Recent productivity outcomes and Australia's potential growth

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In recent years, employment has grown strongly while output has grown modestly. This implies a weak growth in labour productivity that is difficult to interpret. In this article, we explore some possible explanations for recent economic growth and labour productivity outcomes, with a focus on developments in the composition of growth. We also examine whether recent productivity outcomes hold any implications for the Australian economy's potential growth rate. We find that recent weak growth in output and strong growth in labour are indeed unusual when compared with previous experiences. However, we also find that the uncommon circumstances surrounding Australia's mining boom explain some of the output and labour conundrum.

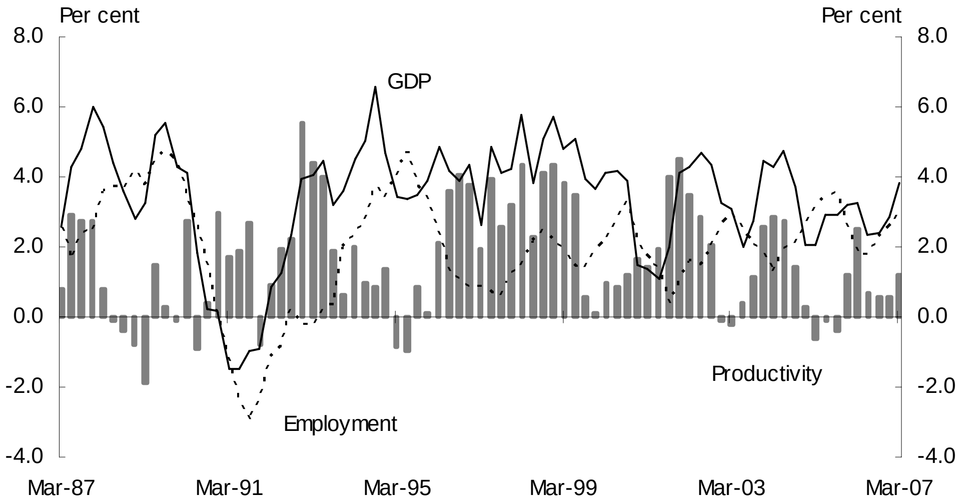
1 At the time of writing, the authors were from the Domestic Economy Division, the Australian Treasury. This article has benefited from comments and suggestions provided by Bryn Battersby, Alicia Da Costa, Andrew Craston, Ben Dolman, Angelia Grant, David Gruen, John Hawkins, Paul O'Mara and Meghan Quinn. The views in this article are those of the authors and not necessarily those of the Australian Treasury.

Introduction

The most important determinant of economic growth is the one that we understand the least. Over the past 25 years, around 80 per cent of the increase in living standards (measured by GDP per capita) has been due to an increase in the level of productivity. While distilling the drivers of long term productivity growth is challenging, understanding short term changes is particularly difficult.

Recent productivity trends illustrate this well. Since June 2004, GDP has grown by an annual average of 3 per cent (well below its 10-year average growth rate of 3¾ per cent), while employment has grown by 2¾ per cent per year (well above its 10-year average of 2 per cent).[2] If employment is growing relatively quickly compared with GDP then labour productivity growth is weak (Chart 1).[3]

Chart 1: Through-the-year growth in real GDP, employment and productivity



Source: ABS Labour Force, ABS National Accounts.

There is no simple explanation for this apparent slowdown in labour productivity.[4] Possible explanations include mismeasurement of outputs and/or labour, changes in the composition of the economy, lags between growth in output and growth in labour leading to short run productivity cycles, and developments in particular sectors of the economy. One explanation, popular with the press, is that the economy has hit

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2 Business investment has also grown strongly since June 2004, by 11 per cent per year, compared with a 10-year annual average growth rate of 9 per cent.

3 Throughout the paper, productivity and labour productivity are used interchangeably unless otherwise indicated. For quarterly data, we mostly analyse the period since June 2004. For annual data, we analyse the financial years 2004-05 and 2005-06.

4 See the Reserve Bank of Australia (2006) for a discussion on recent productivity growth.

'capacity constraints' and is finding it difficult to grow at past rates. This raises the question, how fast do we expect the economy to grow on average? Moreover, what rate of growth is consistent with low and stable inflation? That is, what is the potential growth rate of the Australian economy?

The long-run potential growth rate of an economy is determined by the growth of inputs (labour and capital), and the rate of growth in the efficiency with which these inputs are used to produce outputs (that is, multi-factor productivity). An economy can grow faster than the potential growth rate without generating inflationary pressures if, for example, there is excess capacity in input markets.

In constructing projections of economic growth for budget purposes, Treasury considers likely trend rates of growth in labour inputs and labour productivity. Average productivity growth over the past 30 years is used as a guide for trend productivity growth while the growth in labour inputs reflects projected demographic changes and participation rates. Currently these estimates are 1¾ per cent annual growth for productivity and 1¼ per cent for employment growth leading to real GDP growth of 3 per cent.[5] Broadly speaking, this growth rate could be thought of as Australia's current potential growth rate.

Keeping in mind this notion of potential growth, we examine recent outcomes in labour productivity in three ways. First, we examine if recent growth in labour productivity is consistent with historical relationships between various determinants of productivity growth. Second, we explore the growth in labour input and its relationship with wages and output. Finally, we examine whether there are any factors at play within the economy that would disturb the typical relationship between output and labour, and for example, whether measurement issues are likely to be more pronounced than usual.

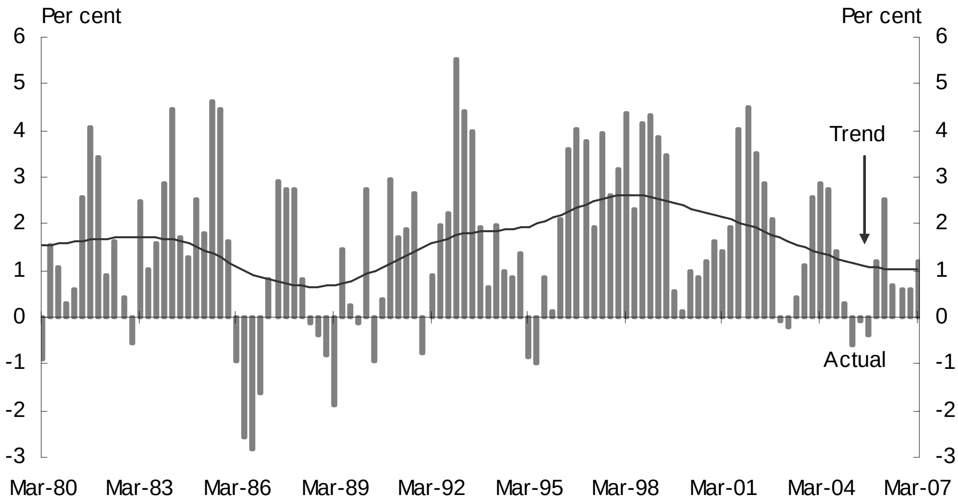
We find that recent weak growth in output and strong growth in labour are indeed unusual when compared with previous experiences. However, we also find that the uncommon circumstances surrounding Australia's mining boom may contain some of the explanation for the weakness in labour productivity. These findings suggest that, at this stage, recent events hold little for policymakers to worry about in terms of the underlying dynamism of the economy, although they hold implications for policy makers as to, until recently, which economic aggregates are providing the best read on the strength of the economy.

5 Primarily driven by increased immigration, the growth rate of working-age population has increased recently. If the working-age population continues to grow at a faster pace, then this will lead to an increase in trend employment growth and potential real GDP growth.

Labour productivity outcomes

In recent years, labour productivity has grown little. However, low growth in labour productivity for short periods is not a particularly unusual outcome (Chart 2). There are two main reasons for this. First, productivity growth is cyclical, and this cyclical pattern implies high and low productivity growth from year to year. And second, productivity growth is difficult to measure, and hence is susceptible to measurement errors. For both of these reasons, the usual practice in examining productivity outcomes is to use a technique that takes into account these factors by examining medium to longer term influences. One way we can examine the underlying trend and cycles in productivity is by using a mathematical filter to separate out the trend. We can then examine whether the deviation from this trend is consistent with the typical shorter-term cycles in productivity.[6]

Chart 2: Through-the-year growth in actual and trend productivity



Source: ABS National Accounts; authors' calculation.

The smooth line in Chart 2 shows that growth in one estimate of trend productivity slowed in the 2000s after strong growth through the late 1990s.[7] Since June 2004, annual productivity growth has averaged around a ¼ of a percentage point less than

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6 The Australian Bureau of Statistics (ABS) averages rates of growth across identified 'productivity growth cycles'. The cycles are defined as the period between two 'productivity peaks', where the peaks are the local maxima above a smoothed (Henderson 11-period moving average) series of multi-factor productivity in the market sector (ABS 2005). In practice, these cycles are constructed such that there is only one weak period, usually early, in each cycle. The latest productivity cycle was for 1998-99 to 2003-04 over which economy wide labour productivity growth averaged 1.7 per cent per year.

7 See Dolman, Lu and Rahman (2006) and Eslake (2007) for discussions on productivity trends since the end of the 1990s, and Australian Government (2003) for a longer run perspective.

the trend growth rate would predict. This current deviation from trend growth is, however, not unprecedented.

The trend productivity in Chart 2 is derived by using the Hodrick-Prescott (HP) filter, a very common detrending method in macroeconomics.[8] However, the HP filter is a mathematical technique that makes no use of other economic information, whereas productivity growth is affected by the capital-labour ratio and technological progress in the long run and the business cycle in the short run. We can further enhance our understanding of recent movements in labour productivity by using a decomposition that accounts for factors related to capital deepening, trend productivity and the business cycle. This approach is derived from a Cobb-Douglas production function, which relates these factors to labour productivity.[9] The details of this analysis are discussed in more detail in Appendix A.

Our analysis suggests that after growing rapidly during the 1990s, trend productivity growth slowed in the current decade. Even after accounting for this trend slowdown, however, the relationship between output, labour and capital has sometimes been outside the usual historical experience in recent years. For example, our analysis suggests that in the September quarter 2006, labour productivity was about 1¾ per cent below the level the equation would predict.

In summary, part of the recent outcomes in labour productivity can be explained by a moderating in the rate of trend productivity growth from the high growth rates experienced in the latter half of the 1990s. Nevertheless, even after taking into account this moderation, and the trends in the level of capital, there is still a substantial part of the recent productivity outcomes that is not yet explained, so we need to turn to other approaches.

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8 The HP-filter assumes that a given time series contains a trend component and a cyclical component, and chooses as smooth a trend component that is possible while being as close to the actual observed value of the series as possible. Denoting p as the log of productivity and p* as its trend, the HP-filter satisfies the following optimisation problem.

$$\underset{P_t^*}{Min} \sum \left(P_t - P_t^* \right)^2 + \lambda \sum \left(\Delta P_t^* - \Delta P_{t-1}^{\ *} \right)^2$$

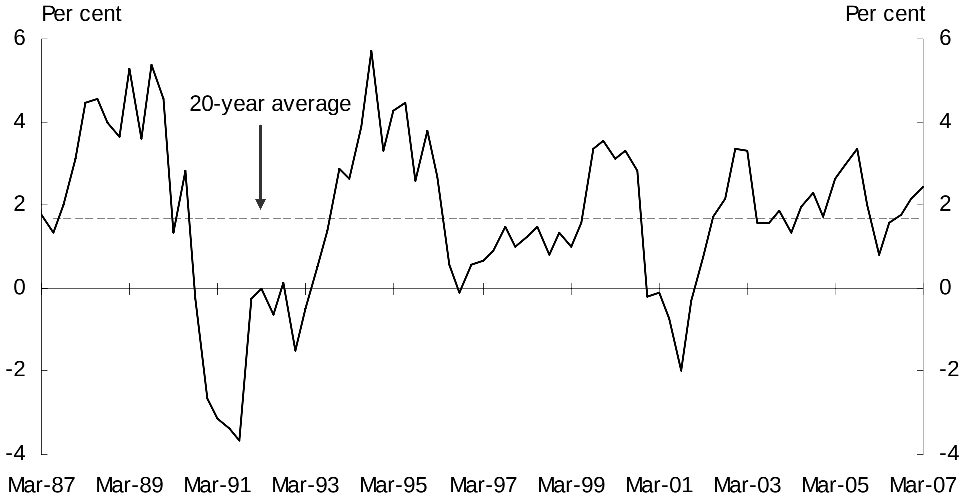
Here, the first term describes the closeness of the actual productivity to its trend; the second term shows the variability of the trend itself. The smoothing parameter λ is the relative weight given to these terms and a larger λ means a smoother trend. We follow the common practice for quarterly data and set λ =1,600 (Hodrick and Prescott 1981).

9 These estimates are an update of analysis originally undertaken at Treasury by Ben Dolman and David Gruen. Another, less theoretically grounded, approach is to augment the univariate HP-filter with other variables using more sophisticated detrending techniques (see Rahman and Tunny 2006).

Labour demand

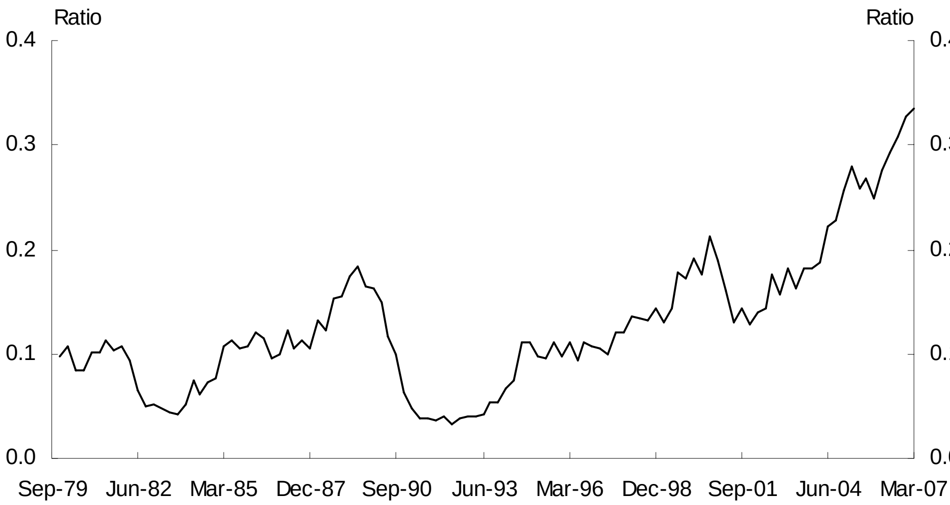
Labour input has grown rapidly in recent two years (Chart 3). This has seen the unemployment rate fall to 32-year lows and the vacancy rate (measured as the ratio of job vacancies to the number of people unemployed) rise to levels not seen in nearly three decades (Chart 4). Moreover, while wages accelerated in early 2005 they have since settled at around 4 per cent annual growth.

Chart 3: Through-the-year growth in labour input (hours worked)



Source: ABS National Accounts.

Chart 4: Job vacancies per unemployed person

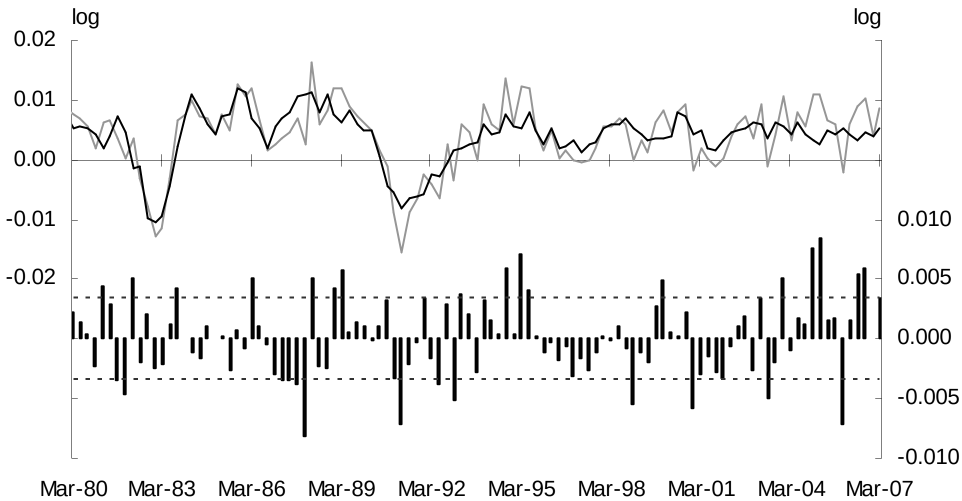


Source: ABS Labour Force, ABS Job Vacancies.

One way to examine whether the growth in labour input is consistent with current economic conditions is through a labour demand equation. In this analysis we use a full-time equivalent measure of labour input rather than a 'heads' measure of employment. A labour demand equation relates the growth in labour input to the growth in output, and importantly, to the growth in real labour costs or wages. This equation captures the longer run relationship between labour, output and wages as well as shorter dynamics driven by lags between output growth, wages and labour. This equation also allows us to take account of changes in the long term trends in labour productivity. Further details about the estimated equation and data used can be found in Appendix B.

In Chart 5, we show the predictions of the labour demand equation and the actual growth in labour input for the past 27 years. This analysis suggests that in recent years, labour input has been growing faster than we would expect given the average historical relationships between full-time equivalent employment, growth in output and changes in real wages.

Chart 5: Actual and predicted growth in labour input



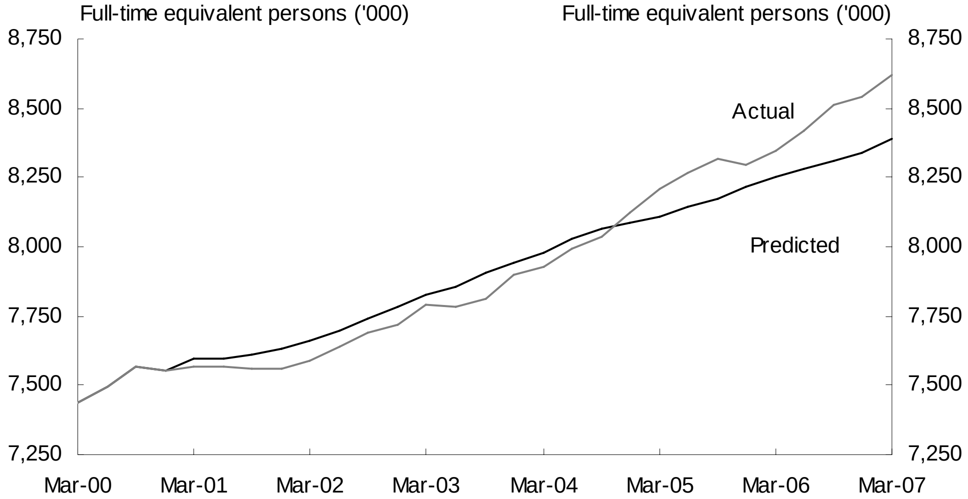
Source: Authors' calculations. The top panel, represented against the left axis, shows the predicted values (dark line) and actual outcomes (light line) for the equation, in terms of log differences. In the bottom panel, represented against the right axis, the equation's residuals (differences between actual and predicted outcomes) are shown as the bars and its standard error is shown as the broken lines.

Interestingly, our measure of labour costs or producer real wages captures the strong growth in profits in the mining sector and resultant decline in producer real wages by using an economy-wide output price that includes the increase in export prices, yet it still fails to explain fully why labour input has grown so strongly.

To illustrate the extent to which labour input has grown more strongly than historical relationships would suggest, we conducted the following exercise. We estimated the relationship up until December 2000 (with the productivity trends imposed from the full-period equation), predicted labour input thereafter, and compared this simulated outcome with what actually occurred.

The results of this exercise suggest that while growth in labour inputs was somewhat below the model prediction up until around late 2004, since then it has been significantly stronger than predicted (Chart 6). Since December 2004, (full-time equivalent) employment has increased by around 495,000, while the average relationship between employment, output and wages would suggest an increase of around 300,000.

Chart 6: Actual versus predicted labour demand, equation from December 2000



Source: Authors' calculations.

The analysis conducted thus far confirms that recent labour productivity outcomes are not explained in terms of typical macroeconomic relationships between labour input, output and the real wage. This could suggest that either measurement issues may be at play or there has been a slowing in productivity to below-trend growth rates. However, there are alternative explanations of the current outcomes. In particular, the current degree of change within the economy could be sufficiently dramatic that it is being reflected in unusual movements in macroeconomic aggregates. We explore this explanation in the following section.

The composition of growth

If we cannot explain the recent trends in productivity outcomes by the macroeconomic explanations discussed so far, can we find the answer by examining trends within individual sectors? Australia is currently experiencing a very significant increase in the terms of trade, which is having widespread effects on the economy.

Australia's terms of trade hit their highest level in over 50 years in the December quarter 2006 and continued to rise in the March quarter 2007. As is well known, the high terms of trade predominantly reflects a rapid increase in commodity prices driven in significant part by strong demand from China. The Australian economy has been responding to this rapid shift in relative prices with a massive increase in mining investment and accompanying surge in mining and construction employment.[10] In the five years to 2005-06, real mining investment rose by around 200 per cent and mining and construction employment rose by around 30 per cent. The increase in mining and construction employment accounted for around 25 per cent of the increase in employment in that period compared with their combined industry share of employment of 10 per cent.

To explore how these dramatic changes might be being reflected in measures of aggregate output growth and labour productivity we divided the economy into three sectors: mining and construction; the market sector excluding mining and construction; and the non-market sector.

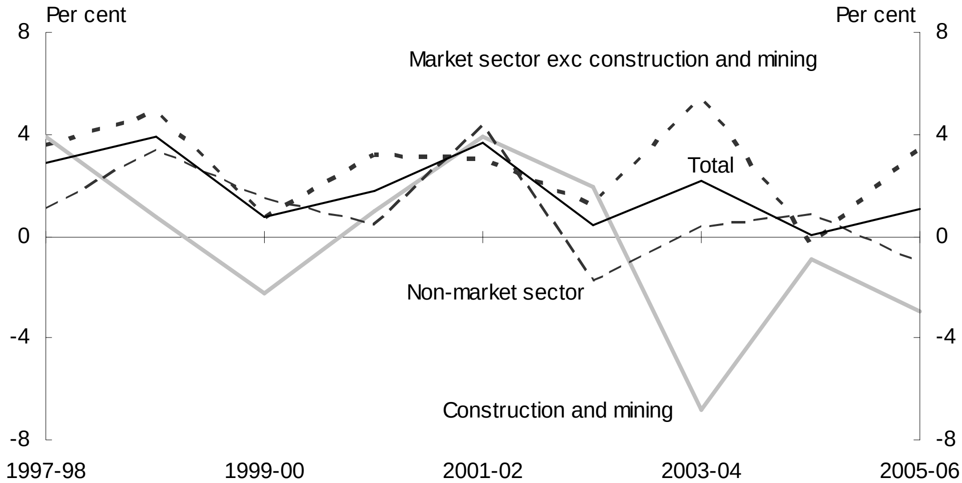
While examining the mining and construction sector separately from the rest of the economy seems an obvious step given the rapid changes in commodity prices, dividing the rest of the economy between the market and non-market sectors may not seem so obvious. The non-market sector is comprised of those parts of the economy where output is difficult to measure. It includes industries such as health, education, and government. In some parts of the non-market sector such as the provision of health and education services, it is difficult to measure output because it is not priced and sold into a market, while in other parts (such as business services) it is difficult to disentangle price and volume movements from overall turnover. It is for these reasons that the ABS does not publish estimates of productivity for these industries, and given the acknowledged output measurement issues it is worth considering them separately from the rest of the economy when examining changes in economy-wide labour productivity.

Chart 7 shows growth in labour productivity for mining and construction, the market sector excluding mining and construction, and the non-market sector. It is immediately

10 Mining and construction are considered together as much of the increase in mining-related investment represents activity being undertaken by the construction sector.

apparent from the chart that much of the slowdown in productivity in recent years is due to low productivity growth overall in 2004-05, and low productivity growth in the non-market sector and mining and construction in 2005-06.

Chart 7: Labour productivity in selected sectors



Source: ABS National Accounts and authors' calculations. Calculations are made at producer prices, and so total productivity growth rates may differ from those published by the ABS.

To explore further how changes in different industries and sectors are contributing to the overall change in productivity we conducted a shift-share analysis (see Appendix C for details). The total contribution of each industry or sector to the change in overall productivity reflects two components. First, the extent to which changes in within-industry productivity contributed directly to changes in productivity. Second, the degree to which the movement of labour between industries with relatively low productivity levels and industries with high productivity levels contributed to productivity change (a composition effect).

Table 1 shows the results of this exercise for the three sectors considered in this paper. For example, because mining has a relatively high level of productivity, an increase in the share of labour going to mining will increase overall productivity. In fact this was the case in 2005-06, as can be seen in Table 1, but because the change in productivity within mining was large and negative, this more than completely offset the positive composition effect, leading to mining's overall contribution to productivity being negative.

Table 1: Industry decomposition of labour productivity growth

	2004-05			2005-06		
	Total	Productivity growth within industry	Industry share of hours worked	Total	Productivity growth within industry	Industry share of hours worked
Total economy	**0.05**	**-0.15**	**0.20**	**1.03**	**-0.01**	**1.04**
Market sector	**-0.26**	**-0.41**	**0.16**	**1.46**	**0.34**	**1.11**
Mining & Construction	**-0.04**	**-0.28**	**0.24**	**-0.32**	**-1.01**	**0.69**
Mining	0.06	-0.24	0.30	-0.52	-1.27	0.75
Construction	-0.11	-0.04	-0.06	0.20	0.26	-0.06
Other	**-0.21**	**-0.13**	**-0.08**	**1.78**	**1.35**	**0.42**
Non-market sector	**0.31**	**0.26**	**0.04**	**-0.43**	**-0.35**	**-0.08**

Source: Authors' calculations based on ABS National Accounts and unpublished data. Calculations are made at producer prices, and so total productivity growth rates may differ from those published by the ABS.

In 2004-05, a fall in market sector productivity largely offset the positive contribution from the non-market sector. The market sector detracted around a ¼ of a percentage point from total labour productivity growth. Within the market sector, mining made a small positive contribution, with the share effect outweighing the fall in within-mining productivity.

In 2005-06, the non-market sector and the combined mining and construction sector dampened labour productivity. The non-market sector subtracted around ½ of a percentage point from productivity growth, with both components of the decomposition falling. The mining and construction sector subtracted around 0.3 of a percentage point in 2005-06 as a fall in within mining productivity more than offset a strong positive contribution due to an increasing share of employment. The fall in mining sector productivity was due in large part to capital shallowing (see the box on the following page).

The following exercise illustrates the contribution that the non-market sector and mining and construction are making to slow productivity growth, particularly over the past year. If we set productivity in these two sectors to their trend rates of growth and hold employment shares constant, productivity growth in 2005-06 would have been slightly above its long-run trend.

Capital deepening and labour productivity

The Cobb-Douglas framework used earlier in this paper shows the contribution of labour, capital and productivity to economic growth at an aggregate level. Using this framework we can also examine at an industry level the contribution to labour productivity growth from multi-factor productivity (MFP) and capital deepening/shallowing.

Labour productivity growth = MFP growth + Capital deepening/shallowing effect

The current terms of trade shock that Australia is experiencing is influencing the allocation of capital and labour among industries (Kennedy and Garton 2007, Henry 2006). According to the most recent Annual National Accounts, capital services to the mining industry grew by 13.5 per cent over the past two years. But at the same time, mining labour input grew by an astonishing 31.7 per cent. As a result, the amount of capital provided per worker has fallen in the mining sector, that is, the mining sector has experienced capital shallowing.

To calculate the effect that capital shallowing is having on mining sector labour productivity, we decomposed the contribution of within-industry productivity growth in Table 1 into MFP growth and capital shallowing/deepening contributions. Over the past two years within-industry mining productivity declines have subtracted around 1.3 percentage points from overall productivity growth. Of this decline, almost ¾ of a percentage point was due to the capital shallowing effect.

Table 2: Decomposition of within-industry productivity growth contributions to total productivity growth

	2004-05				2005-06			
	Total productivity growth	Productivity growth within industry		Industry share of hours worked	Total productivity growth	Productivity growth within industry		Industry share of hours worked
		MFP growth	Capital deepening			MFP growth	Capital deepening	
Market sector	**-0.26**	**-0.82**	**0.41**	**0.16**	**1.46**	**-0.36**	**0.70**	**1.11**
Mining & construction	**-0.04**	**-0.06**	**-0.23**	**0.24**	**-0.32**	**-0.55**	**-0.46**	**0.69**
Mining	0.06	-0.02	-0.22	0.30	-0.52	-0.81	-0.47	0.75
Construction	-0.11	-0.04	-0.01	-0.06	0.20	0.25	0.01	-0.06
Other market sector	**-0.21**	**-0.76**	**0.63**	**-0.08**	**1.78**	**0.20**	**1.16**	**0.42**

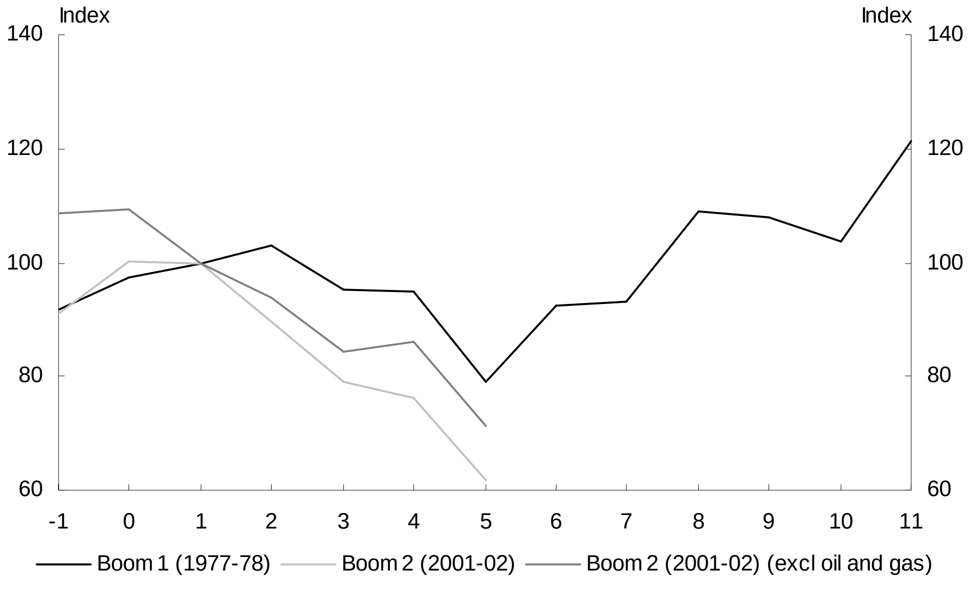
Source: Authors' calculations based on ABS National Accounts and unpublished data. Calculations are made at producer prices, and so total productivity growth rates may differ from those published by the ABS.

What then should we make of low productivity growth in the non-market sector, and mining and construction? It is difficult to analyse the non-market sector given the acknowledged difficulties in measuring output in this sector. For example, the education sector subtracted 0.3 of a percentage point from productivity growth in 2005-06. The output of the education sector is measured using student numbers, so any decrease in student-teacher ratios (smaller class sizes) will be reflected in the national accounts as a fall in productivity.

A more fruitful analysis can be made of the productivity trends in the market sector, and, in particular, falling productivity in the mining sector. As noted earlier, in response to a large increase in commodity prices there has been a rapid increase in investment and labour in the mining sector. However, this is yet to be reflected in higher output. Gruen and Kennedy (2006) compared the current mining boom with the previous boom in the late 1970s and early 1980s and noted that it took around five years for the increase in mining investment to be translated to high growth in output. Furthermore, declining production in the oil sector (which has relatively high productivity within the mining sector) has also subtracted from productivity growth in mining.

In Chart 8, we compare the labour productivity of this and the previous mining boom and adjust for the contribution of oil and gas to the decline in productivity seen over the past four years. Clearly, the experience of the two booms is similar, particularly after we account for the effects of oil and gas production.

Chart 8: Labour productivity in two mining booms



Note: Year 1 = 100 each boom (the first year of double-digit investment growth).
Source: ABS National Accounts, ABARE, and authors' calculations.

While we have isolated some significant factors that help explain recent productivity outcomes, it could be argued that at any time some industries are experiencing poor productivity growth while others experience strong productivity growth, leading to around average productivity growth. However, the effect of mining and construction seems to be relatively large compared with history. Moreover, the current unusual circumstances surrounding the mining boom are also being reflected in strong public revenues and this may be part of the explanation for why employment growth in the non-market sector, particularly in the health and community services industry, has been strong.[11] In combination, these factors go at least some of the way to explaining recent labour productivity outcomes.

Summary

Labour productivity trends over recent years have been unusual. There are a number of factors at play that partly explain the unusually low growth in labour productivity.

First, low relative labour costs in mining and construction industries (reflecting a rapid increase in the price of their output) are encouraging very strong demand for labour in these sectors. Moreover, output growth in the mining sector has been weak due to a combination of declining oil and gas production and what appear to be long lags between increases in inputs in the mining sector and stronger output growth.

Second, the non-market sector accounted for a larger-than-average proportion of growth in employment in 2005-06. As this sector's measures of productivity are not reliable, the strong employment growth in this sector may have been confounding the overall productivity picture.

This suggests that because of the unusual circumstances surrounding the economy, changes in productivity have been difficult to interpret. This also suggests that it is too early to read much into the slowdown in productivity over recent years.

11 Health and community services accounted for 39 per cent of the total increase in hours worked in the non-market sector over the past two financial years, with property and business services accounting for a further 36 per cent.

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APPENDIX A

Cobb-Douglas decomposition of productivity growth

We assume that in the long run output can be represented by a Cobb-Douglas production function, with constant returns to scale and steady, exponential technological change over time (1).[12]

$$Y_t = AK_t^{\alpha} L_t^{(1-\alpha)} e^{\delta t} \tag{1}$$

Here Y is output, L is labour input, K is capital input, α is the importance of capital in the production process (and in a competitive economy, it is capital's share of national income) and δ is the exogenous rate of technological change. We can rearrange (1) to express labour productivity ($P = Y/L$) in terms of the capital-labour ratio ($\Gamma = K/L$) and the technology available at a given point in time (2).

$$P_t = A\left(\Gamma\right)^{\alpha} e^{\delta t} \tag{2}$$

Taking logs of (2) yields the following linear relationship between the log levels of output, labour, capital and technology (3).

$$p_t = a + \alpha k_t + \delta t \tag{3}$$

Here p is the log of productivity, and k is the log of the capital-labour ratio.

We estimate (3) using quarterly data. Our measure of productivity is the ABS index of GDP per hour worked. For the capital-labour ratio, we take the ratio of a capital services index for the whole economy derived from the ABS market sector capital services index and the ABS index of hours worked in the whole economy. To reflect the observed patterns of medium-term productivity growth rates, we allow for breaks in the trend rate of technological growth in December 1981, June 1990 and September 2000.

12 In estimation, the assumption of constant returns to scale was tested and accepted by the data. The model also assumes constant capital and labour elasticities of output (and constant capital and labour shares of income).

Table A1 decomposes the estimated productivity growth between these periods in terms of the contribution of capital deepening and technological progress (interpreted as growth in multi-factor productivity in the table).

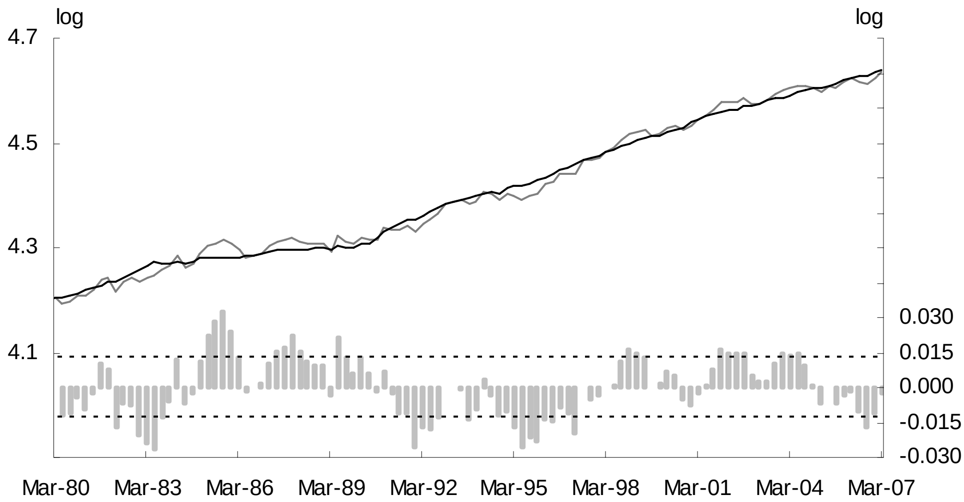
Table A1: Decomposing medium-term productivity growth

	Capital deepening	Contribution of capital deepening α = 0.32	Multi-factor productivity growth	Labour productivity growth
Sep 1978 to Dec 1981	2.0	0.6	1.1	1.7
Dec 1981 to Jun 1990	1.1	0.3	0.5	0.9
Jun 1990 to Sep 2000	1.9	0.6	1.6	2.2
Since Sep 2000	2.5	0.8	0.9	1.7

Source: Authors' calculations.

Chart A1 compares the actual log labour productivity with our estimates and shows that in recent quarters, actual productivity levels have been below those implied by the historical experience.

Chart A1: Actual and predicted log productivity

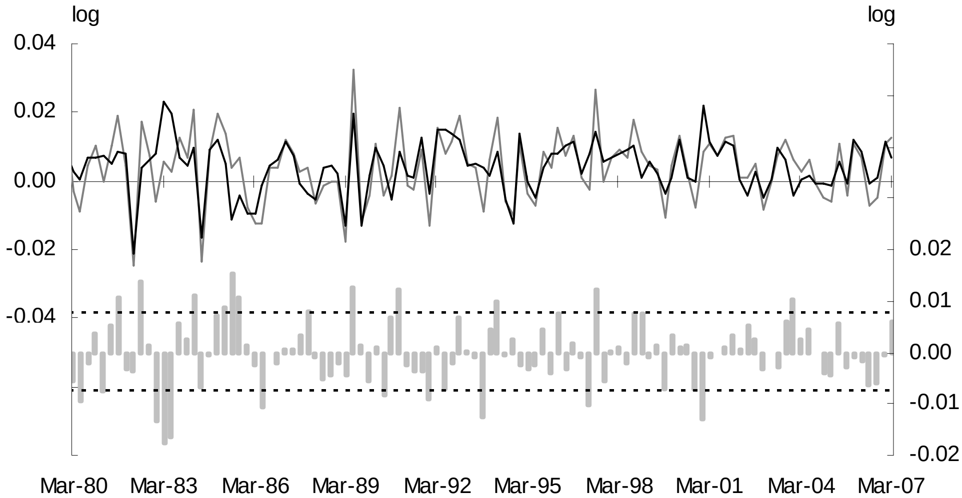


Source: ABS National Accounts, authors' calculation. The top panel, against the left axis, shows the predicted values (dark line) and actual outcomes (light line). In the bottom panel, represented against the right axis, the equation's residuals (difference between actual and predicted outcomes) are shown as the bars and its standard error is shown as the broken lines.

Productivity and the capital-labour ratio wander over time. Therefore, to maintain the long-run relationship, we would expect these recent deviations from this relationship to affect the subsequent rate of growth in labour productivity. This suggests estimation of a short-term equation within an error-correction framework. Short-run growth in labour productivity will differ from this long-run linear trend according to the stage of the business cycle. For example, during economic slowdowns firms hoard labour to mitigate hiring and firing costs and retain firm-specific skills. Alternatively, the economy may experience pro-cyclical short-term technology shocks. As an indicator of the business cycle, we use quarterly changes in the capacity utilisation measure published by the National Australia Bank.

Chart A2 compares the actual quarterly changes in log labour productivity (that is, quarterly growth rate in productivity) with our estimates and shows the difference between these two series. It appears that in recent quarters, actual productivity growth has been somewhat below what would be implied by the model, but these differences have usually not been significant.

Chart A2: Actual and predicted differences in log productivity



Source: Authors' calculations. The top panel, represented against the left axis, shows the predicted values (dark line) and actual outcomes (light line) for the equation, in terms of log differences. In the bottom panel, represented against the right axis, the equation's residuals (difference between actual and predicted outcomes) are shown as the bars and its standard error is shown as the broken lines.

APPENDIX B

Labour demand equation

We continue to assume that in the long run, output can be represented by the Cobb-Douglas production function (1).

$$Y_t = AK_t^{\alpha} L_t^{(1-\alpha)} e^{\delta t}$$

We assume that the representative firm uses this production function to maximise profit, $\prod$, subject to the price it receives for its output (denoted ξ) and the ones it has to pay for the inputs (wage, *W*, for the use of labour, and interest, *i*, for the use of capital). Equation (4) describes the firm's profit function.

$$\prod{}_t = \xi_t AK_t^{\alpha} L_t^{(1-\alpha)} e^{\delta t}{}_t - W_t L_t - i_t K_t \tag{4}$$

Differentiating $\prod$ with respect to *L* yields the following first-order-condition (5).

$$(1-\alpha) Ae^{\delta t}{}_t \left(\frac{K_t}{L_t} \right)^{\alpha} = \frac{W_t}{\xi_t} \tag{5}$$

We can rearrange (5) and use (1) to solve for *L*. This yields the equation (6).

$$L_t = (1-\alpha) Y_t \Big/ \frac{W_t}{\xi_t} \tag{6}$$

Taking logs of (6) yields the following linear relationship between the levels of labour input, output and their prices (7).

$$l_t = a + y_t - \omega_t \tag{7}$$

Here *l* is the log of labour input, *y* is the log of output and ω is the log of the real wage paid by the firm.

We can estimate (7) using quarterly data. We construct a full-time equivalent employment series from the employment and hours worked series published by the ABS Labour Force Survey for the labour input. Output is GDP. For the real wage, we use a non-farm real labour cost index constructed by the Treasury.

Because labour input, output and their prices wander over time, to maintain the long-run relationship, we would expect any deviations from this relationship to affect the subsequent rate of growth in labour demand. As our interest is in the recent short-term developments, we estimate a short-term equation within an error-correction framework. This short term equation also takes account of changes in the trends in labour productivity by allowing a time trend with breaks in December 1981, June 1990 and September 2000. The results are described in the paper.

APPENDIX C

Shift-share analysis

Aggregate labour productivity is the ratio of total gross value added divided by the number of hours worked in the economy. It is a weighted average of hours worked by industry. As such, movements in labour productivity can be due to: changes in the contributions from productivity growth in each industry; the change in the share of the industry in total employment; and the interaction of these two components.

Let Y be total output, L total hours worked, Y_i be industry output, L_i be industry hours worked and s_i be the industry's share of total hours worked. So we can write economy-wide productivity at time t as:

$$\left(\frac{Y}{L}\right)_t = \sum_i \left\{ \left(\frac{L_i}{L}\right)_t \cdot \left(\frac{Y_i}{L_i}\right)_t \right\} = \sum_i \left\{ s_{it} \cdot \left(\frac{Y_i}{L_i}\right)_t \right\}$$

Hence the change in productivity between time *0* and time *1* can be written as:

$$\Delta\left(\frac{Y}{L}\right) = \sum_i \left\{ s_{i1} \cdot \left(\frac{Y_i}{L_i}\right)_1 - s_{i0} \cdot \left(\frac{Y_i}{L_i}\right)_0 \right\}$$

Now add and subtract $s_{i0}\left(\frac{Y_i}{L_i}\right)_1$ from the equation:

$$\begin{aligned}
\Delta\left(\frac{Y}{L}\right) &= \sum_i \left\{ \left[s_{i1} \cdot \left(\frac{Y_i}{L_i}\right)_1 - s_{i0}\left(\frac{Y_i}{L_i}\right)_1 \right] - \left[s_{i0} \cdot \left(\frac{Y_i}{L_i}\right)_0 - s_{i0}\left(\frac{Y_i}{L_i}\right)_1 \right] \right\} \\
&= \sum_i \left\{ \left(\frac{Y_i}{L_i}\right)_1 \cdot \Delta s_i + s_{i0} \cdot \Delta\left(\frac{Y_i}{L_i}\right) \right\}
\end{aligned}$$

Further decomposing this to refer to base period productivity:

$$\Delta\left(\frac{Y}{L}\right)=\sum_i\left\{\left[\left(\frac{Y_i}{L_i}\right)_0+\Delta\left(\frac{Y_i}{L_i}\right)\right]\cdot\Delta s_i+s_{i0}\cdot\Delta\left(\frac{Y_i}{L_i}\right)\right\}$$
$$=\sum_i\left\{\left(\frac{Y_i}{L_i}\right)_0\cdot\Delta s_i+\Delta\left(\frac{Y_i}{L_i}\right)\cdot\Delta s+s_{i0}\cdot\Delta\left(\frac{Y_i}{L_i}\right)\right\}$$

Where the first term is the 'share' effect — the effect of changing shares in hours worked; the final term is the 'productivity' effect — the effect of changing output per hour in each industry; and the middle term is the 'interaction' effect — the contributions that cannot be decomposed into one or the other.

We can rewrite the first term to take account of relative productivity without changing the results, as the total change in shares sums to zero. The other two terms do not require adjustment.

$$\Delta\left(\frac{Y}{L}\right)=\sum_i\left\{\left[\left(\frac{Y_i}{L_i}\right)_0-\left(\frac{Y}{L}\right)_0\right]\cdot\Delta s_i+\Delta\left(\frac{Y_i}{L_i}\right)\cdot\Delta s+s_{i0}\cdot\Delta\left(\frac{Y_i}{L_i}\right)\right\}$$

Table C1 shows the results of this exercise for all industries and for the three sectors considered in this paper.

Table C1: Industry decomposition of labour productivity growth

	2004-05			2005-06		
	Total	Productivity growth within industry	Industry share of hours worked	Total	Productivity growth within industry	Industry share of hours worked
Total Economy	**0.05**	**-0.15**	**0.20**	**1.03**	**-0.01**	**1.04**
Market Sector	**-0.26**	**-0.41**	**0.16**	**1.46**	**0.34**	**1.11**
Mining & Construction	**-0.04**	**-0.28**	**0.24**	**-0.32**	**-1.01**	**0.69**
Mining	0.06	-0.24	0.30	-0.52	-1.27	0.75
Construction	-0.11	-0.04	-0.06	0.20	0.26	-0.06
Other market sector	**-0.21**	**-0.13**	**-0.08**	**1.78**	**1.35**	**0.42**
Agriculture, forestry & fishing	0.13	0.09	0.05	0.38	0.34	0.04
Manufacturing	-0.34	-0.33	-0.01	0.29	0.32	-0.03
Electricity, gas & water	-0.05	-0.06	0.01	-0.07	-0.22	0.15
Wholesale trade	0.27	0.33	-0.06	0.15	0.18	-0.03
Retail trade	-0.05	0.03	-0.08	0.26	0.11	0.15
Accommodation, cafes & restaurants	-0.06	-0.01	-0.05	0.28	0.18	0.10
Transport & storage	0.12	0.12	0.00	0.09	0.09	0.00
Communication services	-0.11	-0.17	0.06	0.24	0.29	-0.04
Finance & insurance	-0.07	-0.10	0.03	0.22	0.12	0.11
Cultural and recreational services	-0.05	-0.03	-0.03	-0.06	-0.04	-0.02
Non-market sector	**0.31**	**0.26**	**0.04**	**-0.43**	**-0.35**	**-0.08**
Property and business services	-0.09	-0.07	-0.01	-0.10	-0.15	0.05
Government administration & defence	0.06	0.06	0.00	0.03	0.03	0.00
Education	0.43	0.30	0.13	-0.27	-0.20	-0.07
Health & community services	0.05	0.07	-0.02	-0.19	-0.12	-0.07
Personal & other services	-0.15	-0.10	-0.05	0.09	0.09	0.00

Source: Authors' calculations based on ABS National Accounts and unpublished data. Calculations are made at producer prices, and so total productivity growth rates may differ from those published by the ABS.