled labour is used to produce the same volume of output, this represents an increase in labour volume and thus a reduction in 'true' productivity, but it will not show up in measured productivity. Some micro studies have tried to quality-adjust labour inputs (Maré et al 2017 for example).
- **No hours worked in the LBD.** There are no hours worked in the LBD, so labour input is generally based on job counts for micro productivity measures.[3] This means, for example, that if an industry increasingly uses part-time staff to produce the same volume of output, this represents a reduction in labour volume and thus an increase in 'true' productivity, but it may not be picked up in measured productivity.
- **No industry-specific capital price deflator.** Instead, an aggregate capital price deflator is used. This means that capital input could be under- or over-stated.[4]
- **Price and quality adjustment do not reflect variations in market power.** For example, if one region has less intense price competition than others, firms in that region will receive more revenue for any given output than firms in more competitive regions (Jaffe et al 2016). Standard productivity measures will interpret this higher revenue as higher output, and so will infer incorrectly that these firms have higher productivity. A key point is the extent to which price movements reflect quality changes. If a firm's market power is derived from its past investments in technology or product development, which cannot be copied by other firms, higher prices reflect real differences in quality. But if market power reflects a lack of competition, high prices may be misinterpreted as quality improvements. The same principle applies on the input side, where a firm's advantage in commanding lower input prices should be stripped out of productivity measurement.
- **Productivity measures are based on a number of assumptions**, including that markets are perfectly competitive, constant returns to scale etc (see section 2). In practice, markets contain a mix of monopoly, oligopoly and perfect competition. Note that some of these assumptions can be relaxed in micro studies based on the econometric approach.

[3] Adjustments are made where observed data are inconsistent with full-time employment, where an individual works multiple jobs, or where observed earnings are too low to be consistent with full-time work based on the statutory minimum wage (see Fabling and Maré 2015b).
[4] However, a new data set in the LBD has recently created an industry-level capital deflator.

5. Concerns about measurement

This section examines concerns about productivity measurement and their potential scale. Note that these concerns are ones which have been raised across many countries, especially in recent years; this is in contrast with the discussion in section 4 which mainly focuses on New Zealand-specific issues. The section starts by outlining the key measurement concerns, then considers the role of mismeasurement in the global productivity slowdown, and concludes with implications for New Zealand.

Many of the concerns about productivity measurement can be grouped into two broad areas:

1. the challenge of disentangling price and quality changes may be growing
2. productivity measures capture less and less of what matters (discussed further in section 6).

The key conclusion is that mismeasurement is estimated to account for a relatively small proportion of the productivity slowdown. However, growth in the digital economy and the services sector means that mismeasurement may be growing too. Any growing mismeasurement over time could create challenges for analysing productivity trends.

There are a range of measurement challenges and concerns

Table 4 below identifies some of the main challenges or concerns raised in relation to GDP and productivity measurement. Note that while most of the concerns relate to outputs, many of the same issues apply to inputs. Further information is provided in appendix B.

Key points from Table 4 (drawn from Ahmad and Schreyer 2016 unless otherwise stated) include:

- **While many issues are not new, what is new is the scale of the problem.** Issues such as disentangling quality improvements from prices, and consumers receiving free media services paid for via advertising (eg TV channels), have been around for a long time. But the growth in the digital economy is increasing the potential scale of mismeasurement, and is placing pressure on conventional measurement methods. Similarly, the measurement issues could worsen as economic activity continues to shift away from manufacturing to service industries which are not easily captured in productivity measures (Manyika et al 2017).
- **There is significant uncertainty about the scale of the problem.** For example, the composition of IT investment has shifted appreciably toward components, such as software, for which measurement is more uncertain (Byrne et al 2016).
- **The measurement of price and quality changes requires ongoing efforts.** It is hard for measurement to keep pace with rapid quality and price changes in new and improved ICT and other products. Identifying quality improvements in some service sectors is also a challenge.
- **Many of the measurement issues conceptually fall outside GDP.** Many aspects of the digital economy, such as the unpaid-for benefits from digital products and consumers' involvement in the production process, have not conventionally been included in GDP (and thus productivity measures). GDP is only concerned with market production, so only products and services that consumers pay for are currently included. GDP is not a measure of wellbeing.
- **The digital economy is itself part of the solution.** The use of administrative (and other big) data provides opportunities to capture new types of transactions – see section 6.

TABLE 4: CHALLENGES FOR PRODUCTIVITY MEASUREMENT			
ISSUE	**EXAMPLES**	**ESTIMATES OF SCALE OF EFFECT**[5]	**REMEDIES**
Price and quality			
Inadequate price and quality adjustments – new and improved products and technologies may not be fully taken into account in measurement, thus under-stating output volume growth in GDP (so productivity may be *under*-stated); assets such as ICT may be under-stated in the capital stock (an input), so MFP may be *over*-stated	• ICT equipment such as computers • Software • Communications services • Many other digital products • Plus many examples outside the digital economy	• Estimates range from around 0.2 to 0.7 percentage points pa of GDP growth across countries • Substantial variation in countries' treatment of price movements in ICT • Effect on MFP somewhat offset by ICT being an input as well as an output	• Improve price and quality adjustment methods
Digital economy			
Free and subsidised consumer goods – free digital products are not included in GDP (so productivity may be *under*-stated), although consumers do pay for them to some extent via advertising and firms' use of consumer data	• Free apps for smartphones • Facebook • Google • Skype	• Imputing values for free media products has a minimal impact on GDP levels (at most 0.1 per cent pa of GDP), with negligible impacts on GDP growth rates	• Supplement with other measures
Free assets produced by households – free public goods which use volunteer labour are not captured in GDP (ambiguous effect on productivity, as both labour input and output are *under*-stated)	• Wikipedia • Linux	• Wikipedia – up to 0.1 per cent pa of global GDP if a fee were charged	• Exclude from GDP, as conventionally volunteers' services are valued at zero • Supplement with other measures
Peer-to-peer services – consumer-to-consumer transactions facilitated by digital technologies are not fully captured in GDP (ambiguous effect on productivity, as both input and output are affected); assets such as vehicles are not fully captured in the capital stock (so MFP may be *over*-stated)	• UberPOP • AirBnB • eBay	• Uber – effect of including vehicles in capital stock is very small	• Use tax administrative data to better capture output and inputs
Consumers as producers – households' involvement in the production process is not captured in GDP (ambiguous effect on productivity, as both input and output are affected)	• Online travel booking • Self-check at airports • Self-service in supermarkets	• Not known but growing	• Exclude from GDP, as conventionally services provided by households for their own consumption are excluded
Cross-border trade – some production is recorded in the (low-tax) country in which it is registered, rather than the country of economic ownership; this also affects the capital stock (ambiguous effect on productivity)	• Knowledge assets eg human and organisational capital	• Knowledge assets not included in GDP are estimated to be larger than those that are • Despite this, it is estimated that incorporating intangibles makes little difference to the productivity slowdown	• Reallocate income flows to the country of the parent company (so use Gross National Income rather than GDP) • Carefully interpret cross-country comparisons

[5] Specific estimates mainly drawn from Ahmad et al (2017).

Services			
Market services – unique, customised, complex and bundled services create challenges for controlling for changes in quality (so productivity may be *under*- or possibly *over*-stated)	• Telephone service plans • Financial services	• Not known but growing – services account for a large and increasing share of output	• Improve price and quality adjustment methods
Government services – many government services are provided for free and are difficult to aggregate, and their quality is hard to determine; currently the public sector is excluded from NZ official productivity statistics (but included in GDP based on the cost of providing the services)	• Health • Education	• Public services make up around 20 per cent of the economy	• Improve methods for measuring public sector productivity
The environment			
Valuing environmental services – natural and environmental resources are an asset which provides a flow of services to input to production, but they are hard to measure and so tend to be excluded (so productivity may be *over*-stated)	• Water • Atmospheric waste disposal services (GHG emissions)	• Not known	• Improve methods for estimating the value of environmental services
Wider aspects of the environment – GDP does not capture the wider contribution of the environment to wellbeing, externalities etc	• Pollution • Biodiversity	• Not known	• Supplement with measures of the stock of natural capital, physical indicators of environmental quality etc
Fracking – fracking means that a key input to mining (land) effectively fell in quality which, if not taken into account, may lead to an over-statement of input volume (so productivity may be *under*-stated)	• Land quality in mining	• In the US, average annual aggregate labour productivity and MFP growth estimated to be 5 basis points faster	• Improve methods to account for land quality
Other issues			
Restrictive assumptions – in particular, the assumptions used in growth accounting about constant returns to scale and perfect competition are not realistic	• MFP • Industries with different levels of competition	• Not known	• Carefully interpret productivity measures across industries
Lags between large investments and their utilisation – so that in the investment year, the measured growth in capital services is higher than the actual growth, resulting in an over-statement of input volume (so productivity may be *under*-stated)	• Major infrastructure	• Not known	• Improve methods to account for lags • Carefully interpret productivity measures
Source: Ahmad and Schreyer (2016); Ahmad et al (2017); Byrne et al (2016); New Zealand Productivity Commission (2017); OECD (2011); Stiglitz et al (2009)			

Mismeasurement accounts for only a small portion of the slowdown

Since the mid-2000s, productivity growth has been declining across countries. This decline has been substantial, long-lasting, and across the board (van Ark 2016). Globally, labour productivity growth (measured as output per worker) has only moderately slowed from 2.6 per cent per year, on average, in the 1996-2006 period to 2.4 per cent in the 2007-2014 period (van Ark 2016). The slowdown in global MFP growth has been much more dramatic, declining from 1.3 per cent from 1996-2006 to only 0.3 per cent from 2007-2014. The productivity slowdown in New Zealand pre-dated that in most other countries and was less severe.

Mismeasurement of productivity is one possible explanation of the slowdown. A number of studies have focused on mismeasurement in the US in particular. These studies have used different methodologies and data, but their findings are reasonably consistent (Brynjolfsson et al 2017).

The consensus appears to be that, while mismeasurement can explain some of the productivity slowdown, it probably only accounts for a relatively small proportion. Therefore the slowdown is a real effect.

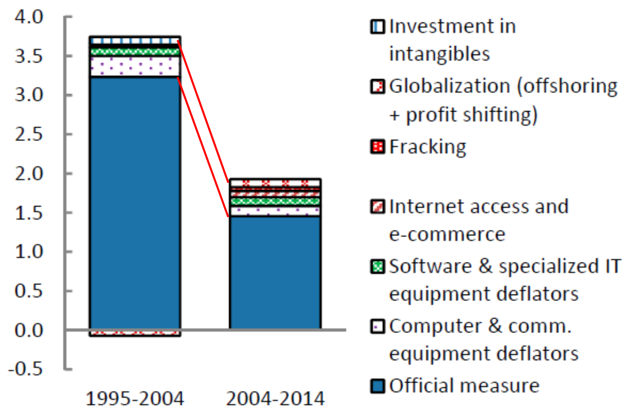
For example, one highly cited study (Byrne et al 2016) found little evidence that the productivity slowdown in the US arises from growing mismeasurement of the gains from innovation in IT-related goods and services. The authors gave three main reasons:

1. Mismeasurement of IT hardware was already significant prior to the slowdown. Because the domestic production of these products has fallen, the effect on productivity was larger in the 1995-2004 period than since. Also, IT mismeasurement affects GDP and labour productivity more that MFP (as IT appears as both an input and an output in MFP, which has offsetting effects).
2. Many of the consumer benefits from smartphones, Google searches, and Facebook are, conceptually, non-market, and so shouldn't appear in productivity measures.
3. Other measurement issues that the authors did quantify (such as increasing globalisation and fracking) are quantitatively small relative to the slowdown.

Figure 18 below (see Adler et al 2017) shows that the effect of adjusting US labour productivity growth for some of these factors is reasonably modest. The largest contributing factor to the adjustment is computer and communication equipment price deflators, reflecting the challenges of price/quality adjustments.

Figure 18: Accounting for mismeasurement doesn't change the story much

US labour productivity growth: official and adjusted (annual average percent)



Sources: Byrne, Fernald, and Reinsdorf (2016); IMF staff calculations.

Overall, these authors' estimates would add only about 0.3 percentage points to GDP growth per year for the US economy. This is small relative to the 1.8 percentage point slowdown in labour productivity growth per year over 2004-14 compared to the preceding decade.

Syverson (2016) reviewed estimates of the consumer surplus from internet access in the US and found a very wide variation in the estimates. He calculated that the smallest would account for a tiny fraction of the productivity slowdown; by far the very largest estimate would still account for less than one-third of the slowdown. He concluded that the case for the mismeasurement hypothesis faces real hurdles when confronted with the data. He gave many of the same reasons as Byrne et al (2016). He also added that the productivity slowdown has occurred in dozens of countries, and its size is unrelated to measures of the countries' consumption of ICT or production intensities of ICT.

Similarly, the IMF concluded that while it cannot be ruled out that growing measurement issues might have played some role in the observed slowdown, the bulk of the slowdown appears to be genuine (see Adler et al 2017).

Overall, studies suggest that mismeasurement accounts for only a small proportion of the productivity slowdown. But it is hard to be sure, as there is significant uncertainty around the estimates. Some commentators suggest that the estimates may be on the low side. For example, Bean (2016) commented that using advertising expenditure to impute digital product value provides very much a lower bound estimate. Aghion et al (2017) noted that most of the estimates in relation to price/quality adjustments only relate to the ICT sector, whereas quality changes in services and other sectors may be more important to aggregate productivity.

The slowdown may have a number of other causes

In brief, reasons other than mismeasurement given for the slowdown include:

- **Secular stagnation.** A shortage of demand and investment opportunities, even in a low-interest-rate environment, is the binding constraint on growth, essentially choking off productivity growth (Manyika et al 2017).
- **Weaker technological innovation.** Today's innovations may not be as transformational as those in the past (Gordon 2016, cited in Manyika et al 2017).
- **Technological gains are yet to emerge.** The New Digital Economy may be in the installation phase rather than the deployment phase (van Ark 2016), causing a delay between recognition of a technology's potential and its measureable effects (Brynjolfsson et al 2017).
- **Weaker technological diffusion across firms.** Skill mismatches, competition failures, investment constraints, and other factors have slowed the diffusion machine (OECD 2015a).
- **The 1995-2004 period was an anomaly.** With the Internet, the reorganization of distribution sectors etc, a lot of things came together at once in the 1995-2004 period; this may have been a one-time upward shift in the level of productivity rather than a permanent increase in its growth rate (Byrne et al 2016).

But overall, the sharp decline in productivity remains a puzzle yet to be resolved (Feldstein 2017).

It is hard to know how New Zealand compares

It is difficult to be sure how New Zealand compares to other countries in terms of the measurement issues, as New Zealand has not featured in recent studies that have directly compared countries. Some indirect factors tend to suggest New Zealand could compare favourably, and others do not.

Stats NZ follows best practice guidelines for productivity measurement such as those from the OECD (see OECD 2001), and continually refines its productivity measures. New Zealand is reasonably well placed in relation to some measurement concerns. For example, New Zealand has relatively good data on ride-sharing companies due to the use of tax administrative data in productivity measurement, and to the ride-sharing market being subject to regulation.

Some insights may be gained from considering the structure of the economy, and in particular the relative importance of the services sector and the digital economy to New Zealand compared with other countries. If these sectors feature comparatively strongly in New Zealand, then it seems plausible that the associated measurement challenges are prominent too.

As with most modern economies, the share of services is growing in New Zealand. Compared with other countries, in 2015 the share of the services sector in New Zealand (around 70 per cent of GDP) was just under the OECD average.[6] This tentatively implies that the associated productivity measurement challenges may be broadly similar to the OECD average.

The significance of the digital economy to New Zealand tentatively suggests that the associated productivity measurement challenges may be comparatively significant too. Assessing the importance of the digital economy is not an easy task, as there are numerous definitional issues (see OECD 2017c). However, the OECD's most recent digital economy outlook report (see OECD 2017d) suggests that New Zealand is a comparatively digital nation. New Zealand appeared in the top half of OECD rankings for many of the measures included in the report, such as the proportion of tertiary graduates in ICT, the proportion of employees in the ICT sector, and the penetration of fixed broadband in the population. In particular, New Zealand devoted the largest share of telecommunications revenue to telecommunication investment, reflecting the rollout of broadband.

Other insights may be gained from considering the extent of mismeasurement in countries similar to New Zealand. One such country is Australia, which arguably has some characteristics similar to New Zealand, such as distance from major markets.

If Australia is a useful comparator, the scale of measurement issues in New Zealand may be small compared with other OECD countries. Australia is included in some comparative studies about distinguishing between price and quality changes. For example, Ahmad et al (2017) estimated productivity mismeasurement due to inadequate price and quality adjustment of digital products in a number of OECD countries, including Australia. The implied adjustments to GDP growth were lower in Australia (0.02 percentage points per year) compared with other countries (around 0.2 percentage points per year), which appears to largely reflect patterns of ICT output and investment in the Australian economy. Assuming that ICT price adjustment methods, and the composition of ICT, in Australia and New Zealand are similar, this tentatively implies that the scale of this source of potential mismeasurement may be small in New Zealand compared with other OECD countries.

Comparisons over time and between countries may become trickier

It is hard to know whether mismeasurement now is greater than in the past, but factors like the growth in the services sector and the digital economy suggest this may be the case (Feldstein 2017).

Changing mismeasurement over time hampers our ability to analyse productivity trends. We would be less worried if mismeasurement were stable over time. For example, a stable error in measuring the GDP growth rate would not cause productivity growth to slow (Adler et al 2017). Given that productivity is a long-run concept, this bias over time is worrying.

Changing mismeasurement over time also makes comparisons with other countries increasingly problematic. For example, as countries introduce changes to their measurement practices at different points in time, their measured comparative productivity performances will change.

[6] See https://data.worldbank.org/indicator/NV.SRV.TETC.ZS?end=2016&locations=OE-NZ&start=1990&view=chart.

6. Potential remedies

This section expands on some of the potential remedies to address the concerns about productivity mismeasurement set out in section 5.

We identified three key remedies:

1. improve methods to adjust for price and quality changes
2. carefully interpret productivity measures
3. recognise what productivity is and isn't.

Improve methods to adjust for price and quality changes

This report has highlighted challenges around the price/quality/volume relationship. As Ahmad and Schreyer (2016) pointed out, the measurement of price change, and in particular the distinction between quality and price change, requires increased and concerted effort.

There are two key ways in which output (and input) can be adjusted for quality change (Office for National Statistics 2007).

1. **Adjust the price indices that are used as deflators.** Approaches include the following:
   - **Option costing**. If the difference between two products consists of one extra option (such as parking sensors in a car), this extra option could be valued by its price as if it were purchased separately.
   - **Hedonic price adjustment.** This approach essentially unbundles the contribution to prices of different characteristics of a product. It is based on the principle that market mechanisms allow consumer preferences to be revealed through price. To apply hedonic pricing, products are defined as bundles of characteristics. A hedonic regression relates the measurable price of a good to its measurable characteristics.
   - **X specs**. X specs is a method used for the construction of price indices for services. X specs denote additional information collected from service providers about the expected price of services. For a service they delivered in the current period, providers are asked to estimate for which price they would have provided the identical service in the preceding period.
2. **Find quality indicators and use these to adjust volume.** As an alternative to deflation, volumes can be measured directly to arrive at output in constant prices. Quality is captured by differentiating according to quality characteristics, so that compositional changes in the aggregate automatically capture quality change.

Some of these methods are used in New Zealand, but only for a few products. For example, option costing is used in relation to desktop computers, and hedonic pricing in relation to used cars and some electronic equipment such as computers and mobile phones.

Some of the key developments which Stats NZ has planned or underway to improve price and quality adjustment methods include (Bentley and Krsinich 2017):

- **Transaction/administrative data**. Transaction (or scanner) data and administrative data are valuable for their richness and timeliness, and (compared with surveys) reduced respondent burden. These data are already used for consumer electronics products. Administrative data is planned to be used to simplify price collection for second-hand cars. Research is also underway to assess the viability of using government administrative data for rent.

- **Web scraped data.** Web scraped data have similar benefits to transaction/administrative data. In the short-term, the feasibility of replacing some of the prices currently collected in the field with web scraped data will be assessed. Also planned is the automation of the collection of web prices that are currently included in the CPI. The longer-term goal is to replace as much survey data as possible with digital data (which will itself directly increase firm productivity).
- **Model-based (hedonic) methods.** There is an opportunity to use big data to transform hedonic or regression-based methods. Up until now, big data such as scanner data has been plugged into the fixed basket index. In future, the aim will be to measure pure price change, while controlling for the changing composition of the products being sold. The medium-term objective is to replace the monthly food price index with big data and a model-based approach. Depending on the success of this, the approach may be expanded to other products.

Carefully interpret productivity measures

When interpreting productivity measures, it is important to bear in mind how the specific data that are used in constructing those measures relate to the underlying concepts of outputs, inputs, and efficiency (Jaffe et al 2016).

Like all measures, productivity measures have limitations in the extent to which they capture the underlying concepts they are targeting. For example, in New Zealand inputs are not quality-adjusted, and the absence of hours worked in the LBD affects the accurate measurement of labour input for micro productivity measures. The limitations of New Zealand's productivity measures are discussed in section 4, and some rules of thumb to help interpret productivity measures are identified in section 3.

One issue that this report has highlighted is the need to interpret productivity trends with care. The growth in the digital economy and services sector make it increasingly difficult for measurement to disentangle pure price changes and quality changes. Any potential growth in mismeasurement over time hampers the analysis of productivity trends.

Recognise what productivity is and isn't

Productivity is about market production. Productivity is not a measure of wellbeing or welfare. The output component of productivity measures is often based on GDP. GDP generally values output at its market price; consumer surplus is the extent to which willingness to pay is above the market price (Syverson 2016). As Coyle and Mitra-Kahn (2017) commented, GDP never pretended to be a measure of economic welfare. In practice, however, it is very much used as one.

Some commentators have questioned the ongoing relevance of GDP. For example, Coyle (2014, cited in Feldstein 2017) commented that GDP is a measure of the economy best suited to an earlier era. Will Page of Spotify (cited in Bean 2016) commented that GDP faces a 'square peg, round hole' dilemma in that it was originally designed to measure tangible manufactured goods which are losing relevance in the modern economy. As a consequence, a few authors (see for example Coyle and Mitra-Kahn 2017) have advocated a radical overhaul or replacement of GDP. If the gap between GDP and wellbeing widens, the general public may start to lose faith in official productivity measures (Feldstein 2017).

However, major reviews of GDP (such as Stiglitz et al 2009; Bean 2016) have not gone as far as recommending that GDP measurement should be abandoned. In fact, Stiglitz et al (2009) commented that measuring production (via GDP) is essential for the monitoring of economic activity.

Corrado et al (2017) argued that, rather than being ‘demolished’, GDP should be ‘repointed’ and ‘extended’. These authors commented that wellbeing indices often suffer from 1) double counting and 2) arbitrary weights. In contrast, GDP captures production in a way that doesn’t double count (via value added) and that has flexible and informative weights (via prices).

This report has highlighted that the digital economy has many benefits to New Zealanders that fall outside conventional productivity measurement. The main issue here is how best to measure these benefits. There appear to be two key opportunities here. Firstly, Stats NZ is connected to international work to better measure the digital economy. Secondly, Stats NZ and MBIE are currently developing a Digital Nation Domain Plan. This Domain Plan identifies enduring questions about New Zealand’s digital transformation, and any gaps in the data needed to address these questions. The enduring questions include some about the impact of New Zealanders’ engagement in digital technologies (Stats NZ 2018), and so potentially could cover the unpaid-for benefits from digital products.

7. Conclusions and implications

The findings from this report imply that, for a number of reasons, productivity remains highly relevant to MBIE's work.

Firstly, conceptually, productivity growth is the most sustainable way of lifting incomes. Productivity growth means that resources are being used more efficiently, and this in turn provides us with more choices.

Secondly, productivity measures still appear to broadly reflect the underlying concepts to which they relate. Estimates of the scale of mismeasurement suggest that, for the most part, measurement is capturing 'true' productivity. Importantly, productivity mismeasurement is assessed as playing a fairly minor role in the global productivity slowdown of recent decades.

No measure is perfect. Bearing in mind that imperfections are inevitable, a key question to consider is: Do productivity measures tell us something useful? The answer to this question is 'yes'.

The consensus from studies appears to be that GDP and productivity measures should be retained and improved, and that these measures should be complemented with other measures which capture important aspects of wellbeing, such as the unpaid-for benefits to consumers from the digital economy.

Thirdly, New Zealand's historical productivity performance has been poor and mismeasurement is unlikely to be the cause. So there is plenty of scope for improvement. Productivity measures can help point to areas of concern and identify opportunities for further work.

MBIE plays a number of roles in lifting productivity. MBIE has some policy levers that affect productivity, including regulations in relation to businesses, labour markets and a number of product markets, and policies in relation to innovation, skills, internationalisation and competition. In order to inform these policy areas, MBIE undertakes research about the underlying drivers of productivity. MBIE also contributes to the public debate on productivity.

Actively contributing to the public debate requires a deep understanding of productivity and its measurement. This report is itself a step in the direction of one of the suggestions in this report – to improve MBIE's interpretation of productivity measures.

The other two suggestions – to improve methods to adjust for price and quality changes, and to recognise what productivity is and isn't – will involve MBIE working with others. This includes understanding work underway or planned by Stats NZ. In particular, the joint (with Stats NZ) development of a Digital Nation Domain Plan may provide an opportunity to explore these suggestions.

Bibliography

Adler, G., R. Duval, D. Furceri, S. Çelik, K. Koloskova and M. Poplawski-Ribeiro (2017), *Gone with the Headwinds: Global Productivity.* Washington D.C.: International Monetary Fund.

Aghion, P., A. Bergeaud, T. Boppart, P. Klenow and L. Huiyu (2017), Missing Growth from Creative Destruction. *NBER Working Paper No. 24023*.

Ahmad, N., J. Ribarsky and M. Reinsdorf (2017), *Can potential mismeasurement of the digital economy explain the post-crisis slowdown in GDP and productivity growth?* Paris: OECD.

Ahmad, N. and P. Schreyer (2016), Measuring GDP in a Digitalised Economy, *OECD Statistics Working Papers.* Paris: OECD.

Allan, C. (2018), *Getting under the hood: Recent firm-level research on productivity in New Zealand.* Wellington: MBIE.

Australian Productivity Commission (2015), *On productivity: concepts and measurement*. Melbourne: Australian Productivity Commission.

Australian Productivity Commission (2013), *On efficiency and effectiveness: some definitions.* Melbourne: Australian Productivity Commission.

Bean, C. (2016), *Independent Review of UK Economic Statistics.* London: London School of Economics.

Bentley, A. and F. Krsinich (2017), *Towards a big data CPI for New Zealand.* Wellington: Stats NZ.

Bloom, N., R. Sadun and J. Van Reenen (2016), Management as a Technology? *NBER Working Paper No. 22327*.

Boarini, R. (2012), *Well-being and GDP: why we need them both.* Paris: OECD

Brynjolfsson, E., D. Rock and C. Syverson (2017), Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics. *NBER Working Paper No. 24001*.

Byrne, D., J. Fernald and M. Reinsdorf (2016), Does the United States Have a Productivity Slowdown or a Measurement Problem? *Brookings Papers on Economic Activity.* (Spring): 109–157.

Carlaw, K. and R. Lipsey (2003), Productivity, technology and economic growth: What is the relationship? *Journal of Economic Surveys.* Vol. 17, No. 3.

Chappell, N. and A. Jaffe (2016), *Intangible investment and firm performance.* Wellington: Motu Economic and Public Policy Research.

Conway, P. (2016), *Achieving New Zealand's productivity potential*. Wellington: New Zealand Productivity Commission.

Conway, P., L. Meehan and D. Parham (2015), *Who benefits from productivity growth? – The labour income share in New Zealand.* Wellington: New Zealand Productivity Commission.

Conway, P. and L. Meehan (2013), *Productivity by the numbers: The New Zealand experience.* Wellington: New Zealand Productivity Commission.

Corrado, C., K. Fox, P. Goodridge, J. Haskel, C. Jona-Lasinio, D. Sichel and S. Westlake (2017), *Improving GDP: Demolishing, Repointing or Extending?*

Coyle, D. and B. Mitra-Kahn (2017), *Making the future count.*

Daraio, C. and L. Simar (2007), *Advanced robust and nonparametric methods in efficiency analysis: Methodology and applications.* New York: Springer.

Department of Industry, Innovation, Science, Research and Tertiary Education (2013)*, Demystifying Productivity: A Foundation for Policy Debate.* Canberra: DIISTRE.

Diewert, W. and A. Nakamura (2005), Concepts and measures of productivity: An introduction. Chapter 2 in Lipsey and Nakamura (eds.), *Services Industries and the Knowledge Based Economy*, University of Calgary Press, 2005.

Doan, T., D. Maré and K. Iyer (2015), Productivity spillovers from foreign direct investment in New Zealand. *New Zealand Economic Papers 49(3): 249-275.*

Fabling, R. and D. Maré (2015a), *Production function estimation using New Zealand's Longitudinal Business Database*. Wellington: Motu Economic and Public Policy Research.

Fabling, R. and D. Maré (2015b), *Addressing the absence of hours information in linked employer-employee data*. Wellington: Motu Economic and Public Policy Research.

Fabling, R. and A. Grimes (2014), The 'Suite' Smell of Success: Personnel Practices and Firm Performance. *ILR Review 67(4): 1095-1126*.

Fabling, R. and L. Sanderson (2014), *Productivity distributions in New Zealand: The dangers of international comparison*. Wellington: Motu Economic and Public Policy Research.

Fabling, R. and L. Sanderson (2013), Exporting and performance: Market entry, investment, and expansion. *Journal of International Economics, 89(2): 422-431.*

Feldstein, M. (2017), Underestimating the Real Growth of GDP, Personal Income and Productivity. *NBER Working* Paper No. 23306.

Fox, K. (2007), *Progress and Challenges in the Measurement of Productivity.* Sydney: The University of New South Wales.

Fraser, H. (2018), *The Labour Income Share in New Zealand: An Update.* Wellington: New Zealand Productivity Commission.

Gibson, J. (2017), *Quality and Quantity Redux.* Hamilton: University of Waikato.

Gordon, J., S. Zhao and P. Gretton (2015), *On productivity: concepts and measurement.* Melbourne: Australian Productivity Commission.

Jaffe, A., T. Le and N. Chappell (2016), *Productivity distribution and drivers of productivity growth in the construction industry.* Wellington: Motu Economic and Public Policy Research.

Janssen, J. and S. McLoughlin (2008), *New Zealand's Productivity Performance*. Wellington: New Zealand Treasury.

King, A. (2017), *Living Standards Analysis Model: The First Prototype*. Wellington: New Zealand Treasury.

Krugman, P. (1994), *The Age of Diminished Expectations*. Cambridge, MIT Press.

Law, D. and N. McLellan (2005), *The Contribution of Firm Entry, Exit and Continuation to labour Productivity Growth in New Zealand.* Wellington: the Treasury.

Mai, B. and N. Warmke (2012), *Comparing approaches to compiling macro and micro productivity measures using Statistics New Zealand data.* Wellington: Stats NZ.

Manyika, J., J. Remes, J. Mischke and M. Krishnan (2017), *The productivity puzzle: A closer look at the United States.* McKinsey Global Institute.

Maré, D. (2016), *Urban productivity estimation with heterogeneous prices and labour.* Wellington: Motu Economic and Public Policy Research.

Maré, D., D. Hyslop and R. Fabling (2017), Firm productivity growth and skills. *New Zealand Economic Papers.* 51(3): 302-326.

Mason, G. (2013), Investigating New Zealand-Australia productivity differences: New comparisons at industry level. *New Zealand Productivity Commission Working Paper 2013/02.*

MBIE (2017), *Macro meets micro: Quarterly Economic Update – August 2017.* Wellington: MBIE.

MBIE (2016), *What we know (and don't know) about economic growth in New Zealand*. Wellington: MBIE.

Ministry of Economic Development (2011), *Evaluation of the impacts of government cross-vote assistance on firm performance: Stage 2 Impacts of direct financial support for R&D.* Wellington: MED.

New Zealand Productivity Commission (2017), *Measuring and improving state sector productivity: Issues paper*. Wellington: New Zealand Productivity Commission.

OECD (2017a), *OECD Economic Surveys: New Zealand*. Paris: OECD.

OECD (2017b), *OECD Compendium of Productivity Indicators 2017*. Paris: OECD.

OECD (2017c), *Measuring Digital Trade; Towards a Conceptual Framework.* Paris: OECD.

OECD (2017d), *OECD Digital Economy Outlook 2017.* Paris: OECD.

OECD (2015a), *The future of productivity*. Paris: OECD.

OECD (2015b), *How's life? Measuring well-being.* Paris: OECD.

OECD (2014), *Measuring the Digital Economy: A New Perspective.* Paris: OECD.

OECD (2011), *Towards Green Growth: Monitoring Progress. OECD Indicators.* Paris: OECD.

OECD (2001), *Measuring Productivity: Measurement of Aggregate and Industry-level Productivity Growth*, OECD Manual. Paris: OECD.

Office for National Statistics (2007), *The ONS Productivity Handbook: A Statistical Overview and Guide.* Newport: Office for National Statistics.

Schreyer, P. (2012), *Recent developments in productivity measurement.* Paris: OECD.

Schreyer, P. and D. Pilat (2001), *Measuring Productivity.* Paris: OECD.

Sharpe, A., J-F. Arsenault and P. Harrison (2008), *The Relationship between Labour Productivity and Real Wage Growth in Canada and OECD Countries.* Ottawa: Centre for the Study of Living Standards.

Sharpe, A. (2002), Productivity concepts, trends and prospects: An overview. *The review of economic performance and social progress, 2002*.

Sin, I., S. Stillman and R. Fabling (2017), *What drives the gender wage gap? Examining the roles of sorting, productivity differences, and discrimination.* Wellington: Motu Economic and Public Policy Research.

Stats NZ (2017), *Productivity Statistics: 1978–2016.* Wellington: Stats NZ.

Stats NZ (2015), *Producers price index: concepts, sources, and methods.* Wellington: Stats NZ.

Stats NZ (2014a), *Productivity statistics: Sources and methods.* Wellington: Stats NZ.

Stats NZ (2014b), *Quarterly gross domestic product: Sources and methods.* Wellington: Stats NZ.

Stats NZ (2012), *Accounting for quality change in the CPI.* Wellington: Stats NZ.

Stats NZ (2010a), *Measuring government sector productivity in New Zealand: a feasibility study.* Wellington: Stats NZ.

Stats NZ (2010b), *New Zealand Time Use Survey 1999.* Wellington: Stats NZ.

Stiglitz, J., A. Sen and J-P. Fitoussi (2009), *Report by the Commission on the Measurement of Economic Performance and Social Progress.*

Syverson, C. (2016), *Challenges to Mismeasurement Explanations for the U.S. Productivity Slowdown.* Chicago: University of Chicago.

Syverson, C. (2011), What Determines Productivity? *Journal of Economic Literature 2011.* Vol. 49:2, 326–365.

Tangen, S. (2005), Demystifying productivity and performance. *International Journal of Productivity and Performance Management.* Vol. 54 No. 1, 2005, pp. 34-46.

The Treasury (2016), *Budget Economic and Fiscal Update.* Wellington: the Treasury.

The Treasury (2015), *An Introduction to Using the Living Standards Framework.* Wellington: the Treasury.

van Ark, B. (2016), The Productivity Paradox of the New Digital Economy. *International Productivity Monitor.*

Varian, H. (2016), *A microeconomist looks at productivity: A view from the Valley.* San Fransisco: Google.

Wakeman, S and P. Conway (2017), *Innovation and the performance of New Zealand firms.* Wellington: New Zealand Productivity Commission.

Glossary

AES: Annual Enterprise Survey.

Allocative efficiency: See Pareto efficiency.

APC: Australian Productivity Commission.

Consumer surplus: A measure of consumer welfare is defined as the excess of social valuation of a product over the price actually paid.

Digital economy: An economy that is based on digital computing technologies.

Disembodied technological change: The shift in the production function (production frontier) over time. Disembodied technical change is not incorporated in a specific factor of production.

DIISRTE: Australian Department of Industry, Innovation, Science, Research and Tertiary Education.

Efficiency: The degree to which a production process reflects best practice, either in an engineering sense (technical efficiency) or in an economic sense (allocative efficiency).

Embodied technological change: Improvements in the design or quality of new capital goods or intermediate inputs.

Externality: The production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided.

Gross domestic product (GDP): An aggregate measure of production equal to the sum of the gross value added of all resident institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs). The sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, less the value of imports of goods and services, or the sum of primary incomes distributed by resident producer units.

Gross national income (GNI): Equal to GDP less primary incomes payable to non-resident units plus primary incomes receivable from non-resident units. In other words, GNI is equal to GDP less net taxes on production and imports, compensation of employees and property income payable to the rest of the world plus the corresponding items receivable from the rest of the world.

Growth accounting: A procedure used in economics to measure the contribution of different factors to economic growth and to indirectly compute the rate of technological progress, measured as a residual, in an economy.

ICT: Information and communications technology.

Intermediate inputs: Goods and services, other than fixed assets, used as inputs into the production process of an establishment that are produced elsewhere in the economy or are imported. They may be either transformed or used up by the production process. Land, labour, and capital are primary inputs and are not included among intermediate inputs.

Labour productivity: Output per unit of labour input.

Longitudinal Business Database (LBD): A linked longitudinal dataset that covers a range of business information.

Macro economics: The study of the national economy as a whole.

Micro economics: The study of economics at an individual, group or firm level.

Multi-factor productivity (MFP): Relates a change in output to several types of inputs. MFP is often measured residually, as that change in output that cannot be accounted for by the change in combined inputs.

New Digital Economy: The combination of mobile technology, ubiquitous access to the internet, and the shift toward storage, analysis, and development of new applications in the cloud.

OECD: Organisation for Economic Co-operation and Development.

Output: Goods or services that are produced within an establishment that become available for use outside that establishment, plus any goods and services produced for own final use.

Pareto efficiency: Also referred to as allocative efficiency, occurs when resources are so allocated that it is not possible to make anyone better off without making someone else worse off.

Partial productivity measure: Relates output to one particular type of input, usually labour or capital.

Primary input: Those factors of production that are treated as exogenous in the framework of production analysis. They include capital, labour and land.

Productivity: The ratio of a volume measure of output to a volume measure of input.

Public good: A good that one individual can consume without reducing its availability to another individual, and from which no one is excluded – non-rival and non-excludable.

Purchasing power parity: A price relative which measures the number of units of country B's currency that are needed in country B to purchase the same quantity of an individual good or service as one unit of country A's currency will purchase in country A.

Real product wage: Average hourly rate of labour compensation (including on-costs) relative to the price of output – that is, the nominal rate of labour compensation deflated by an index of the prices of the output produced by that labour.

Satellite accounts: A framework linked to the central accounts which enables attention to be focused on a certain field or aspect of economic and social life in the context of national accounts; common examples are satellite accounts for the environment, or tourism, or unpaid household work.

Total factor productivity (TFP): See multi-factor productivity.

Value added: The value of output less the value of intermediate consumption; it is a measure of the contribution to GDP made by an individual producer, industry or sector.

Appendix A – Further information about productivity measurement

Macro productivity measures

New Zealand's productivity statistics are consistent with OECD's (2001) guidelines. The approach used is described by Stats NZ (2014a) as the index number approach in a production theoretic framework. The approach examines how much of an observed rate of change of an industry's (or economy's) output can be explained by the rate of change of inputs. Thus the approach evaluates MFP growth residually.

The estimates are for a subset of the market industries in New Zealand, referred to as the 'measured sector'. Initially, the measured sector included the primary and goods-producing sectors and some services like finance and insurance and communication services. In 2008, a few more services industries (property services, business services and personal and other community services) were added.

The productivity statistics were first released in 2006. They now cover the period from 1978 (Stats NZ 2017). Industry-level productivity statistics were first released in June 2010.

The productivity statistics are produced annually. They cover growth rates (but not levels) in labour productivity, capital productivity and MFP.

The **output measure** is value added at constant prices (Stats NZ 2014a). This is derived from the same procedures used for GDP. This calculates what each separate producer adds to the value of final output by deducting intermediate consumption from gross output. This means there is no double counting of output. The data are drawn from a number of firm surveys (mainly the Annual Enterprise Survey (AES)) and from administrative tax data (Stats NZ 2014b).

There are three methods of deriving the constant price series (Stats NZ 2014b):

- **Quantity revaluation** – the price in the current period is replaced with the price in the base period, so that the quantity is valued in the base period price. This method is usually adopted where there is an extensive range of quantity and price data available. Quantity revaluation is currently used in measuring the value added of agricultural industries.
- **Price deflation** – uses a price index, which measures the change in prices over time, to separate out the price movement from the current price series. The current price series is divided by the price index, with the resulting series only reflecting the change in quantity, or volumes.
- **Volume extrapolation** – a volume index is used to reflect the change in quantity over time. This volume index is used to multiply the base period value. This results in a constant price series, whose movements reflect the movements in the volume index over time.

Labour input is based on hours paid for all employed persons (paid employees and the self-employed) in the measured sector (Janssen and McLoughlin 2008). Hours paid is used rather than hours worked (the preferred measure) as, at the industry level, the hours paid measure is more robust. The key data sources are the Household Labour Force Survey (which has a measure of hours worked), and the Quarterly Employment Survey (which has a measure of hours paid, but is more robust than the Household Labour Force Survey at the industry level) (Stats NZ 2014a).

Capital input is based on the flow of capital services generated by capital stocks, which are themselves developed using the Perpetual Inventory Method (PIM) for 24 asset types within seven asset classes (eg intangible assets; buildings; plant, machinery and equipment; transport equipment), supplemented with estimates for three other assets (livestock, timber for felling, and land used for agriculture and forestry) (Janssen and McLoughlin 2008). The idea behind this is that capital goods provide a flow of capital services that constitutes the actual input to the production process (similar to employees hired for a certain period can be seen as providing flows of labour services from their stocks of human capital) (Schreyer and Pilat 2001). The data are drawn from the Annual Enterprise Survey, as well as estimates for the three other assets identified above.

Labour productivity is calculated by dividing an index of value added by an index of labour volume (Stats NZ 2014a). Similarly, capital productivity is calculated by dividing the value added index by the capital services index.

MFP is based on an index-number approach in which the residual is calculated as the ratio of the output index to the input indices (Stats NZ 2014a).

The benefits of the official macro productivity measures include that they:

- are compiled in line with international best practice, as set out by the OECD; this means that New Zealand's macro productivity measures are broadly comparable with those from other OECD countries, particularly at the total economy level (Mai and Warmke 2012)
- follow a consistent and standardised framework based on macroeconomic assumptions (Mai and Warmke 2012)
- can monitor and analyse changes in economic performance over time, and support economic forecasts (Fabling and Maré 2015a).

The limitations of official macro measures include that they:

- are based on key assumptions, eg constant returns to scale, perfect competition
- are only available for the measured sector, for growth rates and annually
- mask where productivity gains are being achieved
- tell us little about what is driving productivity performance.

In addition to the official productivity series described above, **other macro measures** are widely used. These include GDP per capita, GDP per worker and GDP per hour worked. These have the benefit of being available for the whole economy and quarterly. But (with the exception of GDP per capita) they are constructed by individual researchers, so can be produced in slightly different ways.

Micro productivity measures

In New Zealand, most recent micro productivity studies use data from Stats NZ's LBD. Two main sources are used. The AES uses concepts and measures designed for the purposes of productivity measurement, but the size of the survey has declined over time as the reliance on alternative data sources has grown. The IR10 tax form has relatively comprehensive coverage, but there is limited information contained in the two-page form (Fabling and Maré 2015a).

The LBD has limited data on labour inputs – employment counts (but not hours worked) are available. Price adjustment of outputs is done at the industry level, using available price deflators (Fabling and Maré 2015a).

The benefits of research studies using micro productivity measures include that they:

- allow researchers to avoid having to rely on the average firm by providing firm-level information, which can uncover some of the variation in productivity within aggregated industries (Mai and Warmke 2012)

- allow researchers to relax some of the assumptions used in the growth accounting and index number approaches
- allow researchers to tailor the measure to the specific research question
- provide information on the characteristics, practices, behaviours and performance of firms
- provide information on firm dynamics (firm entry and exit) and the reallocation of resources (between firms)
- can be used to answer a range of questions including: the contribution of firm-level dynamics to aggregate productivity growth; the productivity impact of firm-level characteristics such as managerial practices, firm structure, and input quality and mix; and the influence of factors external to the firm such as competition and regulation (Fabling and Maré 2015a).

The limitations of micro productivity measures include (from Mai and Warmke 2012 unless otherwise stated):

- there are currently no measures of hours, which means that labour input measures are generally based on job counts
- measurement issues are particularly acute for firms where a large proportion of the labour input is provided by working proprietors. This is because the LBD does not have information about the amount of labour input that working proprietors provide, and capital inputs are likely to be mismeasured. These measurement issues are more acute for firm-level productivity measures, as working proprietor only firms make up a much larger proportion of firms than of employment (Fabling and Sanderson 2014)
- gaps in the data, so that the figures are not necessarily representative of the entire population of firms; within the industries that are covered in the productivity dataset, aggregate total income from the data is 62 per cent as large as officially measured total income, with variation across industries ranging from 29 per cent to 96 per cent (Fabling and Maré 2015a). Note that missing data is an issue for both macro and micro measures, but macro measures have established methods for weighting and imputation of missing data
- lack of industry-specific capital price deflators[7]
- no firm-level or industry-level weights, so aggregating across firms can be problematic
- lack of a standardised approach overall, so it can be difficult to compare findings across studies.

[7] However, a new data set in the LBD has recently created an industry level capital deflator.

Appendix B – Further information on concerns about productivity measurement

Prices, quality and volumes

A key challenge presented by digitalisation is in relation to measuring price change (Ahmad et al 2017). Inadequate adjustment for **quality** change may affect the distinction between **price** and **volume** changes when estimating growth of output and capital inputs. This concern is especially pronounced for ICT products, which tend to undergo frequent changes in quality and specifications. When technological progress is rapid, standard methods may undervalue the quality improvements embodied in new models, leading to overestimation of the growth of quality-adjusted prices and underestimation of output volume growth. New products and services are not reflected in the price indices until they represent a significant level of expenditures (Feldstein 2017).

This is not a new issue. For example, disentangling quality improvements in services has been a challenge for a long time.

Hal Varian has been at the forefront of raising concerns about the measurement of GDP, including in relation to quality changes. He provided an example in relation to photos (see Varian 2016). Worldwide, the number of photos increased from around 80 billion photos in 2,000 (easy to measure) to around 1.6 trillion in 2015 (harder to measure). The price per photo has gone from 50 cents to 0 cents. The increase doesn't show up in productivity measures since: the price index for photography includes the price of film, developing, and cameras, all of which are vanishing; photos are mostly shared, not sold (a non-monetary transaction); GDP went *down* when cameras were absorbed into smartphones, as no quality adjustment was applied to smartphones.

A simple first indication of the possible scale of price mismeasurement can be constructed by comparing measured price changes across countries. Particularly during a period of relatively low global inflation, price movements can be assumed to be broadly similar across countries for globally traded goods, after allowing for pass through of exchange rate movements.

Ahmad et al (2017) considered price movements for three kinds of products – ICT equipment, software and databases, and communications services – over the period 1994 to 2015. They found substantial variation across countries. For example, prices of computers and telecommunications equipment showed little change over the two decades in Spain, and declines of between 70 and 90 per cent in Australia, Canada, Germany, the Netherlands, UK and the US.

The same authors used the price variations to derive upper and lower bounds that indicate the scale of the potential mismeasurement of growth in investment or output caused by deflators. The implied adjustments to GDP growth were around 0.2 percentage points per year for most of the countries they looked at. They noted that while all of the adjustments to GDP translate almost directly into adjustments to labour productivity, the implications for MFP are more complicated. For ICT goods and software, the upward adjustments to growth also increase estimates of capital stock and inputs of capital services. The offsetting output effects and input effects are likely to make the adjustments to MFP estimates much smaller than those for labour productivity.

Another study by Goldman Sachs (2015, cited in Bean 2016) estimated that the mismeasurement of quality change in IT output leads to a 0.7 percentage point underestimation of annual GDP growth in the US and up to 0.5 percentage points in European countries.

Schreyer and Pilat (2001) argued that quality adjustment of ICT price measures tends to have a comparatively small effect on the measurement of economy-wide productivity, and is not of a size to account for differences in measured productivity growth between countries. But the effects on measured output volumes are likely to be significant in individual industries such as the office equipment and computer industry.

However, some commentators have questioned the (small) size of some of the estimates of mismeasurement of price and quality changes. For example Aghion et al (2017) commented that many of the estimates are based solely on the ICT sector rather than the economy as a whole. They also argued that, to date, attention has focused on the challenges of measuring quality improvements when incumbents upgrade their products, or on not capturing the benefits of brand new varieties. They argued that there is a subtler, overlooked, bias in the case of creative destruction. When the producer of the outgoing item does not produce the incoming item, the standard procedure is to resort to some form of imputation. Imputation inserts the average price growth among a set of surviving products that were not creatively destroyed. These authors argued that this misses some growth because inflation is likely to be below-average for items subject to creative destruction, and in fact *deflation* will be prevalent.

These authors developed a model of the US economy (non-farm businesses) over the period 1983-2013 to examine the effect of imputation on productivity growth, and estimated that 1) missing growth from imputation was substantial – around one quarter to one third of total productivity growth and 2) it was mostly due to creative destruction.

The challenges that statistical agencies face when developing price indices include the following (Byrne et al 2016):

- **Data limitations.** For the most part, statistical agencies rely on direct survey collection of data on transaction prices for constructing price statistics. Data from consultancies, trade groups, and advertisements is available, but not fully exploited in the official price index programmes.
- **Reproducibility.** Statistical agencies should avoid index calculation procedures that depend on subjective judgment and would not be invariant to which analyst processes the data. This argues against, for example, routinely adjusting price indexes by the apparent bias indicated by research results for previous periods.
- **Conceptual incompatibility.** There can be a mis-match between economic concepts and feasible price index methods, especially in relation to imported goods.
- **Limited window for historical revision.** Knowledge gained by research cannot be easily incorporated in the revision window for price indexes.
- **Budgetary constraints**. Funding limitations for statistical agencies may impair their ability to address the measurement needed for productivity analysis.

Realistically, with products continually evolving, there are limitations to what statistical agencies are able to do as they are continually forced to play catch-up (Byrne et al 2016). This means that in practice, the extent to which quality changes can be fully adjusted for is uncertain (Gordon et al 2015).

Free and subsidised consumer products

Free digital products for consumers are frequently put forward as examples of output or consumer welfare that go unnoticed in GDP figures (Ahmad and Schreyer 2016). Such products include free apps for smartphones or tablets and free search capacity provided by websites such as Google.

The provision of free services by corporations to households is not a new phenomenon. Households have long received free media services (television and radio) financed implicitly via advertising. But digitalisation has increased the scale of the issue (Ahmad and Schreyer 2016).

In terms of the scale of these issues, McKinsey Global Institute (see Manyika et al 2017) focused on Skype and found that it generated enormous consumer surplus that was not measured anywhere. 40 per cent of international call minutes in 2013 were Skype-to-Skype calls, equivalent to $37 billion of lost revenue for telecom firms. Lower usage of *paid* calls will affect measured productivity if there are economies of scale.

Because there is no explicit payment by the consumer there is an argument that GDP is underestimated by the value of the free services received (Ahmad and Schreyer 2016). But this to some extent overlooks the fact that the consumer does indirectly pay through the higher prices paid for advertised products, as the firms paying for the advertising recoup their costs.

Facebook and Google are therefore counted in GDP as providing advertising services to businesses, not services consumed by households (Byrne et al 2016). So the rise in GDP can be traced to households' production of ad-watching services. The authors argue that this approach is reasonable; it monetises an implicit barter transaction that consumers undertake with Google and Facebook and other advertising-supported service providers and it recognises that consumers value the services they receive.

A more recent development is the emergence of new data-driven business models involving the acquisition of large amounts of information on consumers' preferences, characteristics and spending patterns. Again, consumers pay for this to some extent as the information is used by producers in the marketing of their goods and services.

More generally, GDP is not a measure of welfare or consumer surplus, and so should only capture consumption that consumers pay for (Ahmad and Schreyer 2016). Examples where free or subsidised consumer products are correctly excluded from GDP include the following (Byrne et al 2016):

- The gains implied by consumers' time spent on the internet etc are linked to home production of non-market services, not the market output that is the object of productivity measures.
- The number of websites or videos available on the internet is not, per se, a direct aspect of the quality of the internet service provider and so should be excluded from GDP; in contrast, an improvement in download speed conceptually represents a larger quantity of market services.
- The greater variety of products available online, and better matches available from more information and consumer reviews etc, makes more efficient use of existing products and raises welfare, but does not represent an increase in market output.

Ahmad et al (2017) tried to assign a value to the free media products that are provided to households by assuming that it equals the revenue that the producers of these products receive from advertisers. Note that media products include programming and broadcasting, publishing and web portals. Their estimates of the turnover of media industries, financed primarily by advertising, range from 0.4 per cent of GDP in Greece to 1.3 per cent of GDP in the US in 2013. The impact on average annual GDP growth over the period 2009-13 ranged from an extra 0.07 percentage points per annum to GDP in the US, to a 0.17 percentage points per annum *decline* in Greece (driven by contractions in programming and broadcasting and publishing excluding books and software industries). Overall, they concluded that imputing values for free media products is likely to have a minimal impact on GDP *levels* (at most 0.1 per cent per annum of GDP), with negligible impacts on GDP *growth* rates.

The same authors also considered the value of data to businesses. They commented that the information available on this is scant. They estimated that the value of user data as a share of GDP is around 0.02 per cent per year at the global level in 2016. They concluded that while the value has increased over the last few years, it is clear that the impact of including free services consumed by households on estimated GDP volume growth consumption would be very marginal. They also noted that if both advertising and data revenues were used in combination there would be significant double counting.

In sum, the effects of these free services appear to be small (Ahmad et al 2017). It is also important to note that conceptually GDP (and productivity) is a measure of production, and not a measure of welfare or consumer surplus (Ahmad and Schreyer 2016). In other words, GDP should only capture consumption that consumers pay for. Having said that, it would be useful to supplement GDP figures with estimates of consumer surplus from these free services.

Free assets produced by households

Another free service is the creation of public goods using labour provided for free, and where financing is typically only provided by donations (as opposed to paid services for the use of the goods, whether directly as fees or indirectly via other forms of financing eg advertising). Wikipedia and Linux are two well-known examples.

Ahmad et al (2017) provided estimates of the value of Wikipedia if it sold advertising or charged a fee for its services – 0.0004 and 0.1 per cent respectively of world GDP in 2016.

While these services have provided significant benefits for consumers and a case can be made that time spent on these activities includes an element of production, it is also clear that, within the current framework at least, they (correctly) do not enter into GDP (Ahmad and Schreyer 2016). This is because the current framework values the services provided by volunteers at zero.

Peer-to-peer services

Peer-to-peer (consumer to consumer) transactions facilitated by web-based intermediaries in the corporate sector are a key feature of the digitalised economy (Ahmad and Schreyer 2016). This is sometimes referred to as the sharing economy. Perhaps the best known examples today are UberPOP and AirBnB, but others such as eBay have provided similar intermediation services for considerably longer.

Households have long engaged in peer-to-peer transactions such as the provision of dwelling rental services, the provision of taxi services (often unlicensed), and the sale of second hand (and indeed new) goods (eg via car boot sales and classified adverts). And GDP, at least conceptually, captures all of the related transactions and value added created. What is different now is the scale of the issue.

However, even if the output of these services is reasonably well captured in current estimates of GDP, at least for taxi services, the underlying fixed assets (vehicles) used in the provision of these services are often not correctly recorded as fixed assets (Ahmad et al 2017). This affects the current official estimates of the capital stock, and, in turn, productivity.

Ahmad et al (2017) estimated the effect on US productivity of including Uber cars in the capital stock in 2015; the effect is very small.

Peer-to-peer transactions should theoretically appear in the tax administration data (Ahmad and Schreyer 2016) so this data can be used to include these transactions in GDP. Note that this is already the case in New Zealand.

Consumers as producers

Increasingly, households are involved in intermediation that would previously have been undertaken by a dedicated intermediary. In other words, households are increasingly engaged in activities that would previously have been included in GDP (Ahmad and Schreyer 2016). Examples include the use of internet search engines or travel websites to book flights, self-check in at airports, self-service at supermarkets, cash withdrawal machines, and online banking.

This is a long-standing issue. For example, in the early 20th century, paid domestic workers did many tasks that by mid-century had been taken over by the homeowners themselves (Byrne et al 2016).

Households have also long combined purchased market goods and services with their own time to generate the actual service they value. For example, they buy a soccer ball (which is part of GDP), and combine that market purchase with their (leisure) time, and their children's time, to obtain soccer services (Byrne et al 2016).

The key question is whether this increased displacing participation should be included in GDP, one of the main arguments being that GDP would be higher, for example, when a travel agent acts as an intermediary to conduct the search. By convention, the answer is no (Ahmad and Schreyer 2016). There has been a long-standing critique that many services provided by households for their own consumption (cooking, cleaning, baby-sitting, shopping) could in theory be provided by a third-party and so should be included in the production boundary.

Cross-border trade

The measurement of trade presents some significant challenges in areas such as intra-firm transactions in data, digital services, and intellectual property. The large jump in Irish GDP estimates, reflecting the relocation of some US firms to Ireland, is a key example (Ahmad et al 2017).

In particular, intellectual property products (IPPs) have increased the ability of firms to shift the registration (legal ownership) of their IPPs from one (high-tax) jurisdiction to another (low-tax) one, and as a consequence also shift the underlying value added created by these assets. IPPs include R&D and computer software and databases (Ahmad and Schreyer 2016).

The issue here is not whether the flows from the assets are recorded in national accounts, but whether the recording aligns with concepts of ownership. Rather than legal ownership, the principle of economic ownership (who runs the risk and receive the rewards) should determine in which country's national accounts the assets should be captured. Any mis-classification affects the interpretation of GDP statistics and the comparability of GDP across countries. Because these assets are part of the capital stock, productivity is also affected.

This problem is exacerbated when the scope of digitalised assets is expanded. The most commonly used classification of a broad scope is called knowledge-based assets and includes:

- computerised information, ie knowledge stored in programmes
- innovative property, ie R&D assets
- economic competencies, ie human and organisational capital.

In most countries, estimates suggest that the contribution made by knowledge-based assets not included in the national accounts is typically larger than those ones that are (Ahmad and Schreyer 2016).

One solution is to reallocate income flows related to the use of the underlying assets as value added generated in the territory of the parent company, resulting in higher labour productivity figures in those countries with positive net receipts from knowledge-based assets and lower labour productivity in those with negative net receipts (Ahmad and Schreyer 2016). This approach equally applies to those knowledge-based assets currently outside of the national accounts. This implies some caution in interpreting the productivity results that emerge from extending the asset boundary without adjusting for the cross-border use of the underlying assets.

Market services

Measuring the output and prices of services is inherently more difficult than for goods as the basic unit of production is harder to define (Bean 2016). Services are often tailored to a particular consumer's requirements. This customisation makes it hard to compare like with like and thus to construct an appropriate price index. This affects not only the measurement of consumer services, but also business services and thus the construction of intermediate consumption.

New digital technologies increase the scope for mass customisation to fit specific consumer preferences, leading to greater variety across services (Bean 2016).

The measurement difficulties include (Diewert 2005, cited in Fox 2007):

- **Unique services** – how to construct indexes over time if the service is only observed once? This is becoming more common.
- **Complex services** – such as telephone service plans.
- **Tied services** – how to separate the prices and hence quantities of bundled services?

The service sector has grown dramatically in most industrialised countries – including New Zealand – over recent decades. These factors make controlling for quality differences more complicated (Ahmad et al 2017).

An important point in relation to the growth of services is Baumol's cost disease (or the Baumol effect). This is the rise of salaries in jobs that have experienced no increase in labour productivity, in response to rising salaries in other jobs that have experienced labour productivity growth. Rising labour productivity in sectors like manufacturing allows employers in that sector to increase wages. This has a knock-on effect to other sectors which are competing for workers, including services. But it is harder to lift productivity in labour-intensive services. So the effect is to raise the price (wages) of labour, with no corresponding increase in aggregate output (and hence productivity). In fact, aggregate productivity falls because of reallocation of labour between productive and less productive sectors.

Government services

Measurement difficulties are particularly pronounced in relation to government services and include the following (New Zealand Productivity Commission 2017):

- **Lack of prices.** Many government services (eg education, health, administration and defence) are provided free or at nominal charges. Because the outputs cannot be valued, they cannot be aggregated in the same way that private sector outputs can.
- **Collectively consumed.** Some government services – like defence – are not directed at individuals but at the population at large. For collective services it is especially hard to measure outputs.
- **Defining outputs.** Outputs are the completed services produced and ready for consumption. But determining the correct level of aggregation of outputs for government services is difficult (eg x-ray versus entire course of treatment for a broken leg).
- **Quality changes.** There is a lack of systematically-available information on how the quality of services is changing over time. Not adjusting for quality can create perverse effects. For example, an education policy of smaller class sizes may lift the quality of education, but may be measured as a reduction in productivity (when output is measured by student places and labour input as teacher FTEs).

Due to these measurement challenges, national accounts have traditionally valued public sector outputs at the cost of their production (New Zealand Productivity Commission 2017). In New Zealand (and elsewhere), public sector outputs are included in official GDP statistics via their cost, but not in official productivity statistics, which only cover the measured sector. It would be meaningless to calculate productivity (outputs divided by inputs) when outputs are estimated as inputs.

In 2010, Stats NZ began to explore options to measure the productivity of government services (see Stats NZ 2010). They concluded that it *was* feasible to estimate changes in the productivity of government health and education services. In 2013, they provided the first official estimates of productivity for the education and training, and health care and social assistance industries. The initial series covered the period 1996–2011, and the series has subsequently been updated each year. The productivity measures reflect output growth relative to input growth (New Zealand Productivity Commission 2017). Output growth reflects the change in the amount of activity undertaken (Stats NZ 2010). But as noted above, the productivity estimates for government services have not been integrated into the wider official productivity estimates.

To provide some sense of scale of these issues, note that public services make up around 20 per cent of the economy (New Zealand Productivity Commission 2017).

Ways to improve productivity measurement in the public sector include (New Zealand Productivity Commission 2017):

- **Directly count the outputs in a given area** – for example, to count the number of court trials, and divide it by the total cost of administering trials.
- **Cost-weight the outputs.** To enable outputs to be aggregated, the counts can be weighted by what it cost to produce them.
- **Apply an additional quality-weighting.** To adjust for quality variations, an additional weighting can be applied to the total outputs weighted by unit costs metric.

The environment

Natural resources are an asset which provides a flow of services which are an input to production. So in theory their productivity can be calculated in the same way as for capital services.

Rising environmental and resource productivity would appear to be a necessary condition for green growth (OECD 2011). When the use of natural resources is not recognised as a cost of production, there is less incentive to use these resources optimally (Stiglitz et al 2009). If services provided by natural assets are shown, resource productivity can be tracked and put on the same footing as measures of labour productivity or (produced) capital productivity. Choices between promoting GDP and protecting the environment may be false choices, once environmental degradation is appropriately included in our measurement of economic performance (Stiglitz et al 2015).

As with the other measurement challenges noted above, conceptually GDP is based on market valuations of goods and services. Externalities such as pollution are excluded from GDP, but are important in terms of society's valuation (OECD 2011). In addition, as a gross measure, GDP takes no account of depreciation, depletion or degradation of assets, whether produced or natural.

When natural resources are included in productivity measurement, as with other inputs, it is important to capture quality changes. Failing to capture a decline in the quality of natural resources, such as declining soil quality, may lead to an over-estimation of input volumes, so productivity may be under-estimated (Schreyer 2012). For example, fracking enables lower quality land to be used as an input into mining (Byrne et al 2016). If this fall in input quality is not taken into account in the production process, input volumes may be over-stated and thus productivity may be under-stated.

In practice, services from natural assets are rarely quantified in economic models and accounting frameworks (OECD 2011). This is partly due to the challenges in producing a reasonable estimate for the value of the service. At a minimum, this requires an estimate of marginal abatement costs, at best an estimate of society's marginal valuation of the environmental service. In some cases, such as the environmental services from biodiversity, it is very difficult to derive a robust valuation.

Excluding natural resources from productivity measurement means that productivity growth can be overestimated in countries where output growth relies to a large extent on the depletion of natural capital, and in countries that hold production costs down by relying on heavily polluting technologies (Brandt et al 2014). Conversely, the economic performance and sustainability of an economy that invests in a more efficient use of the environment in production may be underestimated, as some inputs do not serve to increase the current production of goods and services, but to reduce the associated negative externalities.

Brandt et al developed productivity measures which incorporate natural capital as a factor of production (Brandt et al 2013), and which include externalities as bad outputs (Brandt et al 2014).

In their first paper, Brandt et al (2013) extended aggregate economy productivity measures mostly from the OECD Productivity Database by incorporating natural capital as an additional input factor into the production function. Their analysis covered the period 1985-2008. More specifically, these authors considered oil, gas and various minerals as natural capital inputs, drawing on data from the World Bank. Their results suggested that failing to account for natural capital tends to lead to an underestimation of productivity growth in countries where the use of natural capital in production is declining because of a dwindling natural capital stock. In addition, productivity growth is sometimes overestimated in times of natural resource booms, if natural capital is not taken into account as an input factor. The direction of the adjustment to productivity growth depends on the rate of change of natural capital extraction *relative* to the rate of change of other inputs.

In their second paper, Brandt et al (2014) developed a productivity measure that explicitly accounted for undesirable goods, or bads (CO_2, SO_2 and NO_x emissions), as an output of the production process. They used aggregate economy data for a sample of OECD countries along with Russia and South Africa for the period 1990-2008. Their results suggested that the adjustment of the traditional productivity growth measure for bad outputs is small. They argued that this is good news for two reasons. First, it implies that ignoring these bad outputs results in a relatively small bias of productivity measurement. Second, it also implies that the acceleration in productivity growth that would help to substantially reduce these bad outputs, without reducing output growth, should be possible to achieve.

In the second study, emissions growth was found to be below GDP growth in all countries, so the correction of the traditional MFP measure for the effect of bad outputs was positive. The interpretation of this upward correction was that traditional MFP measures fail to take into account environmental technological progress and structural change towards sectors with lower emissions, like services. New Zealand had one of the lowest adjustments, due to our high emissions rates compared with other countries.

SPP 4204 October 2018