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On productivity:
concepts and measurement

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The Productivity Commission

The Productivity Commission is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. Its role, expressed most simply, is to help governments make better policies, in the long term interest of the Australian community.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by concern for the wellbeing of the community as a whole.

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On productivity: concepts and measurement

Productivity growth is frequently lauded by the business community, media commentators and politicians as the solution to improving living standards, yet there is little agreement on what productivity actually is. To some people productivity growth comes from working harder and longer (unpaid) hours, to others it is the return from investing more in capital (such as infrastructure and education investment). Productivity has also been equated to ‘working smarter’, but exactly what this implies is rarely defined.

To economists, productivity is the efficiency with which firms, organisations, industry, and the economy as a whole, convert inputs (labour, capital, and raw materials) into output. Productivity grows when output grows faster than inputs, which makes the existing inputs more productively efficient. Productivity does not reflect how much we value the outputs — it only measures how efficiently we use our resources to produce them. Putting aside the problem of ensuring we produce what people want to consume,¹ productivity growth is a good way of improving living standards. But how can firms and the economy more generally produce more with less? Moreover, are the productivity statistics — which have told a fairly gloomy tale in recent years (figure 1) — a good guide to how well we are doing on this front?² This note aims to shed light on these two issues.

What drives productivity growth?

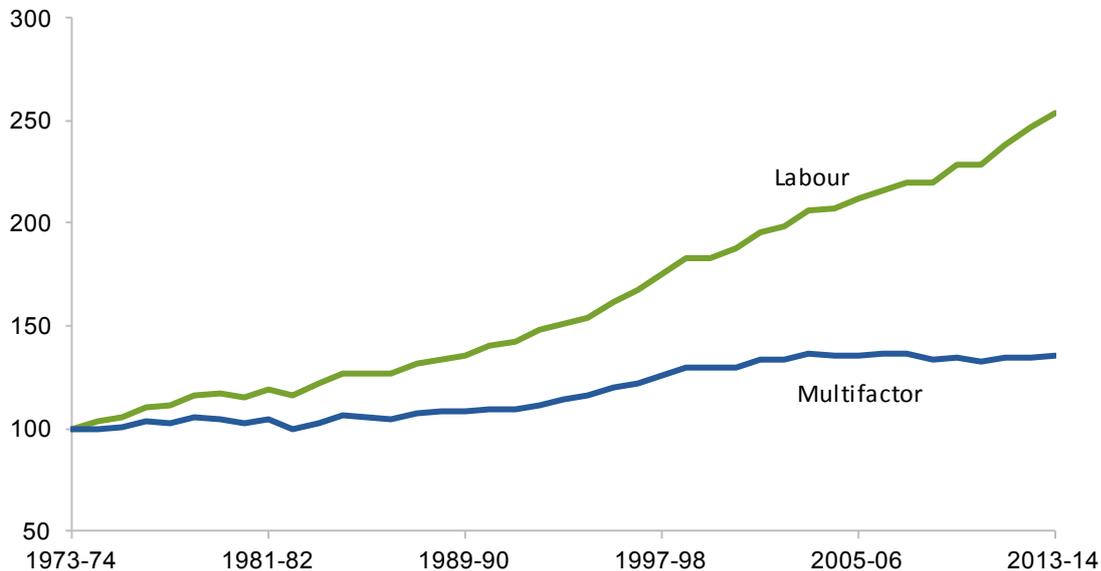
Productivity growth comes from:

- growth in the productive potential of an economy, that is, the maximum level of output that can be produced given available labour, capital, resource endowments and current technologies; and
- how quickly the economy is moving to this potential (box 1).

¹ Government needs to worry about whether the economy produces what people want (allocative efficiency) as much as it does about productivity growth. A well-functioning market delivers allocative efficiency, which is why in market economies the focus is often on what can be done to promote productivity growth.

² Official measures of productivity are about production of goods and services on the record of market transactions. Productivity improvement in something that is not marketable or does not have a market value may not be recorded in the official statistics, but it still can improve living standards.

Figure 1 Trends in productivity growth
1973-74 to 2013-14



Sources: ABS (*Estimates of Industry Multifactor Productivity, 2013-14*, Cat. no. 5260.0.55.002, December 2014); Commission estimates.

Economies that are well below their productive potential can experience rapid productivity growth as they catch-up to their potential. The rapid growth of the Asian ‘tiger’ economies of Japan, South Korea, Taiwan, and Singapore illustrates how fast economies can grow once they were exposed to international competition after barriers to trade and efficient investment are removed.³ Australia’s rapid productivity growth in the 1990s was in large part a product of competition and trade reforms that created incentives for firms to reach their potential.

Economies that are close to their productive potential have to rely mainly on on-going technological and organisational change — producing new and improved products or more efficiently organising production — to drive growth in productivity. This is why, as the Asian tigers caught up to the developed economies, their economic growth slowed. The challenge for Australia, along with other developed economies, is to push out the productivity frontier, and to resist falling behind their potential.

Microeconomic reform plays an important role when it removes barriers to firms realising their productive potential. Competition reform can contribute to firm-level innovation (technological and organisational change) through improving the incentives for change. While government can support innovation by creating an environment for efficient investment in education, infrastructure, and research and development (R&D), a

³ Capital markets reforms that allowed foreign investment also played an important role.

productivity growth agenda must include what drives both firm-level productivity and productivity at the level of the economy.

Box 1 Two sources of growth in productivity

There are two ways in which productivity can grow. The first is where the economy is not operating at full productive efficiency (represented by point A in figure A, which is inside the production possibility frontier (PPF)). Productivity rises if the economy moves from A inside the frontier to B which is on the frontier. This improves welfare as the population can move to a higher consumption (indifference) curve. For example, the 1990 National Competition Policy reforms drove large parts of the utilities sector closer to their PPF, resulting in an estimated 2.5 per cent rise in real gross domestic product (PC 2005).

It is important to note that not all combinations of output that maximise production are preferred (that is, efficient from an allocative perspective). Assuming a closed economy, so consumption equals production, moving from A to C, while more productively efficient, would lower welfare as people would prefer to consume relatively more of good Y than good X than is produced at point C.

The second way that productivity can grow is through a rise in potential (and actual) production (an outward shift in the PPF). For example, the growth in information and communication technology in the 1990s contributed to growth in GDP not just because of additional investment, but because this investment promoted a faster growth in output (PC 2004). Technological progress increased the potential output that could be produced using the current level of resources, and adoption of the new technologies enabled output and hence consumption to increase (from B to D in figure B).

Figure A

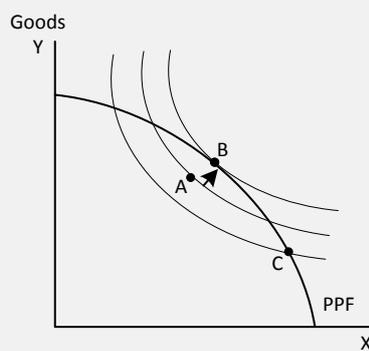
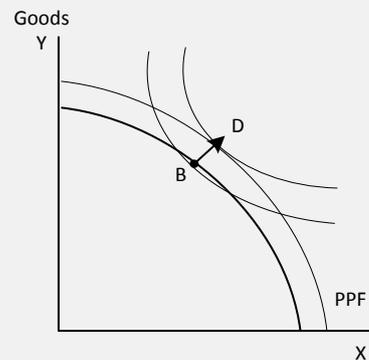


Figure B



Productivity at the firm level

The generation and application of technological and organisational knowledge (innovation) are the main drivers of firm-level productivity growth. These determinants are broader than technology in an engineering sense. The choice of production technology and how production is organised, which are management decisions, play a crucial role in productivity performance.

Firms can improve their *productive efficiency* in three ways:

- **Improvements in technical efficiency** — increases in output can be achieved, at a given level of input, from more efficient use of the existing technologies. This is what working smarter is all about — using resources more efficiently. An improvement in technical efficiency is about moving towards the production possibility frontier (PPF) (that is, the movement from A to B in box 1).
- **Technological progress and organisational change** — as firms adopt technologies or organisational structures that are new to the firm, or develop and apply new technologies or approaches, they can expand output by more than any additional inputs that might be required. This is about an outward shift of PPF — a change in maximum capability afforded by technological change that enables the firm to produce more output with less inputs. (This is represented by the movement from B to D in box 1). Technological progress can be embodied in capital and in labour, or disembodied (box 2).
- **Increasing returns to scale** — as the size of the firm expands, its unit cost of production can fall (Diewert and Fox 2008). This comes about as most technology has a minimum efficient scale and many have falling average costs as volume increases up to some limit. An increase in market size can increase utilisation rates and may also allow a firm to move to a different technology or organisation that has a lower unit cost of production (Sheng et al. 2014).

Box 2 **Types of technological progress**

There are three main types of inputs to technological and organisational change.

- Advances in scientific knowledge acquired and accumulated through research and development, discovery by doing, and observing others, enables producers to manage production more efficiently (such as superior management practices and system design). This type of knowledge is sometimes referred to as *disembodied technology*.
- Improved technology that is intrinsic to capital inputs (such as more powerful machinery, faster computers, and safer and more energy efficient offices), enhances the efficiency of new capital investment. It is often referred to as *capital embodied technology*.
- Enhanced individual capabilities to acquire and apply technological, organisational, and market knowledge, can be applied to business decisions and production processes to improve business outcomes. These knowledge-based capabilities form part of *human capital* (the other main parts being health and other attributes that enhance humans' productive capability).

The magic of productivity enhancing technological and organisational change is that although it takes effort — time and money are necessary to achieve change — the pay-off exceeds the cost (box 3).

Box 3 Sources of growth in productive efficiency

The application of knowledge is at the heart of productivity growth.

- Knowledge is non-rival in consumption, so once generated it can be used by others at no or relatively little cost (Dowrick 2004). The contribution of knowledge (or ideas) and human capital to economic growth sparked the development of 'endogenous growth models', which explain a 'virtuous' cycle of investment in R&D and growth, which in turn funds R&D (for example, Romer 1986; 1990).
- Knowledge can be serendipitous, with ideas seeming to come from nowhere, or acquired at low cost through learning by doing (Arrow 1962).
- Knowledge embodied in labour is complementary to that embodied in capital. Lucas (1988) captured this 'complementarity' between investment in knowledge and human capital in his endogenous growth model.

How cost-effectively investments in education, R&D, and creative activity are translated into new knowledge and ideas, and in turn into technological or organisational innovations, is critical to productivity growth. Both the speed of the innovation process (whether producing new or improved goods and services, introducing improvements in production processes, adopting organisational and managerial changes, or adjusting to market demands) and the magnitude of complementarities between human capital formation and capital investment play a critical role.

To the extent that the market is not constrained by regulation or other factors, firms will tend to maximise productive efficiency in order to maximise their profits. That is, given the size of the market, the cost of different inputs, and available technologies, the firm could not produce more outputs given the inputs available. Competition reinforces the profit incentive to minimise the cost of production, but even a monopolist driven by profits will aim to be productively efficient.⁴ Competition plays an even more important role in productivity at the level of the economy through a process of firm entry and exit (or growth and contraction) that has been called *competitive dynamics*.

Productivity at the national level

Improvements in firm level productivity translate directly into national economic growth, but productivity growth in the economy can exceed that of the individual firms. This is because competition favours firms that are more productive, and so these firms' market share expands, while that of less productive firms contracts. In the process, the average level of productivity is increased (box 4). This process of competitive dynamics is important for keeping the economy close to its production possibility frontier.⁵ Policies and market behaviour that undermine competition may cause the economy to slip below its potential.

⁴ However, as a monopolist will produce less than is socially optimal in order to drive up prices and profits, their market power erodes the allocative efficiency of the market. They may also have less incentive to upgrade technology to accommodate rising demand, if this erodes the rent on their existing technology.

⁵ It is worth noting that changes in the shares of different industries can also arise in response to changes in relative prices of output, which is a movement along the economy's PPF. The extent to which the relative price of output of less productive industries rises (due for example to a shift in preferences or change in

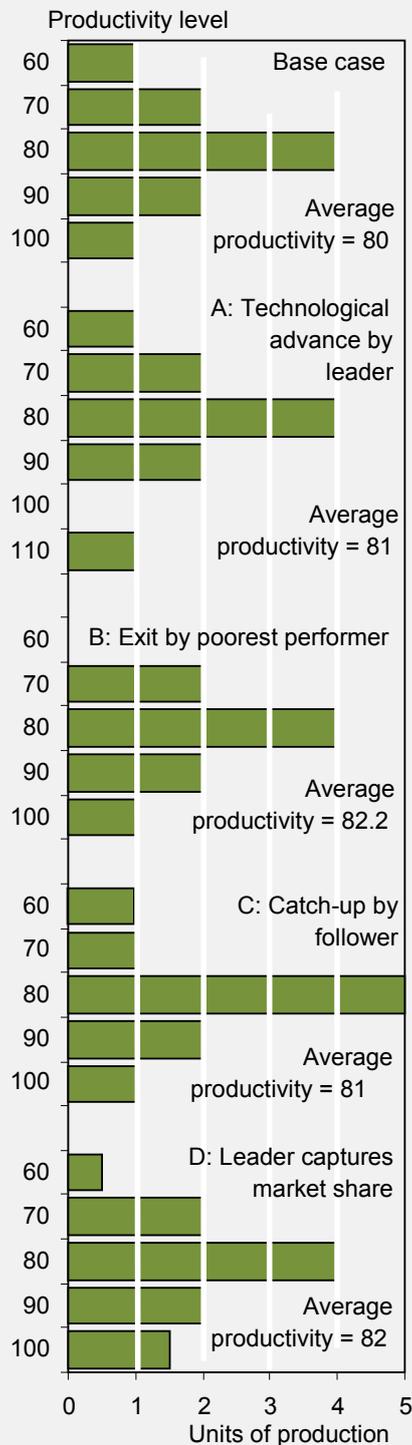
Box 4

Multiple mechanisms for industry productivity growth: a hypothetical example

An industry initially comprises 10 businesses with productivity levels ranging from 60 to 100. The organisations are initially assumed to be the same size. Average productivity is 80.

Average industry productivity will improve (all else equal) in the following situations:

- Case A — a productivity improvement (for example, technological advance) by the leading business raises average productivity to 81.
- Case B — the exit of the least-productive business raises average productivity of the industry (now 9 businesses) to 82.2.
- Case C — a productivity improvement (for example, the diffusion of an existing technology) for a follower organisation that raised its productivity level from 70 to 80, increasing industry productivity to 81.
- Case D — the leading organisation (productivity 100) captures half the market share of the least-productive organisation (productivity 60), raising average productivity to 82.



Source: Adapted from PC (2009)

the terms of trade), the measured level of productivity in the economy will fall (compared to no shift in relative prices), although the economy is still on its PPF.

Competitive dynamics differ from the process of *creative destruction*, a term coined by Schumpeter (1934) to describe how new, higher quality products and processes drive out old products and processes. Innovations by successful firms tend to eliminate the returns from previous product improvements (by competing firms or indeed their own previous improvements). Competitive dynamics is an important driver of growth at the level of the economy, however the role of competition as a driver of creative destruction is not straightforward (Aghion and Griffith 2008). The effect of competition on the rate of *innovation* in an industry is heavily influenced by the structure of the industry, the dynamic nature of the business environment, and the appetite firms have for risk, which all influence the rewards to a firm of moving first.

There is also potential for *spillovers* between firms that mean productivity improvements can be contagious. That is, the things that firms do benefit other firms as well, through the same kinds of mechanisms that improve productivity within firms (box 3), including:

- sharing of knowledge, as it only needs to be produced once and can be used many times;
- workers learning by doing and transferring technology and creating complementarities when they move to new firms;⁶ and
- economies of scale and scope associated with greater utilisation of infrastructure, and growth in market size that allows firms to adopt more productively efficient technologies.

Proponents of proactive industry policies (such as government support for innovation hubs and clusters) often cite the importance of spillovers as a source of productivity growth.⁷ While in theory positive spillovers are sources of productivity growth, proposals for public expenditure need careful scrutiny to ensure that:

- spillovers are indeed generated
- they are from activity that otherwise would not have occurred (additionality)
- the benefits exceed the public cost, including the deadweight losses associated with raising government revenue.

Output grows with input growth as well as productivity growth

Figure 2 summarises the drivers of output growth, which depends on growth in inputs (second column) as well as improvements in productivity (third column). The fundamental processes that determine the resources available for production (the first column) are:

⁶ For example, Lucas (1988) described how the productivity of a worker is enhanced not only by their own human capital but also by the level of human capital of other workers — private investment in human capital has an external effect.

⁷ See McDougall and Witte (2010) for a summary.

-
- population dynamics, which determines the working age population and, along with participation, the supply of labour;
 - saving and investment, which determines the stock of capital including the stock of human capital and knowledge;
 - natural environmental change, which along with investment made in the natural environment, determines the level of environmental services; and
 - social change, which determines the evolution of institutions and rules, and how they are applied, which shapes the business environment in which firms operate.

While growth in physical inputs is expected to increase output, a doubling of inputs may give a doubling of output. To get more than double the output requires productivity growth. As discussed above, this comes from pushing out the production frontier through:

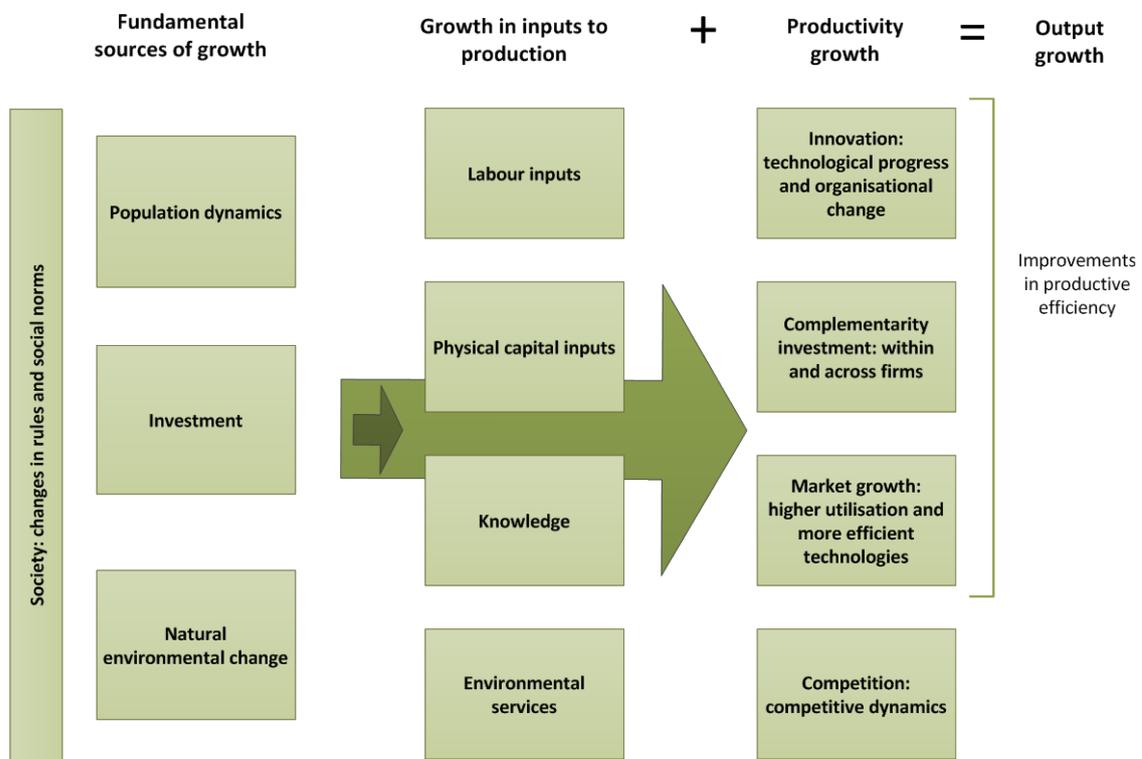
- innovation — new and better products and production processes through technological progress and organisational change;
- complementary investment — harnessing the complementarities between capital and labour and knowledge, and promoting spillovers between firms and between industries; and
- market growth — enabling higher utilisation of fixed capital and adoption of more efficient technologies.

It also comes from competitive dynamics that give firms an incentive to be technically efficient and helps to keep the economy at the frontier of its potential.

While we can measure productivity as the change in output that is not explained by a change in inputs, it is much harder to determine the contribution that each of these sources of productivity improvement make.⁸ At a firm level, examination of changes in production processes, investments in capital and labour, and changes in scale can shed light on the sources of productivity growth for the firm, but at the level of the economy this is much more difficult. This poses a major challenge for policy makers facing pressures to commit taxpayer's money to infrastructure, R&D, innovation precincts and a host of other expenditures that are supposedly 'productivity enhancing'. Measuring productivity is an important part of developing an evidence base that will improve understanding of when these different sources contribute to productivity growth, and whether government policy, beyond promoting the process of competitive dynamics, can make a difference.

⁸ An additional complicating factor can arise when changes in relative prices mean that the industry shares in total output change. If relative prices move in favour of an industry that has lower measured productivity then aggregate productivity can fall even though the shift of resources to the industry with the rise in relative output price would increase national income. This demonstrates one of the problems with linking productivity growth directly to welfare. Removing price distortions should unambiguously improve welfare, but may or may not improve *measured* productivity.

Figure 2 Sources of output growth and productivity growth



Measuring productivity growth

Measured productivity is the ratio of a measure of total outputs to a measure of inputs used in production of goods and services. Productivity growth is estimated by subtracting the growth in inputs from the growth in output — it is the residual.

There are a number of ways to measure productivity (box 5). In Australia, the most common productivity measures used are:

- multifactor productivity (MFP), which measures the growth in value added output per unit of labour and capital input used; and
- labour productivity (LP), which measures the growth in value added output per unit of labour used.

Measures of productivity, and particularly MFP, have been described as estimates of what we do not know about the economy (Solow 1957; Abramovitz 1956). Unpacking the unexplained change in output, to the extent that we can, can add considerable insight into what is happening in the real economy. It is for this reason that the Commission continues to analyse productivity trends for different sectors in the economy, and produces the annual *PC Productivity Update*. This analysis has shed light on some major sources of real

change in the economy — both good and bad. It has also shed light on some major measurement issues, which mean that MFP and LP estimates can at times conceal important information about an industry and its growth. For effective analysis, productivity estimates need to be unpacked to provide a fuller understanding of an industry's productivity performance.

The rest of this note focuses on productivity measurement, how well it captures the concept of productivity, and inherent measurement issues that users of productivity estimates need to be aware of.

Measuring the volume of inputs and outputs

To measure productivity at the level of the economy and industry requires estimating the volume of output and the volume of one or more inputs. This involves several steps.

- As data on output and most inputs is mainly available in terms of sales revenue, the data has to be converted from value data to volume data. The influence of changes in price is usually removed through deflating by an appropriate price index.⁹ MFP and LP calculate industry output as real value added (gross production less the value of intermediate inputs) deflated by the relevant price index. The volume of output for the economy is the sum of industry outputs. At the economy level, the ratio of nominal to real value added is called the GDP deflator.
- As output and input quality can change over time, improvements in quality should be quantified and treated as an increase in volume. In practice, statistical agencies are limited in the quality adjustments they can make, and the extent to which these fully adjust for quality is uncertain. There are particular problems in some industries, such as information and communication technology (ICT) and motor vehicles.
- For partial measures of productivity, only a single measure of the relevant input is required. For LP this is the hours of work. However, to calculate MFP, which is a total measure, inputs need to be combined in a total input measure. For MFP, an index of changes in the volume of value adding inputs is calculated using the weighted sum of the indexes of capital and labour inputs, where the weights are given by the factor income shares.¹⁰

⁹ There is a considerable literature on the choice of an appropriate price index, and the choice can significantly affect the estimates of productivity (Griliches 1991). How price changes are estimated, the weights used to construct the price index, and the method by which it is constructed are all relevant.

¹⁰ This definition is consistent with the *Growth Accounting Method* which is used by ABS (and other official agencies) in the compilation of productivity estimates and it is used throughout this document. Under assumptions of constant returns to scale and perfect competition income shares of capital and labour are used as weights to add capital and labour to get an input index. If the assumption is not valid, factor cost shares should be used.

Box 5 Growth accounting and productivity measures

Productivity measures are derived from the Swan-Solow growth model, where output growth was explained by input growth and a residual. An example is a Cobb-Douglas production function, where output (Y) is a function of capital (K) and labour (L) inputs, and there is constant returns to scale. Output growth (indicated by a dot over the variable) is a function of the growth in inputs. The residual can be interpreted as disembodied technological progress (A) and any measurement error in capital or labour inputs.

$$Y = AK^{\alpha}L^{(1-\alpha)}$$

$$\dot{Y} = \alpha\dot{K} + (1 - \alpha)\dot{L} + \dot{A}$$

Growth of multifactor productivity (MFP) is calculated as \dot{A} . In this formulation, output is the value added by the capital and labour used in production. That is, it is the volume equivalent of the value of all final sales of the industry less the intermediate inputs used in production.

An alternative approach is to estimate total factor productivity (TFP). This recognises that intermediate inputs (T) are used in production along with capital and labour. Hence, it uses a gross output measure (G), and includes intermediate inputs as a factor of production.

$$G = (Y + T) = AK^{\alpha}L^{\beta}T^{\gamma}$$

$$\dot{G} = \alpha\dot{K} + \beta\dot{L} + \gamma\dot{T} + \dot{A}$$

$$\alpha + \beta + \gamma = 1$$

TFP and MFP are conceptually similar, but numerical differences can arise because of the way that intermediate inputs are measured for estimating industry value added and as an input index for calculating TFP. The ABS produces MFP estimates regularly, but are exploring measures of TFP by measuring, in addition to capital and labour, energy (E), materials (M) and services (S). This is known as the KLEMS method.

The calculation of MFP using the traditional accounting methods requires independent measures of inputs and outputs. For Australia, this can only be calculated for 16 industries, which the ABS terms the market sector of the economy.¹¹ For the remaining industries (the ‘non-market’ sector) the value of output is estimated as the sum of the cost of inputs where other output measures are not available. This precludes using the traditional accounting method for measuring changes in industry productivity. Hence, economy-wide MFP estimates reflect productivity growth in only the market sector part of the economy (the 16 industries account for around 80 per cent of GDP).

¹¹ The 16 industry market sector includes Agriculture, forestry & fishing, Mining, Manufacturing, Electricity, gas water and waste services, Construction, Wholesale trade, Retail trade, Accommodation and food services, Transport, post and warehousing, Information, media and telecommunication, Financial and insurance services, Arts and recreation services, Rental, hiring and real estate services, Professional, scientific and technical services, Administrative and support services and Other services.

LP can be measured for both the market and non-market sectors of the economy.¹² This is because labour input can be measured in real volume terms as hours worked (the ratio of value added to hours worked also is relatively easy to understand). As the residual, LP growth measures the contribution to output growth of all factors other than the growth in labour input. It is important to note that both growth in capital and growth in MFP contribute to LP growth (box 6). Indeed, Paul Krugman's comment that the Asian economic miracle was mainly due to capital growth reflects the value added when capital is added to a large underutilised workforce, as well as the complementary nature of this capital to the labour supply available (Krugman 1994).

Box 6 Labour productivity and capital deepening

LP growth is the result of growth in MFP and growth in capital relative to labour (capital deepening). Capital deepening increases output when it increases the productivity of labour — capital is complementary to labour. But the productive benefit of adding more capital diminishes as more capital is added to a fixed stock of labour (and vice versa).

A classic example is the input of five men hired to use one shovel to produce the output of holes dug. Adding a second shovel will come close to doubling the number of holes dug, but as a third and fourth shovel are added the rate at which new holes are dug will decline as rest time between digging is still needed. The fifth shovel will add the least additional holes dug, and a sixth shovel is likely to only add to output through reducing downtime if one of the other shovels fails (that is, through the provision of optimal reserve plant margin). After the fifth shovel, capital deepening may not add materially to output because its impact on labour's marginal product approaches zero.

Thus, changes in LP are partly driven by changes in MFP and partly by changes in the capital to labour ratio (capital deepening/shallowing).

There is usually some ratio of capital to labour after which adding more capital (or more labour) is unlikely to deliver any increase in output. But capital deepening should stop well before the marginal gain is zero, as what matters for productivity is gain in output relative to the opportunity cost of adding more of one input. Labour productivity will only rise if the output forgone by investing in an additional unit of capital is smaller than the increase in output from the capital deepening arising from this investment.

MFP is a measure closer to the concept of productive efficiency than LP as it removes the contribution of capital deepening from the residual.¹³ But MFP also captures changes in output that arise from other sources of productivity growth, including changes in the

¹² The problem with measuring output in the non-market sector still remains, and total factor cost is used as a proxy for output in labour productivity estimates for the non-market sector. Independent output measures are made for some aspects of non-market services, such as education (student numbers) and health (measures of diagnosis related group volumes).

¹³ Considerable attention is given in the productivity literature to the extent to which MFP measures technical progress. From a broader perspective, changes that affect productivity are of interest even if they are not due to technical progress. The OECD (2001) offered an alternative definition of productivity that defines productivity growth as real cost savings in production rather than as technical progress.

utilisation of capital. It is also affected by statistical errors in the measurement of inputs and outputs.

Two potential sources of change in measured productivity warrant special attention: unmeasured real cost determinants and capacity utilisation. There are also a number of measurement problems associated with estimating output and input volumes.

Unmeasured inputs affect real costs

In some industries, inputs other than capital and labour (and knowledge) can have a strong influence on output. Where these inputs are not purchased in the market, as is the case with some natural resource inputs and volunteer effort, they are not included in the measure of inputs. If the availability or quality of these inputs is changing then productivity estimates, as the residual, will be affected. These changes in the real cost of production, due to changes in the quality or quantity of these unmeasured inputs, are captured by the productivity measure and reflect real changes in what is produced that can be used for consumption or investment.

The effect on measured productivity depends on:

- the size of the change in the availability and/or quality of these inputs; and
- the share of such unmeasured inputs in the production of the firm or industry.

The greater the share of total inputs and the greater the change in the input, the bigger the effect on productivity growth (Shreyer 2012).

Commission research in recent years has identified Mining, Utilities, and Agriculture as industries where the MFP estimates are affected by changes in unmeasured inputs (the findings are summarised in Topp and Kulys 2012). These industries are all dependent, to different degrees, on natural resource inputs. What is important to note is that deterioration in the quality of the natural resource input, or more stringent regulatory restrictions on the uses of such inputs, can reduce *measured* productivity despite the productive efficiency of the firms in the industry remaining unchanged or even improving. Where this effect occurs new measures can be introduced to indicate changes in productive efficiency. Such measures can complement, but should not replace, standard productivity measures, which focus on the capacity of the economy to produce output.

The contribution of education and skills to labour inputs is another ‘unmeasured’ input. The use of hours worked as a measure of the volume of labour input means that improvements in the quality of labour are reflected in MFP (and LP). In many cases, this is the effect of previous investments in education that are reflected as expenditures at the time and so are not recorded as inputs. Similarly, not all measures of capital inputs are fully adjusted for improvements in the quality of capital, so part of the effects of capital embodied technical change will be reflected in MFP, while part will be captured in the measure of capital input growth and capital deepening. To the extent that capital is fully

adjusted for quality due to embedded technology, MFP will not reflect capital embedded technological progress (box 2).

Changes in measured productivity that are the result of changes in unmeasured real cost determinants (such as natural resources and environmental factors, the quality of labour, and some aspects of the quality of capital) affect business costs. As these changes affect real resource costs and measured real national income, productivity measures that reflect changes in real costs from all sources provide information that is useful to analysts and policy makers.

Capacity utilisation affects annual productivity estimates

Business output responds to market demand. As demand rises or falls over time with the business cycle or other influences, firms adjust the output they produce. Although firms also accumulate, hold, and run down inventories to smooth out production costs, there are costs to holding inventories that limit how much a firm can smooth production. In the case of cyclical downturn, many firms will reduce output volumes, but cannot easily reduce their capital and labour inputs as they need these inputs ready for when demand recovers. As a result, firms are likely to ‘underutilise’ their capital and labour inputs in a downturn and productivity will be lower. When business is booming, firms will fully utilise their capital and labour. Some firms may ‘overuse’ capital (for example, running machines beyond their designed capacity or for longer hours than normal) imposing additional costs (such as shorter life of machines) in the future, which are not taken into account in measures of productivity at that point in time. Hence, measured productivity tends to be pro-cyclical as utilisation rates of inputs rise in upswings and fall in downswings, and overuse costs are possibly deferred to the future.¹⁴

Many industries experience cycles in demand that affect capacity utilisation. However, industries with high levels of fixed capital, such as manufacturing, tend to be more exposed to the business cycle.¹⁵ This means that annual productivity estimates are likely to under or overstate the underlying trend level of productivity depending on where the industry is in the business cycle (Barnes 2011).

To assist users to interpret measured productivity, the ABS divides time series MFP into productivity cycles for the market sector. The start and end points of the cycles correspond to points where the levels of capacity utilisation are likely to be comparable. Average productivity growth between these points is a more reliable measure of productivity growth

¹⁴ In addition to cycles in capacity utilisation Basu and Fernald (2001) suggested that technological progress itself could be pro-cyclical and a range of economic factors (such as increasing returns to scale and imperfect competition in the market) could also reinforce the pro-cyclicality of measured productivity.

¹⁵ Barnes (2011) estimates Australia’s productivity cycles at industry level, finding that only the manufacturing industry has the same cycles as the market sector. Other industries (such as agriculture and mining) display cycles that are clearly driven by different factors.

over a given period than those based on different years in the cycle.¹⁶ Box 7 provides more details about the productivity cycles.

Box 7 Productivity cycles

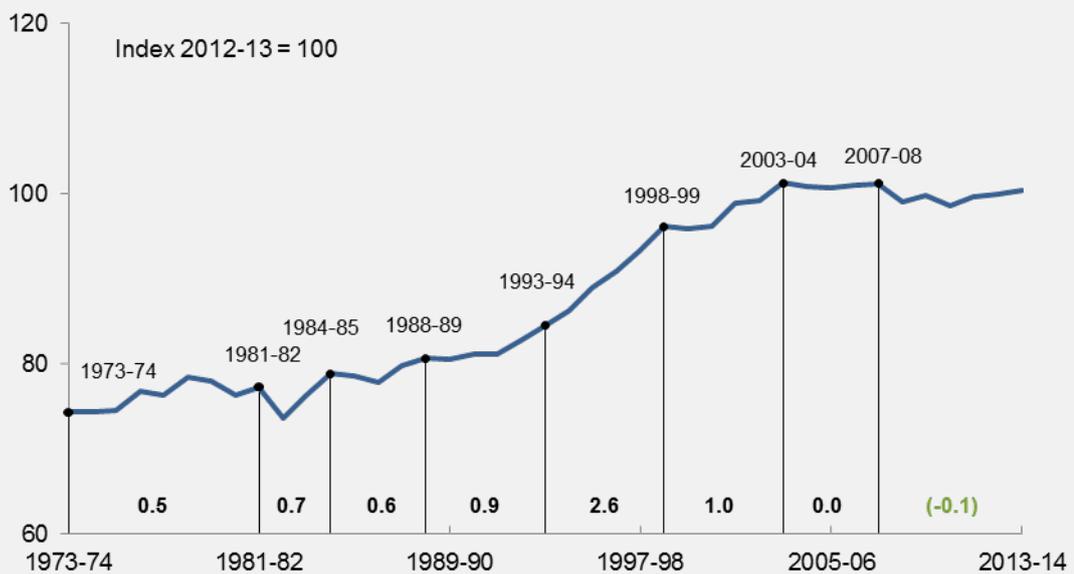
The aim of the ABS in identifying what it calls MFP growth cycles, or peak-to-peak periods, is to provide a more accurate measure of the trend in measured MFP for the market sector. The change in measured MFP from peak to peak is more likely to reflect technological or organisational change than changes in utilisation due to short-run changes in activity levels. The ABS approach to determining MFP growth cycles for the market sector has two stages:

1. the identification of years in which measured MFP peaks in its deviation above the estimated long-term trend; and
2. an assessment of the suitability of the peaks identified in stage 1 for use in growth cycle analysis, by reference to general economic conditions at the time.

The resulting cycles are shown in the following graph for the 12-industry market sector MFP index for the period from 1973-74 to 2013-14.

Over this period, the MFP index can be divided into 7 complete cycles. The current cycle, starting from 2007-08, is not yet complete.

Market sector (12) MFP, 1973-74 to 2013-14, ABS productivity growth cycles (update)



Source: Barnes (2011) Series extended to include 2013-14.

¹⁶ The choice of start and end years for calculating productivity trends can give differing views of underlying trends. Care is needed in the identification, reporting, and interpretation of productivity cycle information. This is particularly so when productivity data is reported in the context of other cycles, such as the electoral cycle.

Some measurement difficulties

Problems in both the accuracy of the raw data and in the methodologies applied generate measurement errors. Improvements in data quality and methodology are a part of the ongoing function of the ABS, resulting in periodic revisions of the estimates of MFP (see, for example, ABS 2011 and ABS 2012b). Recent changes to the system of national accounts, and the industry classification scheme, have shortened the time period for which official industry-level MFP estimates are available (currently 1989-90 to 2011-12).¹⁷ Given that the ABS continues to refine and develop the MFP estimates, future revisions, including to the existing time-series, will occur.

Two problems in measuring inputs that can introduce errors into the estimates of productivity are difficulties in measuring the volume of capital services, and lags between investment (when it is counted as adding to the productive capital stock) and when it is actually utilised in production. These issues arise mainly where there are large infrastructure projects and when major new technology is introduced, such as ICT. Investments in knowledge and in human capital also often take years before they add to productive capacity. Output estimates too can be subject to measurement biases. These tend to be specific to the industry and related to the difficulties in accurately adjusting nominal output estimates using quality-adjusted price indexes. These measurement problems mean that industry productivity statistics need to be analysed carefully to understand the underlying performance of the industry.

Measuring capital services

Capital inputs are the services provided by the capital stock. The capital services index is based on the measured productive stock of capital, which increases with investment, and declines with decay. Growth in capital stock (and hence capital service capacity) occurs when investment exceeds decay.¹⁸

The addition to the capital stock from real investment is typically derived by dividing the nominal values of investment expenditures by the relevant price indexes. While the data for investment expenditures are generally accurate and reliable, the quality of the price index can be problematic. This is partly because of the difficulty in developing reliable price indexes for investments of diverse nature (such as investment in machines, buildings, computer hardware and software, and R&D).

¹⁷ To assess longer run trends in industry productivity and the possible implications for future productivity levels in the economy, the Commission projects industry productivity back to 1974-75 using historical data (PC 2012).

¹⁸ The decay of the productive capital stock used in production is represented by an asset specific age-efficiency profile, which in practice represents the expected decay due to wear and tear and expected obsolescence. The depreciation of the asset is equal to the decline in the asset value implied by the decline in age-efficiency.

While an increase in price may be an effect of general inflation, it may also reflect an improvement in the quality of new capital. The main difficulty in the compilation of the price index lies in separating these two effects — the price index needs to include the effects of pure price inflation but exclude improvements in the quality of the capital inputs. If this is achieved, the changes in the quality of capital inputs will be reflected in its volume measure (expenditure is deflated by the price index) (Smedes 2012).

Box 8 provides an example that illustrates the importance of the quality adjustment of the price index for computer services. The assumptions applied to adjust the accumulated capital stock for depreciation through wear-and-tear and obsolescence, and asset retirement, is also of importance for the estimation of the net capital stock of industries and the nation as a whole.

Box 8 Issues in measuring productive capital: the example of computers

Computers and other ICTs often embody substantial improvements in technical characteristics. For example, there have been significant improvements in memory capacity in different generations of computer. In 2009, average memory of computers on the market was about 2 gigabytes, four years later it was 8 gigabytes.

Technical improvements in computers can be exponential. 'Moore's Law' says that the capacity of semi-conductors doubles every 18 months to 2 years. This implies exponential growth in chip capacity of 35-45 per cent per year.

A true measure of the quantity of capital input produced and purchased makes allowance for the additional characteristics and improved functionalities embodied in new equipment. For example, suppose that a computer purchased today is twice as powerful as a computer purchased two years ago. Today's computer would be two computer-equivalents measured in terms of the old computer's power. Failure to allow for such improvements would understate the accumulation of productive capital available for use in production.

To continue the example, assume that the nominal expenditure on the old and new computer is the same. If a standard equipment price deflator showed a 10 per cent increase in price and was used as the computer price deflator, the real volume of investment in computers would be measured as decreasing by around 10 per cent with the purchase of the new computer. In contrast, a hedonic price index, allowing for technical improvements, would have decreased by around 50 per cent (since twice the computer power is available for the same nominal price). Using a hedonic price deflator would show an approximate doubling in the volume of investment in computers. The volume measure reflects the interpretation of investment in computer power, rather than investment related to expenditure or the number of computers purchased.

Source: Parham, Roberts and Sun (2001).

Lags between investment and utilisation

With large investments, such as major infrastructure projects, there can be several years between the investment and the utilisation of the capital. This means that in the investment year the measured growth in capital services is higher than the actual growth in capital services. This will result in an over estimate of inputs and an under estimate of productivity growth.

Where growth rates are steady over time this measurement issue is not evident as the ‘over count’ of capital remains a constant share of the total capital stock so it does not affect the growth rate in capital services. However, if there is an acceleration or deceleration in the rate of growth of investment, the capital services index will ‘overstate’ the growth in the actual utilisation of capital in production in the case of an acceleration, and ‘understate’ it in the case of a deceleration. The impact on measured productivity can be large. For example, the Commission’s analysis of productivity growth in the mining industry estimated that the average three year lag between investment in mining capital and its utilisation accounted for around one third of the measured decline in mining sector productivity between 2000-01 and 2006-07 (Topp et al. 2008). It is important to note that detecting a capital lag is important in interpreting productivity estimates, but does not imply that productivity is being mismeasured. Indeed, if the new capital investments fail to be fully utilised (for example if commodity prices fall substantially) productivity will remain below the potential.

The difficulty in adjusting output for quality

Quality of outputs has many dimensions which include: design, convenience, and novelty, as well as features such as comfort, durability, and freshness. Many can be valued by consumers but are difficult to take into consideration in measuring output. As with inputs, accurate measurement includes determining whether the observed price rise reflects general inflation or improvements in quality. The latter should be counted as an increase in output, while the former should not. To the extent that quality changes are mismeasured in data series, output will be under or overstated.

A different problem arises where the market price does not fully capture the increase in value to consumers of improvements in quality. This is an unmeasured improvement that unambiguously improves economic welfare for consumers, but will not show up in estimates of nominal GDP. To the extent that it is not practicable to adjust real output measures for such improvements in quality, productivity estimates will understate the growth in productivity of an industry.

Summing up

Measured productivity growth (MFP and LP) reflects a number of influences.

- *Changes in productive efficiency of the economy*, which are mostly due to technological and organisational change, but also come from changes in complementarities, and scale that affect the productivity of firms. It also reflects any change in the average productivity levels of firms due to competitive dynamics.
- *Changes in the real cost of production*, which mainly arise from changes in the quality and/or quantity of unmeasured inputs, most notably natural resource inputs but also other ‘environmental’ inputs. These affect the productive capacity of the economy, but are distinct from the productivity performance of firms.
- *Lags between investment (when an input is measured) and when it is used*, which is an issue for large fixed investments that vary in magnitude over time and take time to be utilised. This will appear in the short run as lower productivity estimates followed by higher productivity growth estimates, provided the capital does become fully utilised.
- *Variations in utilisation of inputs due to economic cycles* tend to average out over the cycle, making measurement in productivity over the cycle a more relevant measure of trend.
- *Errors and discrepancies in the underlying estimates of inputs, outputs and prices* can affect measured productivity in any one year but should not have any systematic bias unless they are due to systematic data gaps (such as improvements in quality not reflected in prices) or limitations.

The last three of these influences affect measured productivity rather than the underlying real productivity growth, and can be addressed by taking either a long-term measure of trend, adjusting for any known temporary effect, or addressing the relevant systematic data problem. It is also possible to include natural resources (or other ‘environmental’ inputs) in productivity analysis. Such inclusion is warranted if the aim is to estimate changes in the productive efficiency of an industry, but not if the productivity estimates are used to measure the productive capacity/potential of the economy.

The key point is that it is important to unpack measures of productivity to understand the proximate and underlying factors affecting productivity growth. The Commission’s studies on Mining (Topp et al. 2008), Utilities (Topp and Kulys 2012), and Manufacturing industry (Barnes et al. 2013) unpacked what was going on behind observed changes in productivity growth giving insight into the real performance of an industry. The Commission’s program of examining industry MFP performance in detail continues with an examination of the Finance, insurance, and superannuation industry (forthcoming).

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