On Productivity: The Influence of Natural Resource Inputs

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Abstract

The production function underlying standard estimates of multifactor productivity (MFP) typically restricts the list of explicitly measured inputs to capital, labour and intermediate inputs (energy, materials and services). These inputs are measured in the national accounts, and in most industries are the most important or significant inputs to production. All other influences on output are captured by the MFP 'residual.'

However in some industries – mining, agriculture, and utilities – output can also depend significantly on unmeasured inputs of natural resources. Rainfall in agriculture is an obvious example, but so too is the issue of mineral resource deposits in the mining sector, particularly where mining is a mature industry and the richest and most accessible deposits have already been developed.

In this article we attribute a substantial part of recent large negative changes in MFP growth in the mining, agriculture and utilities industries in Australia to unmeasured natural resource input changes. As MFP growth estimates derived from the application of the usual production function are generally interpreted as measuring improvements in the 'technology' used to convert standard inputs into output, where there are significant changes in natural resource dependent industries this interpretation of MFP needs to be adjusted.

Multifactor productivity (MFP), which is measured as a residual (the growth in the volume of output not explained by the growth in the volume of labour and capital inputs), reflects other sources of change in the productive capacity of an industry or economy as well as technical change. This article looks at the effect of one of these other possible sources of change, namely natural resource inputs.

Many natural resource inputs are not directly measured in the national accounts, yet changes in their use in production or changes in their quality can affect measured value added and hence MFP estimates. In recent years, there have been sustained periods of strongly negative MFP growth in three important Australian industries – mining, agriculture, forestry and fishing (AFF or agriculture for short), and utilities (electricity, gas, water and waste services) (Chart 1). Changes in natural resource inputs appear to have been a major contributor. This article draws heavily on two research studies undertaken by the Australian Productivity Commission that looked at the productivity performance of the mining industry

1 The authors are economists at the Australian Productivity Commission (APC). An earlier version of this article was released as an APC working paper (Topp and Kulys, 2013). The APC 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 well-being of the community as a whole. Further information is available at www.pc.gov.au. Emails: vtopp@pc.gov.au; tkulys@pc.gov.au.

(Topp *et al.*, 2008) and the utilities industry (Topp and Kulys, 2012).

For natural resource inputs to affect MFP growth in an industry they must be changing, and they must be a significant input for the industry. That is, the production of output must depend on the availability and/or quality of the resource input. The most straightforward example of industry reliance on a natural resource input is rainfall in AFF. Rainfall is *not* included in the measures of inputs to production when MFP is estimated for this industry although changes in rainfall have a direct influence on agricultural output each year. As a result, rainfall variability shows up as variability of output and hence measured MFP, rather than as variability in the total quantity of inputs used. MFP growth in AFF was negative at times during the last decade or so, not because farmers became less *technically efficient*, but because it did not rain as much.

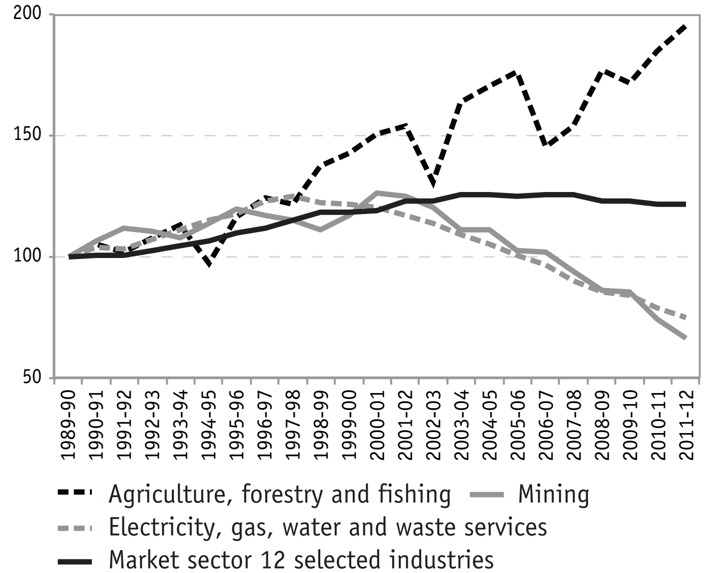
Recent periods of slow or negative MFP growth in all three industries mentioned can be attributed, at least in part, to large reductions in the quantities (or qualities) of natural resource inputs being used in production. If the quality or quantity of unmeasured inputs is declining over time relative to measured inputs, estimates of MFP growth will understate technical progress. Conversely, if the relative quality or quantity of natural resource inputs increases, estimates of MFP growth will overstate technical progress, giving an impression that an industry has achieved greater technical progress than is actually the case.

Declines in MFP growth that are the result of a decline in the availability or quality of a natural resource input do, however, reflect a real

Chart 1

Multifactor Productivity Growth in Australia[a]

Indexes (1985-86=100)



a The MFP estimates are based on value added rather than gross output (see Box 1). The market sector consists of 12 selected industries (ANZSIC06 Divisions A to K and R).

Source: ABS 2012b.

increase in the costs of production.[2] Hence, while this decline in MFP does not reflect technical regress, it does reflect a decline in the output that can be produced by the economy (all else equal). This can be interpreted as a loss in productivity that is not caused by a loss in productive efficiency. Rather it is caused by a decline in natural resource inputs.

There are three main reasons why the quality or quantity of natural resources available as inputs to production can change: natural variability;[3] depletion through use or natural processes; and diversion to competing uses.

2 Note that measures of productivity do not provide any information about allocative efficiency – whether the allocation of resources to production is optimal in terms of maximising national income. Productivity focuses only on the supply side – the production of goods and services – and not on whether these are the goods and services that best meet demand. Since welfare depends on price effects as well as volume changes, the use of MFP as an indicator of welfare or broader economic health has obvious limitations.

3 Natural variability is often temporary, but can reflect long-term trends. Moreover variability in unmeasured resource inputs can be positive as well as negative – for example, a sustained period of higher than average rainfall provides an effective increase in the quantity of unmeasured natural resource inputs used in agriculture, and this would generally have a positive effect on conventional measures of MFP for this industry.

Box 1 Multifactor Productivity Growth Measurement

The Australian Bureau of Statistics (ABS) generates estimates of industry MFP using a conventional growth accounting framework outlined in ABS (2007, 2012a) and Zheng (2005), and recommended by the OECD (2001). Underlying the approach is an assumed production function:

$$Y_t = A_t f(K_t, L_t, I_t) \quad (1)$$

where Y_t, K_t, L_t, and I_t represent output, capital, labour, and intermediate inputs (energy, materials and services inputs) in year t respectively, and A_t represents multifactor productivity in year t.

After differentiating equation (1) with respect to time and making a number of assumptions regarding the underlying production function, f, the ABS derives an index of MFP growth that is calculated from the equation:

$$ln\left(\frac{A_t}{A_{t-1}}\right) = ln\left(\frac{Y_t}{Y_{t-1}}\right) - S_K ln\left(\frac{K_t}{K_{t-1}}\right) - S_L ln\left(\frac{L_t}{L_{t-1}}\right) - S_I ln\left(\frac{I_t}{I_{t-1}}\right) \quad (2)$$

where Y, K, L and I are as above, and S_K, S_L, and S_I are weights used for each input type reflecting their contributions to total industry income (and which collectively sum to 1).

MFP growth is thereby calculated as a residual, and reflects that part of the change in output from one year to the next that cannot be explained by the observed change in inputs.

When MFP growth is negative, it implies a decline in the efficiency of production – that is, an increase in the overall quantity of inputs is required to produce each unit of output – and vice versa.

The ABS also produces an alternative measure of MFP which uses real value added (real gross output minus real intermediate inputs) as the output variable, with only labour and capital inputs appearing explicitly in the production function as inputs. The findings reported in this article are general and applicable to both measures of MFP.

Whether any of these have a material impact on MFP estimates is dependent on the particular situation. The three industries provide some good examples of the contingent nature of this issue.

This article explores these issues in more detail, beginning with why, when there are significant natural resource inputs, the methodology used by the Australian Bureau of Statistics (ABS) to estimate MFP growth can be an inaccurate measure of technical progress. The following sections examine the role of natural resource inputs in the three industries and why they are changing, and the effect that these changes have had on measured productivity growth in these industries. The final section explores possible implications for productivity measurement.

How MFP is Measured

The ABS uses what is commonly known as the 'growth-accounting' approach to derive estimates of MFP. Under this approach, the annual rate of MFP growth is measured as a residual — that is, it is the difference between the growth rate of output and the growth rate of (measured) inputs. Both output and inputs are measured in volume or quantity terms, and are represented using index numbers. (Box 1 contains more information on the growth accounting approach.)

The standard interpretation of MFP growth is that it captures *disembodied technological progress*, such as improvements in the way businesses organize their production processes that allow them to reduce input requirements per unit of output, or to produce a greater quantity of output from a given quantity of inputs (ABS 2012a:429). In practice, however, the conventional growth accounting estimates of MFP reflect the combined influence of any number of factors that might lead to a difference between measured output growth and measured input growth during a particular year or period. According to the OECD, many factors other than technology are reflected in the MFP residual, including adjustment costs, scale and cyclical effects, pure changes in efficiency, and measurement errors (OECD 2001:20).

The Problem of Unmeasured Inputs When Measuring Technical Progress

To the extent that some important natural resource inputs are either mismeasured or not measured at all before estimates of MFP growth are calculated, greater caution is needed in interpreting changes in MFP as measuring 'technical progress'.

In this case, better estimates of technical progress could be obtained by directly accounting for any changes in the quantities of natural resource inputs used in production before the productivity residual is calculated. This would remove the influence of fluctuations in these inputs from the residual so that it would better reflect technical change (although other sources of change would still be reflected in the residual). A more formal description of such a process is outlined in Box 2.

An adjustment such as this would make the resulting MFP estimates better indicators of technical progress, but the trade-off would be that they no longer accurately reflect 'real costs.' That is, they would no longer indicate changes in the average quantities of *purchased* inputs (capital, labour and intermediate inputs) used to produce each unit of industry output.

The Scope of the Effect

As mentioned, natural resource input quantity and/or quality can change through natural variability, depletion through use or natural processes, and diversion to competing uses. Both non-renewable resources (such a mineral deposits) and renewable natural resources (such as fisheries) can have natural variability. Both can also be depleted by use, but for renewable resources this can be prevented if the resource is used at sustainable levels. Non-renewable resources, on the other hand, by definition will be depleted, although the impact on the quantity and quality of remaining resources available to industry will depend on the rate of discovery relative to use.

Regardless of whether a resource is renewable or not, the use by industry can be restricted if the resource is diverted to other uses. At an economy-wide level this affects productivity mainly if it reduces their use in the market economy.[4] Where there are competing non-market uses of the inputs, the main source of change is when governments introduce (or increase) restrictions on the use of the resource by industry.

Examples of the natural resource inputs that are important to production in each of the three industries are provided below. While all of these inputs are similar in the sense that they are 'unmeasured' inputs to production in the respective industries, they are quite different in regard to the reasons why their use in production can change over time.

Agriculture, Forestry and Fishing

Rainfall is an important unmeasured input to production for most, if not all, activities in this industry. Although rainfall is a renewable input, its quality or effectiveness as an input

4 If a resource is diverted to another industry, then one industry's loss is another's gain and productivity is only affected to the extent that the use of the resource in the industries makes a different contribution to the overall volume of production.

Box 2 MFP Growth Estimates When Resource Inputs are Significant

For industries that use significant quantities of natural resource inputs in production a more realistic production function would be:

$$Y_t = A_t f(K_t, L_t, I_t, R_t) \tag{3}$$

where Y_t, K_t, L_t, I_t and A_t are as defined in Box 1, and R represents the volume of inputs of natural resources and/or environmental services used in production. An index of MFP growth would be derived as:

$$.ln\left(\frac{A_t}{A_{t-1}}\right) = ln\left(\frac{Y_t}{Y_{t-1}}\right) - S_K ln\left(\frac{K_t}{K_{t-1}}\right) - S_L ln\left(\frac{L_t}{L_{t-1}}\right) - S_I ln\left(\frac{I_t}{I_{t-1}}\right) - S_R ln\left(\frac{R_t}{R_{t-1}}\right) \tag{4}$$

where Y, K, L, I and S_K, S_L, and S_I are as defined in Box 1, and S_R is a weight commensurate to the contribution of these inputs to total industry income.

In principle, the MFP growth estimates derived from equation 4 would better reflect "true" technical progress in industries where inputs of R make up a significant share of total inputs, compared with the estimates from equation 2 in Box 1.

Note that the measurement issue of concern is not just whether inputs of R are large relative to conventionally measured inputs, but whether they are both large and changing over time relative to aggregate inputs of K, L and I. If inputs of R are constant over time as a share of total inputs, then omitting R from the production function will not influence the estimated growth rate of MFP. In this case, there are no implications for the measurement and interpretation of MFP growth. However, when quantities of R are changing over time relative to conventionally measured inputs, the MFP growth estimates derived from equation (4) will differ from those derived from equation (2) in Box 1. In this case, equation (4) is a better estimate of technical progress than equation (2).

Note also that measuring the quantity of natural resource inputs, R_t, used in production (and the associated weight, S_R) is likely to be a non-trivial exercise. Diewert (2001), for example, listed the problem of accounting for natural resource inputs as one of a number of challenges for productivity measurement and interpretation that is still to be resolved.

A simple illustrative example of how the quantity of natural resource inputs might be measured in practice is to consider the case of agriculture, where R_t might be proxied by annual rainfall (noting that variability in other seasonal conditions also influences annual variability in production). Estimating the corresponding contribution of rainfall to industry income (S_R) is more complicated and is not attempted here. We note, however, that in the standard growth accounting model S_R is effectively captured within S_K, as the latter is derived as a residual and thereby reflects the (percentage) contribution to industry income of all inputs to production other than L and I, including any non-measured natural resource inputs. In general, introducing natural resource inputs to the model should reduce S_K, but leave S_L unchanged.

fluctuates over time due to natural variations in its quantity. Too little rainfall is usually the more serious concern, but too much rainfall leading to flooding or water-logging, or rain at the wrong time, can also reduce industry output with adverse implications for MFP.[5]

5 Major adverse weather events also affect other industries, such as the impact of the 2011 floods on coal mines in Queensland. As large water users, industries like mining and utilities can also be adversely affected by prolonged droughts, either because of reduced output growth (for example, reduced hydro-electricity production), or because of higher costs associated with the need to buy water.

Note that rainfall is not the only natural resource input that is important to production in AFF. For example, the weather more generally, including cyclones, heatwaves and frosts, contributes to volatility in the effective contribution of natural resource inputs to production.

Other natural resource inputs are also important in AFF. For example, land/soil is a critical natural resource input, although the quantity of services it provides over time is likely to be much less variable than that provided by rainfall. Underlying fish and forestry stocks are also key determinants of production in these sub-sectors. Studies of productivity growth in fisheries often include estimates of fish stocks directly into the underlying production function in recognition of the role they play in explaining changes in output over time (see for example, Fox *et al.*, 2003).

Ultimately, variations in the services provided by any of these *unmeasured* inputs will be reflected in the estimates of MFP growth in AFF.

Mining

In the case of mining, the key unmeasured natural resource inputs used in production are the underlying deposits of mineral and energy resources being mined. Examples include coal seams, oil and gas fields, and deposits of metal-ores and raw minerals. No amount of conventionally measured inputs – labour, capital, materials, etc. – can produce a ton of coal or a barrel of oil without a coal seam or an oil deposit from which to extract it. These 'environmental goods' are therefore essential inputs to production, and are non-renewable in nature.[6]

Importantly, the average quality of mineral and energy deposits being exploited is not constant over time, but tends to decline with cumulative extraction.[7] In general, better quality resource deposits, such as those that are more accessible, of higher quality or grade, or closer to markets and existing infrastructure, are exploited first (as they generate higher profits), before miners move on to the next best quality deposits. Box 3 explains the quality attributes of resource deposits in more detail.

In the productivity measurement framework, any change in the quality of an input is synonymous with a change in the quantity of the input. Hence, a decline in the average quality of resource deposits being mined should be considered to be a reduction in the average quantity of inputs these deposits are providing.

Absent true improvements in mining technology, the general decline in the quality (cost characteristics) of resource deposits being exploited over time places upward pressure on the quantities of conventionally measured inputs needed to produce each unit of output. This has adverse effects on mining MFP growth.

The negative influence on mining MFP of declining resource quality is likely to be more pronounced during periods of higher output prices, as it becomes economical to mine less-productive (higher unit-cost) deposits. This is an important point to consider in interpreting the current decline in measured productivity in the Australian mining industry. The opposite is also true: if commodity prices drop sharply, mining firms are likely to cut back on production costs by closing or reducing output at less productive (and hence less profitable) mines and deposits, and this would have a positive effect on MFP growth.

Utilities

In the case of utilities, the unmeasured natural resource inputs used in production largely come

6 New deposits of mineral and energy commodities occur naturally, but at a time scale (millions of years) that is too slow to consider these resources 'renewable'.

7 The discovery of large, high-quality deposits could temporarily increase the average quality of mines in production. Ultimately however, it is more likely that new discoveries will attenuate but not eliminate the long-term decline in the average quality of mineral and energy deposits being mined.

Box 3 Quality Attributes of Mines and Mineral, Oil and Gas Deposits

The quality attributes of mines and resource deposits that influence measured production costs (and hence MFP) include:

- the remoteness of deposits, including their distance from infrastructure and markets for inputs and outputs;
- the depth of oil and gas fields below the surface, whether onshore or offshore;
- the depth and nature of overburden above coal and other mineral deposits;
- quality parameters including grades, milling or processing characteristics, and the extent of any impurities;
- the flow rates of oil and gas fields; and
- the complexity of surrounding terrain.

Ultimately, these factors play a large part in determining the quantities of labour, capital, and intermediate inputs needed to produce each unit of industry output.

Source: Topp *et al.* (2008).

in the form of renewable environmental services inputs. There are three main types:

- Water catchments and their associated creeks and rivers provide inputs to production in the water industry through their role as sites for the capture, storage, and delivery of urban drinking water and rural irrigation water.
- Waterways and oceans provide inputs to the water industry through their use as sinks for the disposal of waste-water. Note that the more polluted the waste-water being discharged, the greater will be the effective quantity of inputs (in the form of waste assimilation services) provided by the environment.
- The electricity supply industry derives inputs to production from the atmosphere (air) by using it as a sink for the disposal of waste products, most notably carbon dioxide. Again, the more polluted the waste material, the greater the effective quantity of inputs (in the form of waste assimilation services) provided by the environment.

Although not as straightforward to conceptualize as 'inputs' compared with the examples of rainfall in agriculture, forestry and fishing or coal deposits in mining, the three environmental services listed above are just as important to production in the utilities industry as conventional inputs. Without these inputs, production would either be impossible – no dam site, no reliable water supply for example – or would require businesses to incur significant additional costs. For example, if CO2 could no longer be discharged directly into the atmosphere, fossil-fuel based electricity generators would require some other means of disposal, such as a carbon capture and storage facility. The latter would almost certainly come at a much greater cost (in terms of conventionally-measured inputs) compared with simply releasing waste material directly into the atmosphere. (In some productivity studies, the issue of pollution is viewed as an unmeasured negative output, rather than an unmeasured input of waste assimilation services by the environment. Both approaches lead to the same conclusion regarding the interpretation of conventional MFP estimates. See Box 4).

Drivers of change in the use or availability of environmental inputs

There are a number of reasons why the quantity (or quality) of natural resource inputs being

Box 4 How to Treat the Issue of Pollution?

In some studies of productivity growth in the water and electricity sectors, the issue of pollution is viewed as an unmeasured 'quality of output' issue, rather than as an unmeasured 'quantity of inputs' issue (see, for example, Murtough *et al.*, 2001). In the former approach, pollution is treated as a negative output, so that a reduction in pollution is treated as an increase in the volume of industry output, and vice versa.

Characterizing the use of the environment to dispose waste material as an unmeasured inputs issue (rather than an unmeasured quality of output issue) permits the use of the same conceptual framework – the introduction of a single new input term R to the production function, as described in Box 2 – for all three industries. The alternative would be to add an adjusted output term to equation (3) in Box 2 to account for changes in the amount of pollution being generated in the utilities industry, and to limit the R term to covering the examples of rainfall in agriculture, forestry and fishing, and resource deposits in mining.

Whatever the treatment, the implications for MFP are the same: conventional estimates of MFP growth will be negatively biased indicators of true technology change if pollution is reduced, and vice versa. This is because, depending on how the issue is viewed, either input growth is overstated (because the reduction in the use of environmental inputs is ignored, while any increase in the use of conventional inputs is counted), or because output growth is understated (because the reduction in a negative output is not counted).

used in utilities production might decline over time relative to the quantity of conventionally measured inputs. In relation to unmeasured waste-assimilation services provided by the environment, there are limits to the maximum quantity of waste material that can be safely assimilated on a renewable basis. Once these limits are reached, producers will need to find alternate ways to process and dispose of waste material. To the extent that these alternatives require greater inputs of capital and labour inputs the consequence is lower measured MFP than would otherwise be the case.[8]

In relation to the inputs to production that are provided by dam sites, there are two issues that have implications for conventionally measured productivity. First, the addition of new dams will tend to be adverse for MFP growth on the basis that the quality (cost characteristics) of dam sites is not distributed uniformly, and the best sites tend to be developed first.[9] Absent true technical progress in dam construction and operation, the conventionally measured costs of supplying water from dams will tend to increase over time because new dam sites will be less 'productive' (on average) than those that have already been developed.

Second, because there are natural or physical limits on the number of sites that are suitable for the construction of new dams, once *all* such sites have been developed it will only be possible to

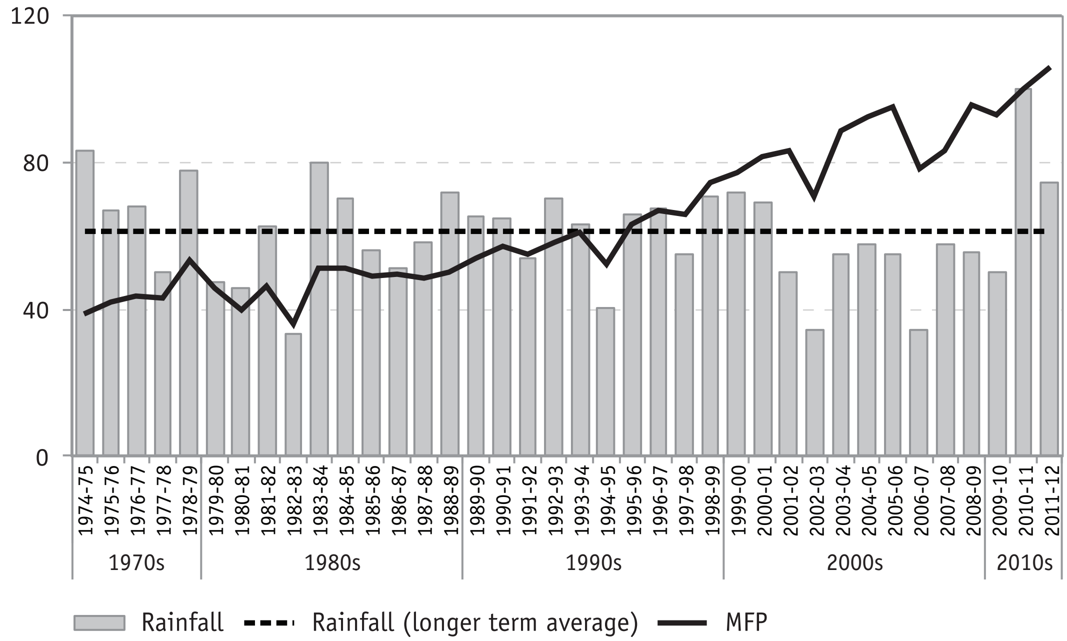
8 Note that exceeding the maximum sustainable capacity of the environment to assimilate waste might jeopardise the ability of the environment to provide a given quantity of waste-assimilation services on a renewable basis. This is similar in principle to the maximum sustainable yield concept in fisheries, whereby overfishing can cause a collapse in the fishery. It is also similar to the issue of land degradation, whereby excessive or inappropriate use of land ultimately causes yields to fall substantially, rather than being sustainable.

9 This is similar to the resource depletion argument in mining, except that individual dam sites provide renewable inputs to production (as long as it rains and river health is not compromised), whereas individual mineral and energy deposits are eventually exhausted. The key point is that new dams tend to be of lesser quality compared with pre-existing dams, in the same way that new resource deposits in the mining industry tend to be of lower quality than previously exploited deposits.

Chart 2

Rainfall in the Murray-Darling Basin and MFP in Agriculture, Foresty and Fishing[a]

Index 2010-11=100



a MFP is measured on a financial year basis (1 July to 30 June), while rainfall is measured on a calendar year basis. For comparison, rainfall in calendar 1974 is labelled 1974-75 and so on.

Data source: ABS 2012b; APC estimates; and Bureau of Meteorology, (http://www.bom.gov.au/web01/ncc/www/cli_chg/timeseries/rain/0112/mdb/latest.txt)

increase industry output by switching to alternate supply technologies. To the extent that the latter require greater quantities of *measured* inputs per unit of water supplied, any shift to non-dam sources of supply will be adverse for conventionally measured MFP growth.[10]

Policy and/or regulatory changes can also influence the use of natural resources in production

Apart from natural or biological limits, the quantity of natural resources used as inputs to production in utilities is influenced by policy or regulatory changes that alter the conditions of access to environmental services. A good example is the adoption of stricter pollution standards, which effectively reduce the extent to which utilities businesses can utilize the capacity of the environment to assimilate waste material. To the extent that any changes to policy or regulatory settings ultimately require businesses in utilities to adopt production technologies that are higher-cost (in terms of conventionally measured inputs) and less intensive in the use of 'unmeasured' natural resource inputs, the impact on measured MFP will be negative.[11]

10 At least until such time as non-dam sources have become the dominant sources of water supply. At this point, MFP growth in the water supply sector should more closely reflect any 'true' efficiency improvements in the dominant supply technologies of the time – desalination or water recycling, for example.

11 Reducing the use of the environment as an input to production (such as by ceasing to dump waste material in rivers and waterways, or cutting emissions of CO2 to the atmosphere) may, of course, be highly desirable from a social welfare point of view if the gain to the community from this outcome exceeds the cost (part of which is reflected in the decline in measured industry productivity).

The Scale of the Effect

Some recent research provides quantitative and qualitative evidence that the problem of unmeasured changes to the quantity and/or quality of natural resource inputs being used in production has played a major role in explaining recent periods of negative MFP growth in agriculture, foresty and fishing (AFF), mining and utilities. Each industry is considered in turn.

Agriculture, forestry and fishing

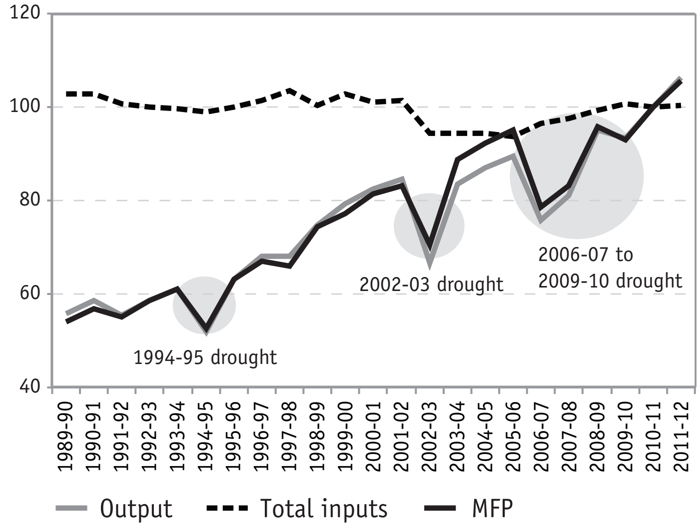
In the case of agriculture, forestry and fishing, changes in rainfall inputs can be substantial from year to year, although there is less variability over the long term. The implication is that the impact of changes in rainfall on industry output will usually be observed in short-term (1-2 years) estimates of MFP growth, but will have less of an impact on the average rate of growth over a longer period.

The link between annual changes in rainfall and annual changes in MFP is quite strong. In Chart 2, average annual rainfall in the Murray-Darling Basin (MDB) is used as a proxy for aggregate or nationwide rainfall on the basis that the basin is a large and important agricultural region that accounts for just under one half of total industry output (around 40 per cent of total agricultural income and over 50 per cent of the total value of cereals grown for grain).[12]

In years when there are widespread and significant declines in average annual rainfall (major droughts), aggregate agricultural output in Australia typically falls sharply, dragging down MFP (Chart 3). While conventionally measured inputs like capital and labour can also fall during major drought years, they do not generally fall by as much as the reductions in output.

Widespread droughts in Australia often last just one year however, and MFP generally recovers all of its 'losses' in the subsequent year. Examples for the 1994-95 and 2002-03 droughts are highlighted in Chart 3. Estimates of annual MFP growth are negative in drought years, and rise above trend in drought recovery years.

Chart 3
Inputs, Output and MFP in Agriculture, Forestry and Fishing[a]
Indexes 2009-10=100



a Note that the MFP series in this figure is value added based MFP, where *output* is real gross value added, and is defined as real gross output (production) less real intermediate inputs, and *total inputs* is defined as the cost-share weighted average of labour and capital inputs, also measured in volume terms.

Data source: ABS 2012b.

Because these 'annual' events in agriculture, foresty and fishing tend not to coincide with the beginning or end years of the market sector productivity 'cycles' (which are chosen to help smooth out the adverse influence of fluctuations in the business cycle on the utilization of capital and labour inputs), they usually do not affect the economy-wide MFP results over the productivity cycle.[13]

However, the extended period of below-average rainfall from 2006-07 to 2009-10 kept strong downward pressure on agricultural MFP over multiple years, and ultimately contributed to the below average MFP result for the market

12 See Murray-Darling Basin Authority (http://www.mdba.gov.au/explore-the-basin/about-the-basin).

Table 1
Estimates of the Impact on Mining MFP of Resource Depletion
(Average annual growth rates)

Study	Time period covered	ABS estimate of MFP % pa	MFP adjusted for resource depletion: (proxy for the rate of technical progress) % pa
Topp, Soames, Parham and Bloch (2008)	1974-75 to 2006-07	0.01	2.50
Zheng (2010)	1974-75 to 2006-07	0.01	1.15
Loughton (2011)	1985-86 to 2009-10	-0.15	2.05

sector as a whole during the most recently completed productivity cycle – that is, the cycle which ran from 2003-04 to 2007-08. In this case the influence of rainfall on measured productivity in agriculture, forestry and fishing was more pervasive.

Mining

In the case of mining, recent research suggests that the ABS estimates of industry MFP are strongly influenced by unmeasured changes in natural resource inputs (see Topp *et al.*, 2008; Bloch and Zheng, 2010 and Loughton, 2011). Although the papers use different approaches to quantify the size of the effect, the results are consistent and unambiguous: a decline in the average quality of resource inputs into mining is responsible for a large share of the poor MFP growth in the industry. In this situation the ABS estimates of MFP in the mining industry are strongly negatively biased indicators of technical progress when viewed over the longer term (Table 1).

Importantly, the influence of resource depletion on the ABS estimates of MFP need to be adjusted for temporal changes in the average quality of deposits being mined *if* they are to be used as indicators of technical progress in this industry. The studies noted above provide alternative approaches to making such adjustments.

Utilities

Major policy and preference shifts during the last 10 to 15 years have combined with the natural pressures arising from a rapidly growing population to substantially reduce the quantity of environmental services available to this industry. As a result there has been an increase in the rate of growth in conventionally measured inputs (labour, capital, and intermediate inputs) per unit of industry output (see Box 5).

A recent staff working paper published by the Australian Productivity Commission found that these developments contributed to strongly negative MFP growth in utilities between 1997-98 and 2009-10 (Topp and Kulys, 2012). In the water sector, the data showed strong growth in investment in tertiary waste-water treatment plants over the period, as well as the construction of high-cost sources of new water supply.

13 See ABS (2011) for a discussion of how the market-sector productivity cycles are determined. Note that productivity cycles identified specifically for the agriculture industry are generally different from the cycles identified for the market sector as a whole. For more information on industry-specific cycles, see Barnes (2011:XVIII). Despite the variability, Australia includes agriculture, foresty and fishing in its economy-wide estimates of MFP. However, in some countries agriculture is excluded from aggregate productivity statistics due to the impact of climatic variation on annual output.

Box 5 Policy and Preference Shifts in the Utilities Sector

The operating environment of water and electricity businesses has changed in three fundamental ways during the last 10 to 15 years. First, a paradigm change in thinking within the Australian urban water industry led to a cessation in the construction of new urban water dams, and a shift to the construction of manufactured water alternatives, such as desalination and recycled water plants. In effect, the industry moved from having an almost complete dependence on a production technology dependent on natural resource inputs (rain-fed dams), to a much greater reliance on supply technologies that used greater quantities of conventionally measured inputs (desalination and water recycling plants).

The shift to manufactured water technologies was partly in response to an urgent need for new urban water supplies in Australia to meet the demands of a rapidly growing population, and to counteract the adverse effect on existing water supplies of an unexpectedly long period of below-average rainfall. However, it was also a response to growing community opposition to the construction of new dams, largely on the basis that their environmental costs were too high. In some states, natural limits on suitable sites for new dams had also been reached, contributing to the speed and scale of the move to non-dam supply technologies like desalination and recycling.

Second, regulatory changes during the period increased the minimum standards of wastewater treatment in Australia. This led to the construction of new or augmented water treatment plants. As with water supplies, a growing population had increased the demand for wastewater disposal services, and there was growing concern regarding the environmental impact of continuing to rely on conventional treatment methods, particularly the use of coastal outfalls. The shift toward tertiary treatment of urban wastewater reduced the use of the environment as an input to production, but increased requirements of conventionally measured inputs.

Third, changes in energy policies in response to the threat of climate change led to an increase in the share of electricity being supplied via renewable and gas-fired power stations, and a concomitant decrease in the share of output coming from coal-fired power stations. The cut in allowable pollution lowered the use of natural resources (the atmosphere) as an input to production, and increased the average quantity of conventionally measured inputs required per unit of output. Green energy typically requires greater units of conventionally measured inputs per unit of output, compared with coal-fired power.

In all three cases therefore, the reduction in the use of natural resource inputs largely came about as a consequence of policy and/or other decisions that were implemented to address environmental issues, especially water and CO2 emissions. Against the background of rapid population growth, natural limits on the availability of suitable sites for new dams also contributed to the decline in the availability of natural resource inputs, and a large increase in the use of conventionally measured inputs.

Source: Topp and Kulys (2012).

The latter included large-scale desalination plants in five of the six mainland states of Australia.

Topp and Kulys also reported the impact on MFP of the move away from coal-fired electricity generation in Australia between the late 1990s and 2010 due to the higher (conventionally measured) costs of less emissions-intensive power sources. However, unlike mining where some measures of resource quality are available, estimates of the change in these environmental inputs are not available.

The motivations for the shift to higher cost production technologies (in terms of conventional inputs) vary. In the case of the shift to lower carbon emission power generation, Topp and Kulys cite climate-change policies and initiatives. In the water sector, the shift to more labour- and capital-intensive production technologies was necessary to meet 'the requirements of government policies on, among other things, water security, the management of environmental impacts associated with the treatment and disposal of sewage, and the quality of drinking water' (IPART, 2010: 27).

While some of the changes in utilities might have been driven by changes in the quantity of natural resources available (such as rainfall and high quality dam sites), others were driven by government decisions. The latter reflected demand from the community for improved environmental outcomes, such as reducing the impact of sewerage outfalls on Sydney beaches, and reducing carbon emissions. Political promises not to build new dams also had an influence, as did commitments to improve the reliability of electricity and water supplies.[14]

Notwithstanding the fact that some investment decisions made in response to regulatory and other market developments could have been more efficient, the broader shift towards supply technologies that use fewer natural resource inputs would appear to be an unavoidable development for the utilities industry. As noted earlier, there are natural or biophysical limits to the maximum quantity of environmental services that can potentially be used each year by utilities, and growing community concern regarding the appropriateness of certain uses of the environment. This means that future output growth is likely to continue to be based on supply technologies that depend more heavily on conventionally measured inputs (labour, capital, and intermediate inputs), rather than on the 'traditional' technologies that used a combination of measured inputs and significant quantities of unmeasured natural resource inputs.[15]

Assuming that businesses in the utilities industry continue to shift towards the use of supply technologies that require greater quantities of measured inputs but fewer units of (unmeasured) natural resource inputs per unit of output, there will be further downward pressure on measured productivity. This should be borne in mind when assessing short- to medium-term developments in utilities MFP, particularly if interested in the rate of technical progress in the industry.

As new technologies that do not rely on natural resource inputs begin to dominate industry production, the contribution to MFP of declining natural resource inputs will dissipate.[16] In

14 Studies of the urban water sector and the electricity distribution sector by the Australian Productivity Commission have criticized recent investment decisions on the basis that there were cheaper or more efficient ways of dealing with growing demand for power and water that should have been adopted first (APC, 2011 and 2012). To the extent that this is true, some part of the recent decline in measured MFP in this industry is excessive and could have been avoided.

15 In contrast to mining, the generation of output in utilities is feasible using technologies that use little or no environmental inputs (or at least not those that are supply constrained). Moreover, it is possible that all three types of natural resource inputs that are currently used by the utilities industry could eventually be replaced by conventionally measured inputs. For example, desalination and water recycling plants could replace dams as the main source of urban water supply; tertiary treatment plants could substantially reduce the use of the environment to assimilate waste-water; and a carbon-free electricity sector could eliminate the use of the atmosphere as a sink for $CO2$.

16 This will also be the case if natural resource inputs become 'market' inputs, and hence are measured explicitly as inputs. For example, as carbon pricing is introduced, what is effectively a free input becomes a priced input (in the form of a carbon permit), and hence is measured as an input in the conventional MFP framework.

this scenario the MFP estimates for utilities will eventually better reflect the technical progress in the industry.

Where To From Here?

In AFF, mining, and utilities changes in the quantities of unmeasured natural resource inputs used in production have had a significant impact on industry MFP over the last decade. This effect of declining natural resource inputs is likely to be much smaller, if at all, in other industries simply because no other industries are as reliant on these types of inputs.[17]

The effect of changes in natural resources inputs on value added is captured in the ABS estimates of MFP, along with the contributions to productivity of technical progress and other sources of changes in output other than changes in the inputs of capital and labour. Adjusting for the change in natural resource inputs is useful for estimating the impact that these changes have on productivity. Such an adjustment would also mean that estimates of MFP (adjusted) more closely measure technical progress.

But making such adjustments is easier said than done. Part of the reason is that the inputs in question are, unlike labour, capital and intermediate inputs, not generally traded in markets. This makes it virtually impossible to gather reliable information on their use in production in a way that could be readily incorporated in the standard growth accounting framework. Accordingly, unpacking the broader industry trends in MFP will remain an important means of understanding these sources of changes in productivity.

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