Sharon Pells

Productivity Measurement in the Digital Age

Abstract

Mismeasurement of productivity is one possible explanation for the global productivity slowdown in recent decades. This article discusses the challenges of measuring productivity in the digital age. The article covers some background about the productivity slowdown and about productivity measurement, the pressure that the growth in the digital economy is putting on productivity measurement, some estimates of mismeasurement from other countries, and the implications for New Zealand. The main conclusion is that, despite measurement issues, the productivity slowdown in New Zealand and elsewhere cannot simply be written off as measurement error. A further conclusion is that the digital economy has many benefits that fall outside conventional productivity measurement.

Keywords productivity slowdown, productivity mismeasurement, digital economy, digital technologies

Robert Solow once famously quipped that 'you can see the computer age everywhere but in the productivity statistics' (Solow, 1987). This comment seems as relevant – if not more so – today as when it was made 30 years ago. We experience the value from new digital technologies every day at work and in our leisure. Yet, at the same time, recent global productivity growth has been sluggish.

Sharon Pells is a Principal Research Analyst at the Ministry of Business, Innovation and Employment.

Productivity growth has been slowing worldwide

Since the mid-2000s, productivity growth has been declining in many 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 year, on average, in the 1996–2006 period to 2.4% in the 2007–14 period (ibid.). The slowdown in global multifactor productivity growth has been much more dramatic, declining from 1.3% per year in the 1996-2006 period to only 0.3% in the 2007-14 period. New Zealand has seen this productivity slowdown too, but the slowdown here predated that in many other countries and was less severe.

A number of explanations have been given for the global productivity slowdown, many of which relate to technology. Some argue that today's technological innovations may not be as transformational as those in the past (Gordon, 2016, cited in Manyika et al., 2017). Conversely, others argue that the gains from technology are yet to

emerge. For example, 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 measurable effects (Brynjolfsson, Rock and Syverson, 2017).

Others argue that the diffusion of technology across firms has weakened. Skill mismatches, competition failures, investment constraints and other factors may have slowed the diffusion machine (OECD, 2015). Another explanation is that the 1995–2004 period was an anomaly. With the internet, and the reorganisation of distribution sectors, etc., many things came together at once. This may have been a one-time upward shift in the level of productivity rather than a permanent increase in its growth rate (Byrne, Fernald and Reinsdorf, 2016).

This article focuses on mismeasurement in the digital economy[1] as a possible explanation for the slowdown (see, for example, Adler et al., 2017). If productivity measures are failing to adequately capture new and improved digital products, 'true' productivity growth may be higher than measured productivity growth.

Why we care about productivity

Productivity is a measure of the efficiency with which inputs (labour, capital and raw materials) are converted into outputs (goods and services) (Gordon, Zhao and Gretton, 2015). The reason we care about productivity is that improving productivity means that we are making more of New Zealand's limited resources, which provides us with more choices. It means, for example, that there are more goods to consume for the same amount of inputs; people can have more leisure time while producing the same amount of goods; and fewer natural resources are required to produce the same amount of output (Fox, 2007).

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 not the only thing that matters. Productivity growth on its own may do little for inequality or poverty, for example (Sharpe, 2002). Productivity measures don't 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.

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Productivity concepts and measurement

Productivity is commonly defined as: 'a ratio of a volume measure of output to a volume measure of input' (OECD, 2001). Productivity rises when the volume of output increases more rapidly than the volume of input, and falls when the volume of input increases more rapidly than the associated output.

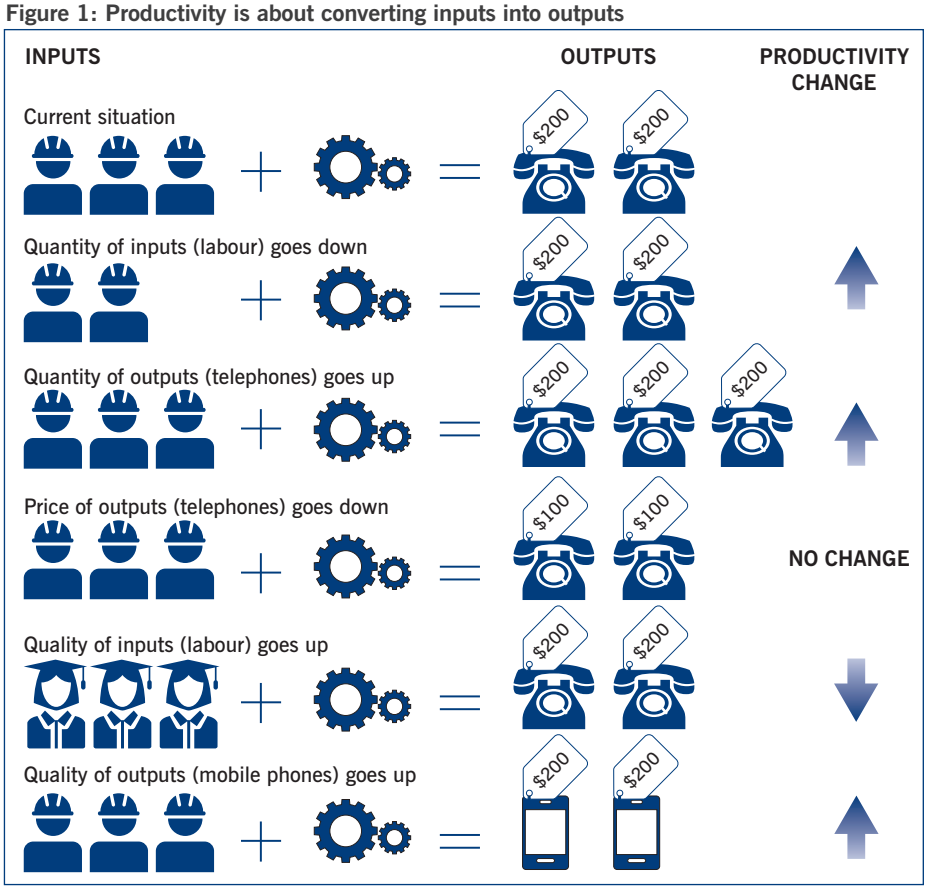
There are two important points to note from this definition. First, productivity is about production. Productivity therefore generally only covers things that are produced and that consumers pay for. Second, productivity is a volume measure. The volume of output has two components: quantity – the number of units (of a good or service); and quality – the description of the characteristics of each unit (Office for National Statistics, 2007). For example, a better (higher-quality) pair of shoes can be thought of as providing more 'running services'. The same concept applies to inputs. For example, higher-skilled (higher-quality) labour represents a higher volume of labour. A key difference, though, is that a higher volume of labour reduces productivity, as labour is an input, whereas a higher volume of output increases productivity.

Measuring productivity involves dividing some measure of the volume of output by some measure of the volume of input. One commonly used measure of labour productivity is GDP per hour worked.

Prices play a key role in productivity measurement. When markets are functioning efficiently, the ratio of one market price to another reflects the relative appreciation of the two products by those who purchase them (Stiglitz, Sen and Fitoussi, 2009). In other words, dimensions of quality prized by consumers tend to be reflected in prices. A key issue from a productivity measurement perspective is determining whether a price rise reflects general inflation or improvements in quality. Quality improvements represent an increase in volume, while general inflation does not.

The relationship between prices, quality and volumes is therefore an ongoing issue for measurement. This is challenging in the services sector, as services are often customised and so it is difficult to

Figure 1: Productivity is about converting inputs into outputs



Source: Author

distinguish between quality and price changes (Bean, 2016). It is also challenging in relation to digital products and services, as quality and price changes can move in different directions for these products and services. For example, the power and quality of computers has increased tremendously in recent decades, while the price has fallen dramatically.

Figure 1 provides a stylised example of how changes in the quantity, quality and price of outputs and inputs 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.

Why we need to understand the digital economy

While the digital economy presents challenges for productivity measurement, it provides opportunities to lift New Zealand's productivity performance – through, for example, the adoption of new digital technologies. Given New Zealand's distance from major markets, there are benefits from a shift to a more 'weightless' economy based on trading knowledge-intensive products (Conway, 2017).

Making the most of new digital technologies implies some changes in economic structure, which requires smooth resource reallocation across industries (ibid.). This structural change has a number of policy implications, including for the labour market, as people need to be equipped with new skills in order to adapt to change.

However, Conway (2016) showed that technology diffusion and resource allocation do not work as well as they could in New Zealand. Reasons include that some New Zealand firms – particularly ones operating in small and insular regional markets – do not face much competitive pressure. These firms can lack incentives to invest in new technologies, and can linger as small, unproductive firms, rather than either grow or exit the economy. These firms can get left behind in the digital age.

Growth in the digital economy is putting pressure on measurement

A number of studies have tried to estimate the effects of the digital economy on productivity mismeasurement. As discussed later, current estimates suggest that mismeasurement of productivity arising from the digital economy is likely to have played a fairly minor role in explaining the global productivity slowdown.

Many of the measurement issues relating to the digital economy are not new. For example, issues such as consumers receiving free media services paid for via advertising (e.g., television channels) have been around for a long time (Ahmad and Schreyer, 2016). But the growth in the digital economy is increasing the potential scale of mismeasurement. Therefore, what is new is the scale of the problem. In addition, there is significant uncertainty about the scale of the problem. For example, the composition of IT investment has shifted toward components – such as software – for which measurement is more uncertain (Byrne, Fernald and Reinsdorf, 2016).

An important point to note is that some of the measurement concerns conceptually fall outside GDP. Many aspects of the digital economy, such as 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 generally only products and services that consumers pay for are currently included. GDP does not include the consumer surplus (or unpaid-for benefits) from digital products.

Table 1 provides more details on some of these issues. Note that digital products such as computers and other IT products appear on both the output and the input side of the productivity ratio. This means that, for multifactor productivity, mismeasurement of IT products has offsetting effects. While much of the table relates to digital products as outputs, many of the same issues apply to digital products as inputs.

Mismeasurement is unlikely to explain the productivity slowdown

A number of studies have estimated the role of mismeasurement in the global productivity slowdown. Many of these studies have focused on the United States (see, for example, Syverson, 2016; Byrne, Fernald and Reinsdorf, 2016), but some have considered productivity mismeasurement in other OECD countries (see, for example, Ahmad and Schreyer, 2016; Ahmad, Ribarsky and Reinsdorf,

Table 1: Challenges for productivity measurement arising from the digital economy

Issue	Examples	Estimates of scale of effect	Potential remedies
Prices and quality – new and improved digital technologies may not be fully identified, 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	· Estimates range from around 0.2 to 0.7 percentage points pa of GDP growth across countries · Substantial variation in countries' treatment of ICT price movements · Effect on MFP somewhat offset by ICT being an input as well as an output	· Improve price and quality adjustment methods
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% pa of GDP), with negligible impacts on GDP growth rates	· Improve price and quality adjustment methods · Supplement with other measures
Free assets produced by households – free 'public goods' which use volunteer labour are not captured in GDP (so productivity may be *under*-stated)	· Wikipedia · Linux	· Wikipedia – up to 0.1% 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 (so productivity may be *under*-stated). Assets such as vehicles are not fully captured in the capital stock (so MFP may be *over*-stated)	· UberPop · AirBnB · E-Bay	· 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 (so productivity may be *under*-stated)	· On-line 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 (so productivity may be *under*-stated); this also affects the capital stock (so MFP may be *over*-stated)	· IP products e.g. R&D and computer software and databases · Knowledge assets e.g. human and organisational capital	· Knowledge assets not included in GDP are typically larger than those that are · Despite this, it is estimated that incorporating intangibles makes little difference	· Reallocate income flows to the country of the parent company (so use Gross National Income rather than GDP) · Carefully interpret cross-country comparisons

Source: drawn from Ahmad and Schreyer, 2016; Ahmad, Ribarsky and Reinsdorf, 2017

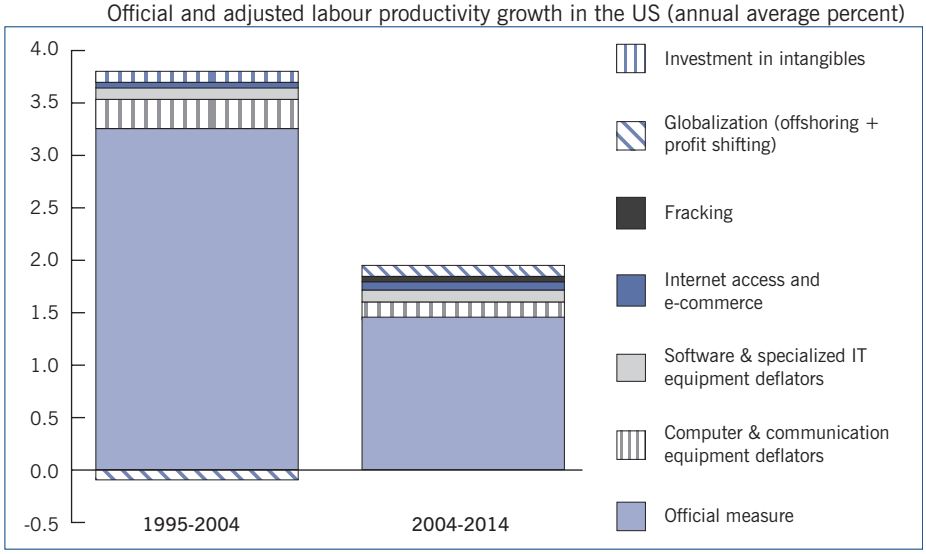
2017). These studies have used different methodologies and data, but their findings are reasonably consistent (Brynjolfsson, Rock and Syverson, 2017). The consensus appears to be that, while mismeasurement can explain some of the slowdown, it probably accounts for only a relatively small proportion (Manyika et al., 2017). This implies that the slowdown is a real effect rather than illusory.

Measuring a measurement problem is challenging. Estimates of productivity mismeasurement vary markedly, and there is considerable uncertainty around the estimates. For example, one US study (Syverson, 2016) reviewed estimates of the unpaid-for gains to consumers from internet access. The author calculated that the lowest of these estimates accounts for a tiny fraction of the productivity slowdown, while the largest accounts for up to one-third of the slowdown.

One highly cited study (Byrne, Fernald and Reinsdorf, 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:

- Mismeasurement of IT hardware was already significant before the slowdown. Because the 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 multifactor productivity (as IT appears as both an input and an output in

Figure 2: Accounting for mismeasurement doesn't add much
Official and adjusted labour productivity growth in the US (annual average percent)



Sources: Adler et al., 2017, using data drawn from Byrne, Fernald and Reinsdorf, 2016

multifactor productivity, which has offsetting effects).

- Many of the consumer benefits from smartphones, Google searches and Facebook are, conceptually, non-market, and so fall outside the market production measured by GDP.
- Other measurement issues that the authors did quantify are quantitatively small relative to the slowdown.

Figure 2 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 and quality adjustments discussed above.

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 points slowdown in labour productivity growth per year over 2004–14 compared to the preceding decade.

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 potential productivity mismeasurement, 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 other indirect factors do not.

In relation to general measurement issues, Statistics New Zealand 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 relative importance of the digital economy to New Zealand compared with other countries. If the digital economy features comparatively strongly in New Zealand, then it seems plausible that the associated measurement challenges are prominent too.

Assessing the importance of the digital economy is not an easy task, as there are numerous definitional issues (see OECD, 2017a). However, the OECD's most recent digital economy outlook report (OECD, 2017b) 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 roll-out of broadband. The significance of the digital economy to New Zealand tentatively suggests that the associated productivity measurement challenges may be comparatively significant too.

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. Australia is included in some comparative studies about distinguishing between price and quality changes – a factor that is assessed as quantitatively the largest contributor to productivity mismeasurement. For example, Ahmad, Ribarsky and Reinsdorf (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 most of the countries included in the analysis (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.

Conclusions and policy implications

Robert Solow's comment that the computer age can be seen everywhere but in the productivity statistics seems as relevant today as when the comment was made 30 years ago. Growth in the digital economy creates opportunities and challenges for productivity and its measurement.

The adoption of new digital technologies provides an opportunity for New Zealand to lift our productivity performance. From a policy perspective, the key issue is how best to capitalise on this opportunity, and how to ensure a smooth transition path.

The digital economy has many benefits to New Zealanders that fall outside conventional productivity measurement. The key issue here is how best to measure these benefits. Statistics New Zealand and the Ministry of Business, Innovation and

Employment are currently developing a Digital Nation Domain Plan, which should provide an opportunity to do this. This domain plan identifies enduring questions about New Zealand's digital transformation, and any gaps in the data that need to be filled to address these questions. The enduring questions include some about the impact of New Zealanders' engagement in digital technologies (Statistics New Zealand, 2018), and so potentially could cover the unpaid-for benefits from digital products.

The digital economy creates challenges for productivity measurement. Mismeasurement is estimated to have played a fairly minor role in the global productivity slowdown. However, mismeasurement is likely to be growing. This means that productivity growth rates need to be interpreted with care, and that our ability to analyse productivity trends over time is hampered. Stable mismeasurement of productivity levels would be less of a worry.

It is important to continually improve the measurement of productivity. Improving methods for making adjustments for price and quality changes to outputs (and inputs) appears to be particularly important. Developments that Statistics New Zealand has planned or underway include the greater use of transaction or scanner data, administrative data and web-scraped data in measuring price and quality changes (Bentley and Krsinich, 2017). These types of data are valuable for their richness and timeliness, and – compared with surveys – reduced respondent burden.

The digital economy is therefore itself part of the measurement solution. The use of administrative and other 'big' data provides opportunities to capture new types of transactions (ibid.). One example is to use big data to transform hedonic or regression-based methods (ibid.). Hedonic price adjustment essentially 'unbundles' the contribution to prices of different characteristics of a product.

Overall, productivity measures play a unique role in our understanding of the economy: they tell us about how efficiently New Zealand's resources are being used. Despite the challenges the digital economy poses for measurement, for the most part productivity measures still appear to capture 'true' productivity, and to broadly reflect the underlying concepts they are targeting.

1 'Digital economy' means an economy that is based on digital computing technologies.

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