OVERVIEW

Key points

- Mining typically accounts for around 5 per cent of Australia's nominal market sector gross domestic product.
  - A 'once-in-a-generation' shock to demand for, and prices of, mining commodities saw this share rise to 8.5 per cent in 2006-07, stimulating substantial growth in new investment, employment, and profits.
  - Yet output growth in mining in recent years has been weak at best, and multifactor productivity (MFP) has declined by 24 per cent between 2000-01 and 2006-07.
- Long lead times between investment in new capacity in mining and the associated output response can lead to short term movements in mining MFP unrelated to underlying efficiency.
  - Around one-third of the decline in mining MFP between 2000-01 and 2006-07 is estimated to be due to this temporary effect. This effect was particularly important in the last few years of this period.
- Ongoing depletion of Australia's natural resource base is estimated to have had a significant adverse effect on long-term mining MFP.
  - In the absence of observed resource depletion, the annual rate of mining MFP growth over the period from 1974-75 to 2006-07 is estimated to have been 2.3 per cent, compared with the measured rate of 0.01 per cent.
- Over the longer-term, MFP impacts of resource depletion have been offset by technological advances and improved management practices. An increase in the use of open-cut mining has been a key development, along with a general increase in the scale and automation of mining equipment.
- An expected rebound in mining MFP from 2008-09 onward may be delayed as a consequence of the decline in world prices for many mineral and energy commodities in mid-to-late 2008. Any temporarily idle capital associated with production cut-backs and mine closures will tend to lower MFP. On the other hand, significantly lower commodity prices may lead mining companies to cut costs, with a positive effect on MFP.
- Despite the impact of the fall in mining MFP, the sector has made a significant contribution to the strong overall growth in national income so far this decade through a substantial improvement in Australia's' terms of trade.

Overview

The measurement and interpretation of productivity frequently presents significant challenges, especially when conducted at the industry level. In this regard the mining industry is no exception. This report identifies measurement and interpretation issues of relevance to productivity estimates for the mining industry in Australia. Quantitative evidence is presented regarding the effect on mining industry productivity growth of two important factors: systematic changes in the underlying quality of natural resource inputs used in mining; and production lags in response to increases in capital investment.

Productivity in the Australian mining industry

The mining industry has had a major influence on Australia's productivity performance and prosperity in recent years. While its influence on prosperity has been positive, the opposite has been the case in relation to productivity.

A surge in commodity prices (figure 1) from 2003-04 to 2006-07 has been the major influence on the sector. Higher commodity prices have resulted in large increases in the *value* of output as well as in income and prosperity. But they have not induced a commensurate increase in the *volume* of mining output. Because substantially increased usage of capital and labour inputs has accompanied only a modest increase in output, multifactor productivity (MFP) has fallen.

Review of productivity trends

Mining has been characterised by:

- a high level of labour productivity (output per hour worked);
- little overall growth in MFP from the mid-1970s to current times (see figure 2);
- long swings of positive growth in MFP (the 1980s and 1990s) and decline (the 1970s and 2000s); and
- significant volatility in MFP over shorter periods (a few years) compared with most other industries.

Figure 1 **Index of mineral and energy commodity prices, 1974-75 to 2006-07**

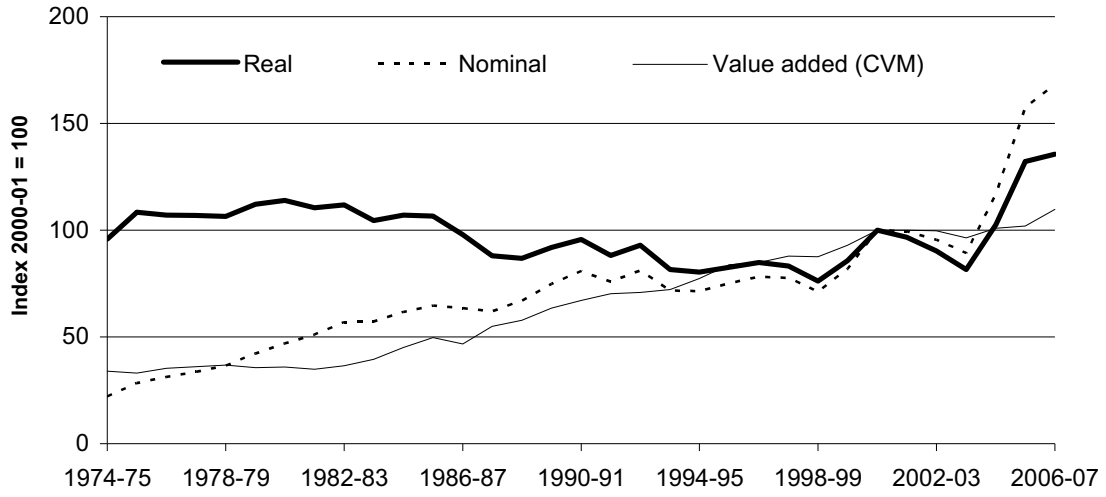
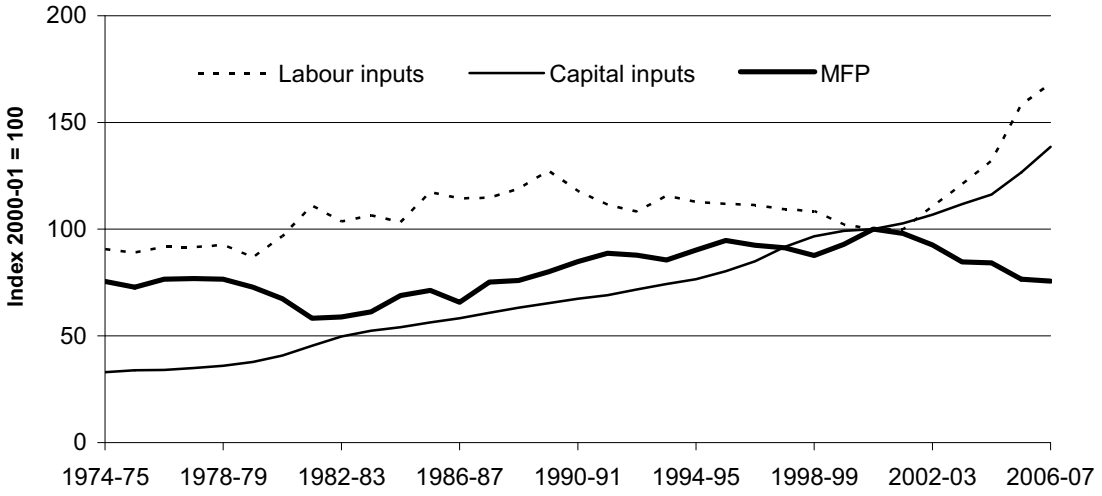


Figure 2 **Mining industry MFP and primary inputs**



The decline in mining MFP since the peak in 2000-01 has been quite marked. Australian Bureau of Statistics (ABS) estimates put the decline in MFP between 2000-1 and 2006-07 at 24.3 per cent. As a sector that generates a substantial proportion of market sector output (around 8.5 per cent of gross value added in 2006-07), the decline in mining productivity has contributed substantially to a slowdown in market sector productivity growth. The sharpest annual drop in mining productivity was in 2005-06, when a 8.8 per cent fall took close to a full percentage point off productivity growth for the market sector as a whole. (The latter was just 0.2 per cent in 2005-06, compared with the longer-term average of 1.2 per cent.)

The decline in mining MFP has been due (in 'proximate' terms) to a combination of a slow rate of output growth over the period, very strong growth in labour inputs, and continued growth in capital inputs (figure 2). This combination is of interest as it seems to imply that miners have continued to invest more capital and employ more labour, but this has yet to deliver a matching increase in output.

Non-renewable resources and mining productivity

Mining differs from other sectors of the economy in that it relies on non-renewable resources as inputs to production, and generally requires large investments in new capacity that can take a considerable time to build and become operational. As a result, conventional estimates of productivity growth in the sector need to be interpreted carefully.

Different interpretation due to the major influence of natural resource inputs

Typically, MFP can be broadly interpreted as an indicator of the efficiency with which capital and labour inputs are used to generate output of goods and services. The efficiency of production is determined by factors such as technology, management, skills and work practices. However, productivity in mining also reflects the influence of a further factor, the influence of which is substantial.

That additional factor is the input of natural resources. While natural resources are obviously a major input into mining production, changes in their quality are not generally taken into account in standard measures of productivity. This omission would not be a problem if natural resources were in infinite supply and of homogeneous quality — that is, available without constraint at the same unit cost of extraction. But neither is the case: resource deposits are non-renewable, and depleted by ongoing extraction. And as mineral and energy deposits are depleted, the quality and accessibility of remaining reserves generally decline. Miners, by choice, focus initially on high-quality, readily accessible deposits, since they produce the highest returns. As these deposits are depleted, remaining deposits may be of lower grade, in more remote locations, deeper in the ground, mixed with greater impurities, require more difficult extraction techniques and so on.

As the quality and accessibility of deposits decline, greater commitments of capital and labour are generally needed to extract them. When deposits are deeper, more development work is needed to access the desired resources. If there are greater impurities, greater costs may be incurred in extracting and processing the material into saleable output. In short, more 'effort' is needed to produce a unit of output.

The additional capital and labour required per unit of output show up as a decline in measured productivity. Consequently, productivity in mining reflects not only changes in production efficiency, but also changes in the underlying quality and accessibility of natural resource inputs to mining.

Measuring the contribution of resource depletion to mining MFP

For the purposes of this paper, the extent to which resource depletion is occurring in the mining industry is measured by movements in a composite index of mining 'yield'. This index is constructed using average ore grades in metal ore mining, the ratio of saleable to raw coal in coal mining, and the implicit flow-rate of oil and gas fields in the petroleum sector. Output in mining can be adversely affected if there is a decline in yield because of depletion.

Between 1974-75 and 2006-07, the composite index of the average yield in mining fell substantially (figure 3). If the changes in mining industry output due to the observed yield declines are taken into account, multifactor productivity in the mining industry is estimated to be significantly higher. That is, resource depletion in the form of yield declines is estimated to have had a significant adverse impact on multifactor productivity in the mining industry over the past thirty-two years (figure 4). Once the effect of yield changes is removed, mining MFP grows at an average rate of 2.5 per cent per year, compared with 0.01 per cent per year in conventionally measured mining MFP.

Figure 3 **Index of mining industry yield**

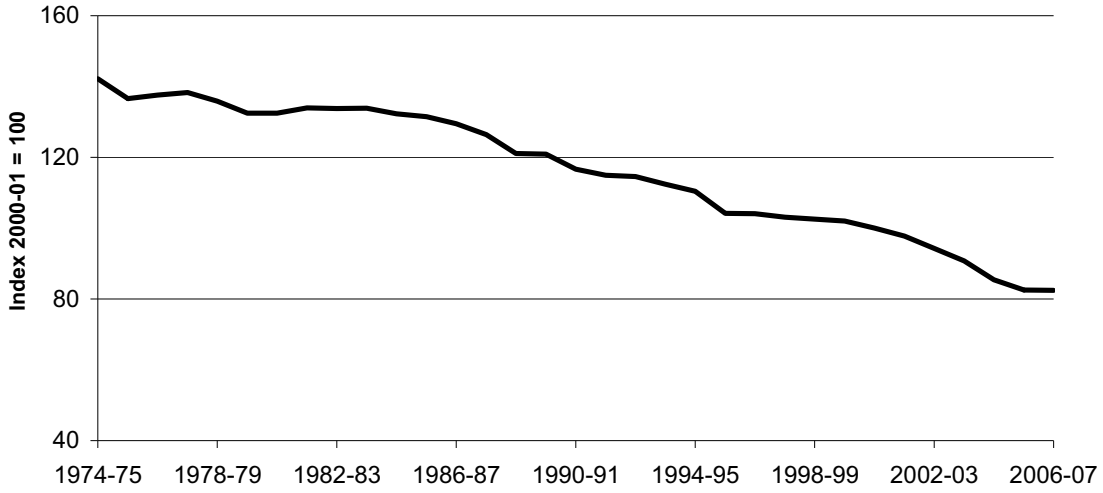
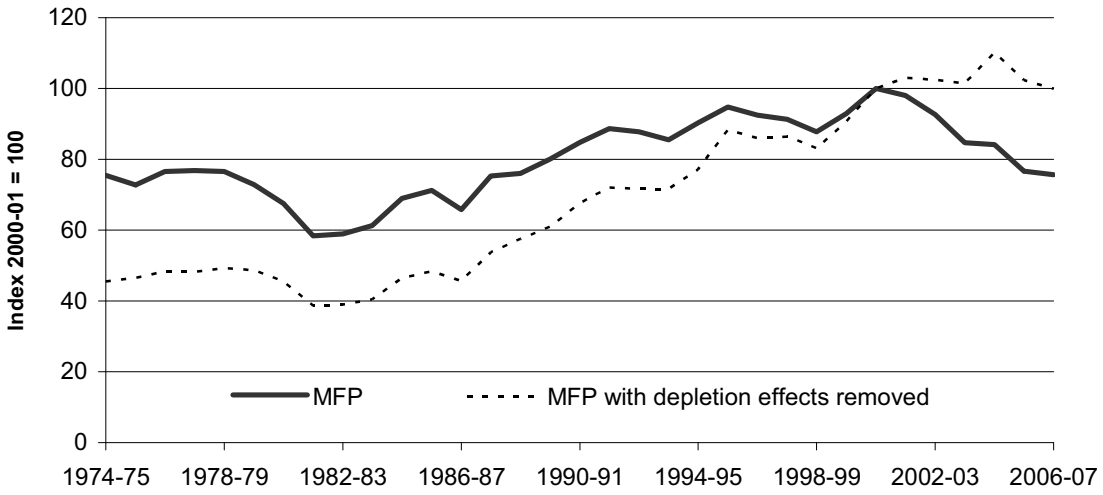


Figure 4 **Mining MFP**



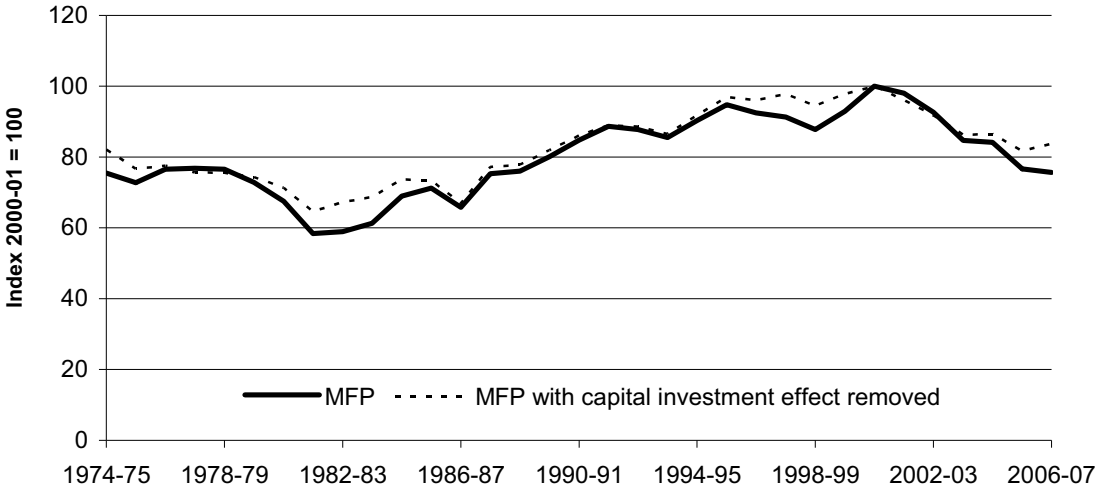
Long lead times in new mining developments

A second reason that movements in mining MFP need to be interpreted carefully is that there are usually long lead times between investment in new capacity in the sector (whether in the form of new mines or mine expansions) and the corresponding output. New investment in the mining industry is highly variable, with occasional surges often followed by large declines. Since new investment is generally recorded immediately in MFP calculations (as an increase in capital inputs), any lag in output response will have an immediate adverse effect on MFP. A concomitant positive effect on MFP will occur at some point in the future when

output from previous new investment comes on stream. The consequence is that in times of major increases or decreases in investment, there can be short-term but substantial movements in MFP that *do not* reflect changes in the fundamental efficiency with which inputs are combined to produce outputs. Although these movements are essentially temporary, there is considerable scope for them to be misinterpreted as changes in underlying efficiency.

The relationship between investment and output is complex and varies from project to project. Empirical and other data suggest that the lead time for new mining projects is, on average, around three years. That is, there is a delay of approximately three years between the time of initial commitment to or construction of new mining projects, and the time output from those developments approaches full or normal capacity. As a result of these lags, changes in the rate of growth in mining investment are found on occasions to contribute significantly to short-term movements in mining MFP. This is illustrated in figure 5, which shows conventionally estimated MFP in the mining industry along with an estimate of mining MFP that has been adjusted to take into account the average lead-time between construction and production for new mining investments.

Figure 5 **Mining MFP with capital lag effects removed**



The role of higher commodity prices

Higher output prices also raise resource rents (revenues in excess of costs of extraction) and encourage miners to increase the rate of extraction. This leads to lower productivity through a number of mechanisms. Higher prices and resource rents enable and induce:

- extraction of more-marginal deposits — that is, deposits that are of lower quality and accessibility and, hence, require more effort per unit of output to extract
  - existing operations can be continued longer than would otherwise be the case, previously mothballed mines can be reopened, and new mines that extract lower-quality, less-accessible and more-difficult deposits can come on stream – that is, higher prices temporarily add to the underlying 'depletion' effects.
- more costly production while the capacity of mines is constrained
  - since mines are usually run at or near full capacity, output can only be increased in the short to medium term by using more labour and intermediate inputs per unit of output (and generally less-efficient methods) with changes in capital constrained in the short run.

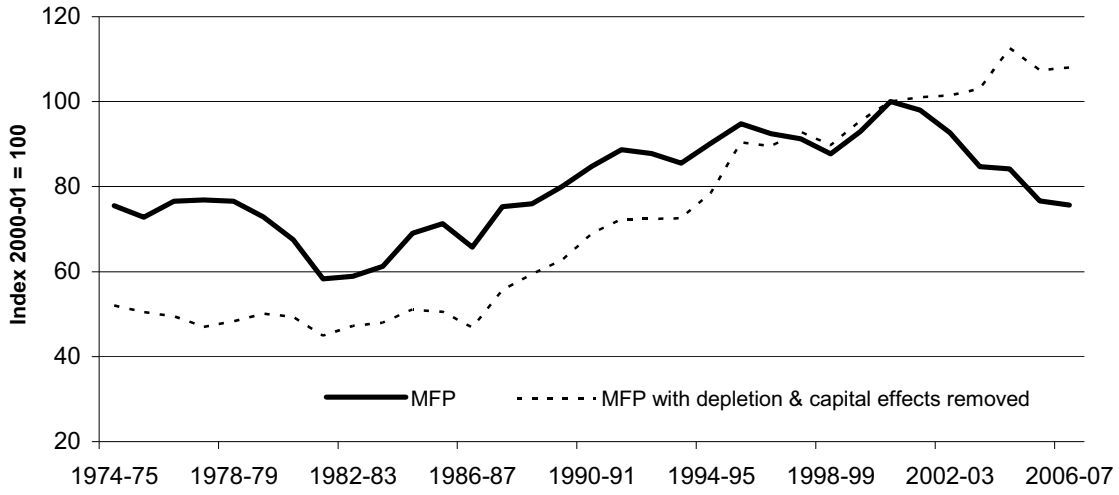
The effect of these phenomena is likely to be temporary or transitional, although they may be quite long lasting in the presence of sustained periods of high commodity prices. At the same time, sustained higher prices provide an incentive to expand exploration for new deposits. If new deposits are discovered they could provide opportunities to increase average productivity. However, some exploration is unsuccessful, and new discoveries may be below-average quality. Furthermore, the lags between discovery and extraction may be so long that any countervailing effect would come only after a considerable time.

Explaining longer-term productivity trends

Together, yield declines due to resource depletion and the temporary effects of long lead-times in new mining developments explain a large amount of the variability in mining MFP over time (figure 6). After removing the influence of these factors, it is estimated that there has been significant underlying MFP growth in mining over the past 32 years — around 2.3 per cent per annum — due to other factors.

Positive contributions to mining MFP over the longer-term include improvements in production efficiency through technological advances and improved management techniques. Some examples include the expansion of open-cut mining (particularly in coal mining but also in metal ore mining), the development of longwall operations in underground coal mining, and greater automation and scale of plant and equipment. Australia, with a long history of underground mining, has also employed innovations in hard-rock mining, such as block-caving and sublevel-caving technologies. In oil and gas production, developments in drilling technology have led to an increase in the use of steeply inclined and even horizontal drilling during the past three decades, allowing access to resources that were not economic using standard vertical wells. Continued developments in drilling technology have also allowed oil to be extracted from wells in deeper and deeper water.

Figure 6 **Mining MFP with depletion and capital effects removed**

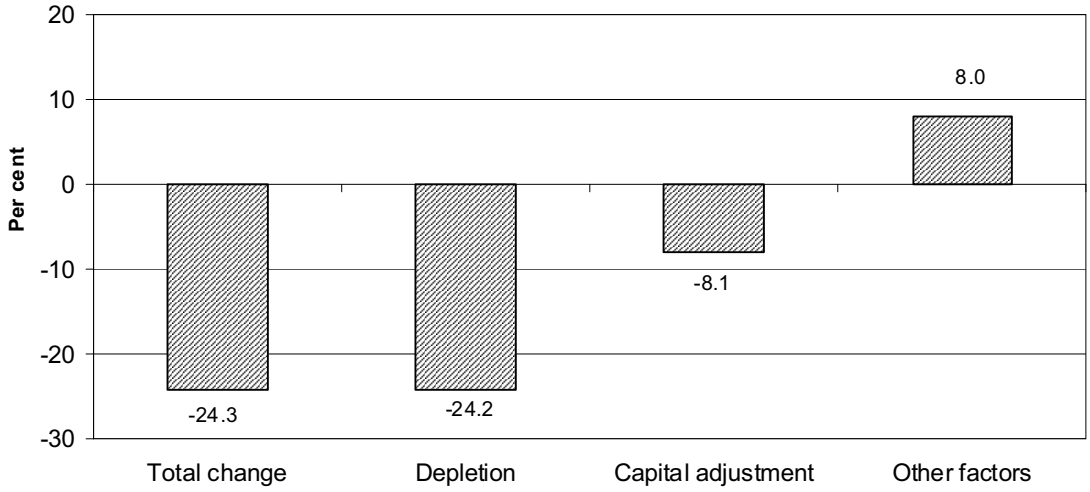


The recent decline in productivity

Yield declines and a surge in new capital investment are estimated to have contributed substantially to the decline in mining industry MFP between 2000-01 and 2006-07. Yield declines are the dominant factor in the first few years of the period, while production lags associated with the surge in new capital investment from 2004-05 to 2006-07 are the dominant factor in the last few years of the period. After removing the influence of yield changes and production lags, other factors are estimated to have raised mining MFP by 8 per cent over the period (figure 7).

Recently released data from the Australian Bureau of Statistics indicate that MFP in the mining industry has fallen again in 2007-08, by just under 8 per cent. Capital investment lags are estimated to explain around 5 percentage points of the decline. Unfortunately, data limitations mean that it is not possible at this time to estimate the extent to which resource depletion contributed to the decline. However, it seems likely that a decline in aggregate production of crude oil and condensate in 2007-08 reflects ongoing reductions in oil and gas flow rates in some fields. To the extent this turns out to be the case, resource depletion is likely to emerge as an important explanatory factor of the decline in mining MFP in 2007-08 as well.

Figure 7 **Contributions to the change in mining MFP between 2000-01 and 2006-07**



Beyond the estimated effects of yield declines and production lags associated with the surge in capital investment, a range of other factors are likely to have had an impact on mining MFP growth in recent years. Some of these factors, such as continued improvements in technology, are likely to have made a positive contribution to MFP, while others such as short-term infrastructure constraints and the weather are likely to have detracted from MFP growth. Higher commodity prices during the period are also likely to have detracted from MFP growth by encouraging higher cost production, as miners attempted to ramp-up production in the short-term. It is difficult to quantify the individual effects of these factors.

Prosperity versus productivity

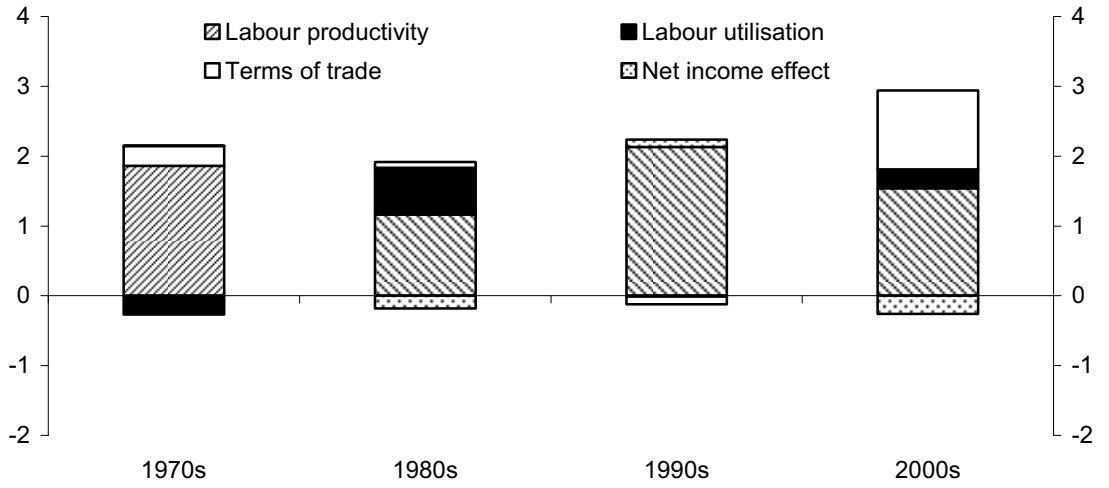
An increase in mining industry commodity prices was a major contributor to an improvement in Australia's overall 'terms of trade' — the ratio of export prices to import prices — between 2001 and 2007. In general, an improved terms of trade increases Australia's real income by allowing greater quantities of imports to be purchased for a given quantity of exports. An increase in the terms of trade is important because it provides a boost to national income, spending and economic activity. However, some of the profits associated with the resources boom accrue to foreign owners of Australian mining industry assets, so not all of the increased income associated with the mining boom necessarily flows through to the rest of the economy.

Figure 8 contains a breakdown of the factors that have contributed to national income growth in Australia over the past four decades, and illustrates the important role played by the higher terms of trade so far this decade. The 'net income effect' — which measures the change in gross national income due to the difference between domestically generated income payable to non-residents, and foreign sourced income payable to residents — detracted from income growth during the period, while improved labour productivity and higher labour utilisation (hours worked per capita) both made positive contributions.

Changes in the terms of trade, however, have had only a small effect when averaged over longer periods. Labour productivity growth, which reflects both MFP growth and the increase over time in the amount of capital per hour worked, has been the main source of income growth. Future income growth in Australia will continue to depend on strong underlying growth in labour and multifactor productivity, including in the mining industry.

Figure 8 **Contribution to income growth — the importance of the terms of trade**

Contributions to annual average growth in real gross national income per capita, percentage points per year



Impact of global economic developments and falling commodity prices

The expectation has been that mining MFP would begin to improve in 2008-09 as production associated with the surge in capital investment in the sector between 2004-05 and 2006-07 began to come on-stream.

However, these projections are now in question due to the decline in world prices of a number of mineral and energy commodities in mid-to-late 2008, and subsequent decisions by mining companies to postpone new developments, close mines, and cut-back production at other mines. Mine closures could be expected to have a positive effect on mining MFP, as higher cost mines will generally be closed first. On the other hand, cut-backs in output at existing mines may lead to lower MFP if they lead to temporarily idle capital.

If mineral and energy commodity prices remain lower over the next few years, it is likely that mining companies will focus heavily on trying to reduce production costs. To the extent that they are successful in this, there will be a positive effect on mining MFP, supporting an expected rebound (albeit possibly further delayed) in MFP as production associated with the recent surge in capital investment comes on-stream.