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Private Business Investment in Australia

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Abstract

The behaviour of aggregate Australian private business investment has attracted relatively little attention in the literature over the past decade or so, probably reflecting the well-known difficulties associated with modelling it. This paper reviews the main drivers of Australian business investment through a discussion of some long- and short-run trends and estimation of error-correction models for its main components. Two innovations are introduced in the modelling approach. The first is that investment in computing equipment is excluded from the models, recognising that it cannot be treated in the same way as other types of investment, particularly in light of the dramatic falls in its relative price over recent decades. The second is that standard techniques are used to exclude influential observations when modelling the short-run variation in the data as a means of accounting for the considerable volatility in these variables. This improves the robustness of the estimation. The different types of investment – equipment, building and engineering – are found to be influenced by their own idiosyncratic factors, though for each type of investment, an inverse relationship between the investment-to-output ratio and its corresponding measure of the cost of capital is found.

JEL Classification Number: E22
Keywords: Australian business investment, cost of capital, computing equipment

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PRIVATE BUSINESS INVESTMENT IN AUSTRALIA

Lynne Cockerell and Steven Pennings

1. Introduction

Despite the importance of private business investment as a determinant of the long-run growth potential of the economy and a contributor to short-run fluctuations in the economic cycle, very little empirical work has been undertaken on Australian investment aggregates over the past decade. The rare exceptions include Bond and Hernandez (2003) and Swift (2006).

This paucity of empirical work in Australia probably reflects the well-known fact that modelling investment is difficult. One reason for this is that investment is a highly heterogeneous activity. The need to model equipment and structures investment (which includes new non-residential building and engineering) separately has long been recognised, but some recent papers have also highlighted some potential sources of misspecification if computing equipment investment is not treated separately as well. This is because of the dramatic fall in the price of computing equipment over the past two decades and its relatively high rate of depreciation – in line with strong technological advances in computing. To this end, computers are removed from investment in the analysis that follows.

A second challenge arises when modelling the volatile short-run changes in investment. In this paper, standard techniques are used to exclude observations that are identified as influential in short-run regressions. This can be justified to the extent that investment is especially lumpy and/or suffers from measurement errors at a quarterly frequency. Between 5 and 10 per cent of observations are excluded from the parsimonious regressions, which is found to improve the robustness of the estimates.

Owing to the relative lack of empirical success of more recent innovations to models of investment (such as Euler equation models – see Oliner, Rudebusch and Sichel 1995), the estimations are based on the traditional neoclassical model of investment (Jorgenson 1963). In its strictest form, the traditional neoclassical model implies that the capital-to-output ratio and the cost of capital should be inversely related; however, in this paper no empirical support is found for such a relationship. Instead, we adopt an approximation of the neoclassical model suggested by Bean (1981), which implies an inverse relationship between the investment-to-output ratio and the cost of capital in equilibrium. Evidence is found to support such a relationship for the main components of investment (equipment, building and engineering).

Other relevant factors are found to influence investment (over the short run), although these vary across components. For equipment investment, swings in business confidence (a highly cyclical variable) and movements in the real exchange rate (RER) are both found to be influential. For engineering investment, movements in the terms of trade are particularly relevant. The building investment equation has the least-rich dynamics, with the error-correction term the dominant influence.

As a precursor to the modelling work, Section 2 provides a discussion of investment trends. Over a long history, the most outstanding feature has been the permanent increase in the investment share of GDP which occurred mid last century. Over the past three decades or so, better quality data allow differences across industries and types of investment to be explored. After a discussion of the methodology and empirical literature in Section 3, an empirical examination of the main components of investment is presented in Section 4. The conclusions of the paper are provided in Section 5.

2. Trends in Investment

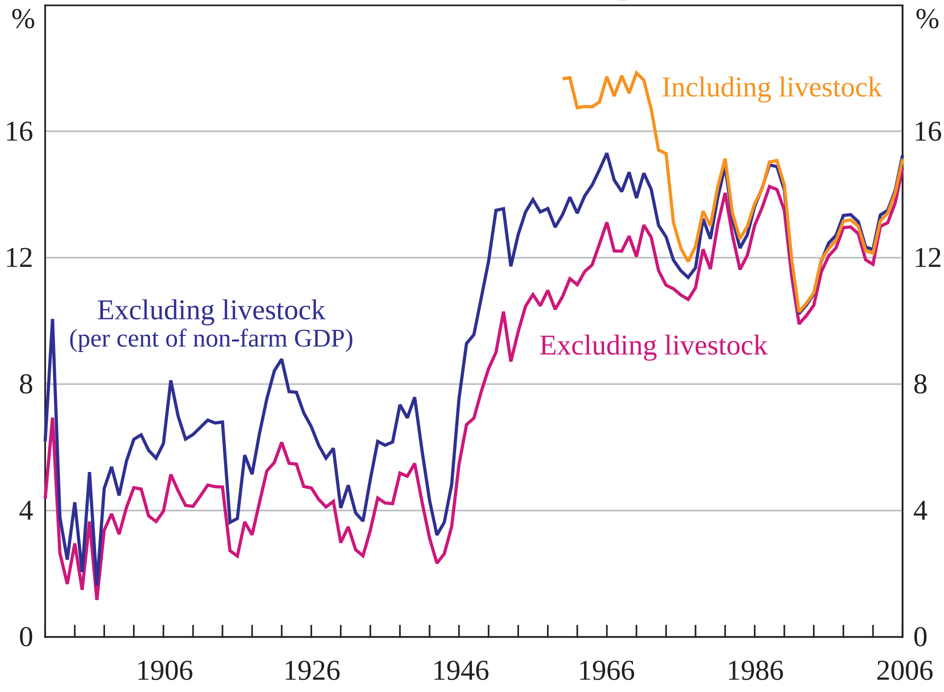
2.1 Long-term Trends in Investment

Private business investment (excluding livestock and in nominal terms) as a share of non-farm GDP increased dramatically and permanently mid last century. The investment share rose from an average of around 5–6 per cent in the first part of the century to average around 12 per cent over more recent decades (Figure 1).

A detailed discussion of the reasons for the change is beyond the scope of this paper, but a number of possible explanations for the existence or timing of the rise are briefly outlined below. First, Maddock (1987) argues that by 1945 the Australian private capital stock was substantially depleted and had aged significantly, given the distractions of two world wars and the intervening depression. This suggests that some of the new investment at the time may have been to modernise an out-of-date and depreciated capital stock. Second, investment (particularly in manufacturing industries) may have been encouraged by some of the policies of post-war governments, such as substantial trade protection for capital-intensive industries, the relaxation of capital controls and generous depreciation allowances (Maddock 1987).

Figure 1: Business Investment

Per cent of GDP, current prices



Sources: ABS; Butlin (1962); Butlin (1977); Foster (1996); Vamplew (1987); authors' calculations

Third, investment in the post-war period could have been buoyed by increases in the cost of labour, which made capital relatively more attractive. This is consistent with a rise in the capital-to-labour ratio and the real wage relative to the Hall-Jorgenson cost of capital (Figure 2).[1] Fourth, the post-war period saw the

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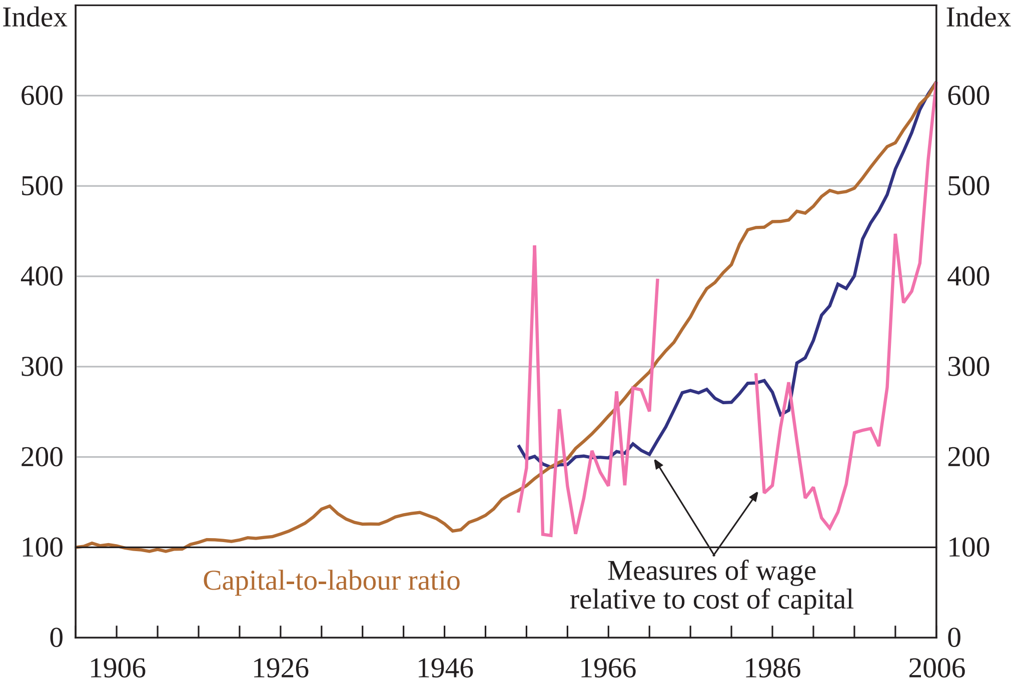
[1] See Section 3 for a discussion of the cost of capital. The measure shown in Figure 2 excludes the cost of equity due to data availability. The 1970s was a period of very low real interest rates, and hence wages relative to the cost of capital appear implausibly high. The broken series shown excludes some of this period, while the other measure excludes real interest rates altogether.

introduction (and increased popularity) of relatively capital-intensive consumer products. Similarly, new technologies often resulted in more capital-intensive methods of production for existing goods.[2]

Figure 2: Capital-to-labour Ratio



Notes: Capital-to-labour ratio is based on hours worked; 1901 = 100. Measures of 'wage relative to cost of capital' differ owing to different cost-of-capital measures used: the more volatile series includes real interest rates, the less volatile measure excludes it; the wage relative to the cost of capital is indexed to the capital-to-labour ratio in 2006. Refer to Footnote 2.

Sources: ABS; Butlin (1977); Foster (1996); Vamplew (1987); authors' calculations

2.2 Investment over the Past Three Decades

The rest of the paper focuses on investment over the past three decades or so for which reliable data are more readily available. After a brief discussion of the data underlying the econometric modelling conducted later in the paper, trends in investment by industry and by type are discussed.

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[2] The Solow-Swan neoclassical growth model suggests that along the balanced growth path the optimum investment share of GDP will be higher if technological progress is more rapid (and the capital-to-labour ratio will grow faster). Without technological change, the diminishing marginal product of capital will limit the increase in capital intensity of production brought about by (even very large) movements in relative prices (Gordon 2001).

2.2.1 Data

The main econometric models presented in Section 3 examine investment by asset type: equipment; non-residential building (such as office blocks and factories); and engineering (largely mines and infrastructure, such as roads, ports and railways). Data are quarterly over 1974:Q2–2006:Q2 for equipment, 1986:Q3–2006:Q2 for building, and 1979:Q2–2006:Q2 for engineering, with models also estimated over a shorter common sample of 1990:Q1–2006:Q2. This shorter period can be characterised both by a deregulated financial system and low inflation. Most data are available from the National Accounts, or from other sources as outlined in Appendix A. Investment by industry (Section 2.2.2) is presented annually as these data are not available quarterly.

Before proceeding with a discussion of recent trends, a few comments are necessary on the usefulness of real measures of investment. Investment theory, and some key related concepts – such as capital stocks and depreciations rates – are inherently based on real values. However, estimates of real investment can be strongly influenced by large trends in relative prices, which means that nominal and real investment shares of GDP can provide very different measures of the strength of investment spending (Figure 3, top panel).

Concerns regarding measures of real investment typically arise because of the behaviour of computing equipment and livestock, which have undergone large price changes relative to other components of investment.[3] A key concern is that the extent of the measured fall in quality-adjusted computing equipment prices may be overstated, thereby raising doubts about the strength in real measures of computing equipment investment. Computing equipment prices are quality-adjusted using hedonic techniques; however, this approach has its limitations and it is unclear whether changes to the characteristics of computers truly describe how their contribution to the productive capital stock has changed.

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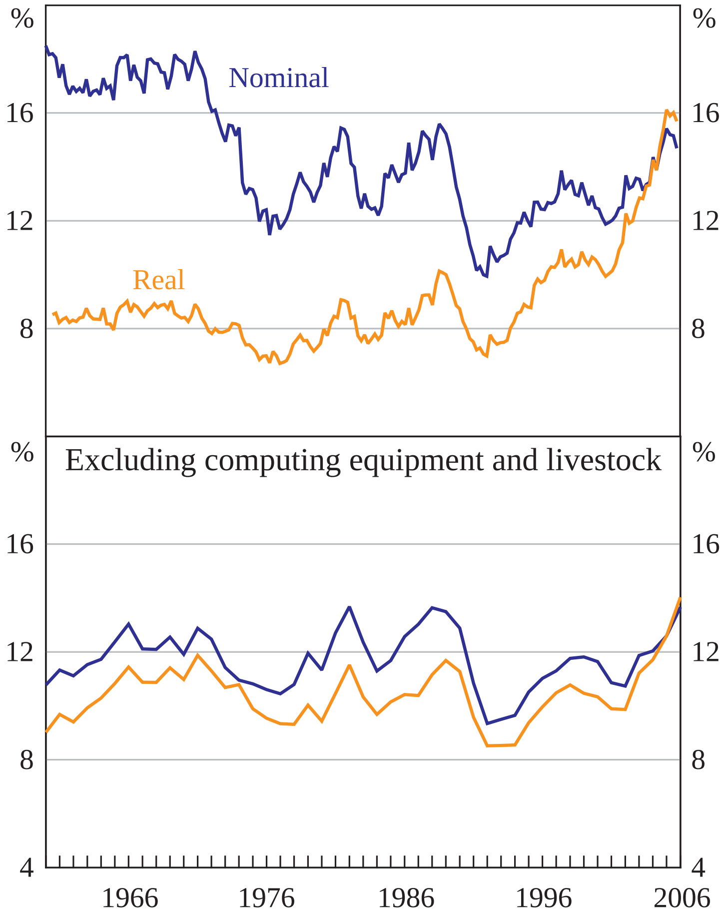
[3] The price of computing equipment in 2005/06 is estimated to be 1.9 per cent of its value in 1985/86, while the price of livestock investment is estimated to be 19.6 per cent of its value in 1965/66, with most of this fall occurring in the 1960s and 1970s (see Table B1 in Appendix B). Livestock is a separate asset type and so is not included in equipment, building or engineering investment in the modelling that follows. Intangibles investment is also excluded from the analysis.

Another concern, even when large relative price shifts are measured correctly, is that the use of chain-linking in constructing real data can produce levels estimates that do not have an intuitive interpretation. In part, this arises because chain-linking no longer guarantees that components will add to their aggregates, with this type of non-additivity being more pronounced the larger the relative price changes. Appendix B provides more detail on these issues.

Figure 3: Business Investment

Per cent of GDP



Sources: ABS; authors' calculations

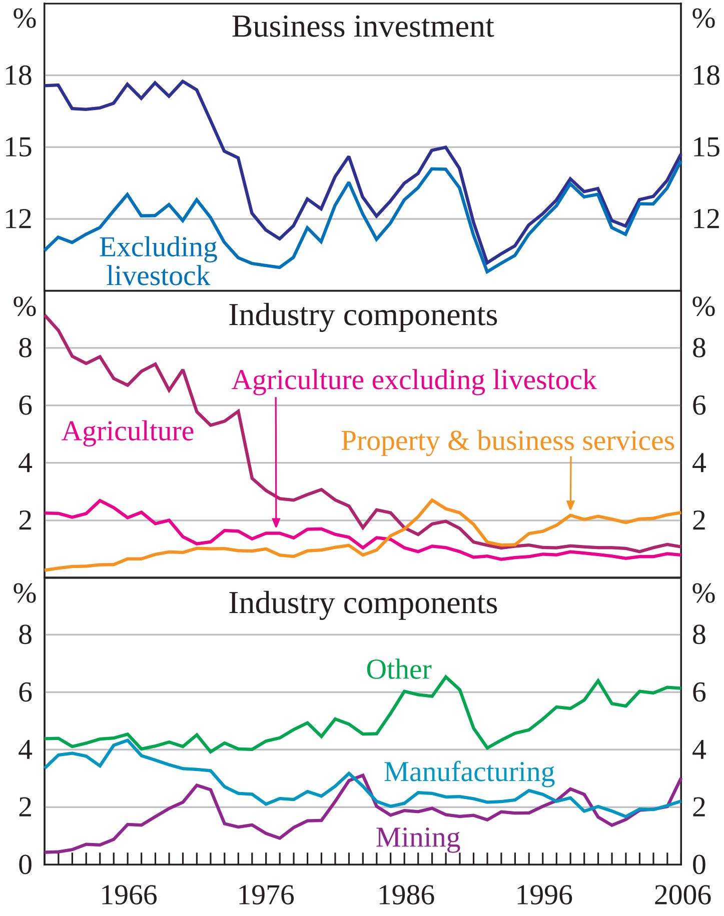
Despite these concerns about the real estimates, once computing equipment and livestock are excluded, there is little to distinguish nominal and real shares of GDP (Figure 3, bottom panel). For this reason, in what follows we exclude equipment (and livestock) from investment where possible. Separating out computing equipment investment is not straightforward when modelling quarterly investment data for Australia, since computing equipment investment data are only available at an annual frequency. In this paper, a quarterly series for non-computing equipment investment is constructed by chain-linking annual estimates and basing intervening quarterly movements on quarterly movements in total equipment investment. This is done using benchmarking procedures developed by Denton (1971) and is very similar to the procedures used by the ABS.

2.2.2 Investment by industry and type

The behaviour of investment has varied considerably across industries over the past few decades.[4] The contributions of the main industries to private investment are shown in Figure 4 (in nominal terms), along with the remaining industries shown collectively as 'other'. The mining booms of the early 1970s, early 1980s

Figure 4: Business Investment by Industry

Per cent of GDP, current prices



Sources: ABS; authors' calculations (Figures 4 and 5)

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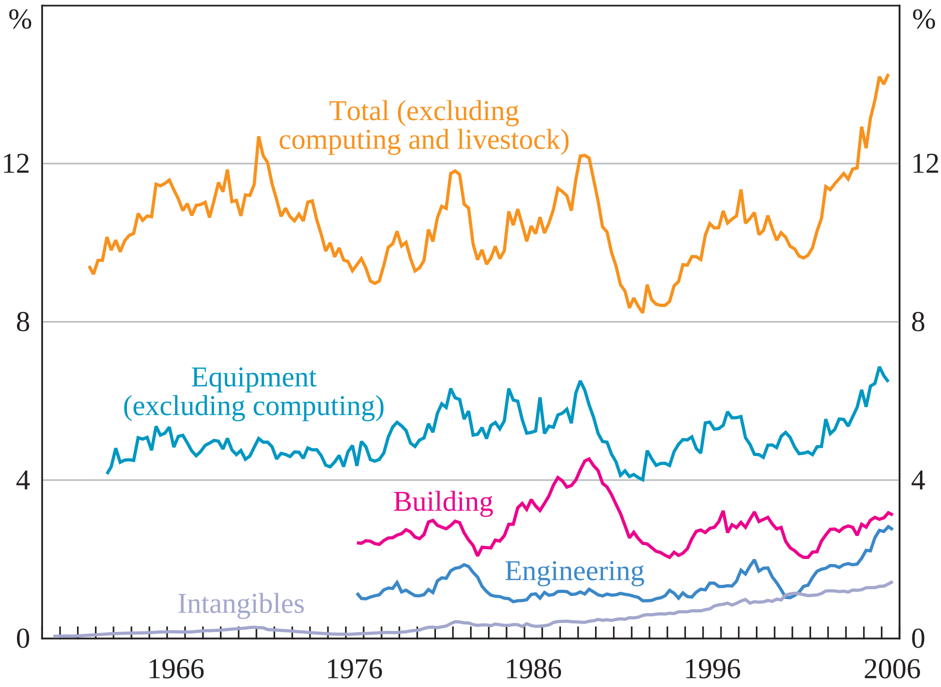
[4] Data availability prevents computing equipment and livestock from being removed from industry estimates in this section, so nominal investment shares are presented instead.

and of recent years are clearly evident. The commercial property boom and bust of the late 1980s/early 1990s is apparent in investment by the property & business services industries and those industries covered by 'other'.[5] The mining and commercial property booms can also be seen in movements of the real shares of engineering and building investment (respectively) when investment is decomposed by asset type (Figure 5).

Figure 5: Business Investment by Type

Per cent of GDP, real values



Because movements in aggregate investment reflect quite different trends and cycles at the disaggregated level, it is likely that modelling undertaken at the disaggregated level (in this paper, by asset type) may be required in order to uncover the main drivers of business investment. For interested readers, Appendix D decomposes industry components into changes in investment intensity and GDP shares, and discusses industry trends in more detail.

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[5] Property & business services and 'other' industries were also affected by a general downturn and subsequent recovery in equipment investment that accompanied the recession of the early 1990s.

3. Modelling Aggregate Investment

3.1 The Neoclassical Model

The starting point for the empirical analysis that follows is the traditional Jorgenson (1963) neoclassical model. In this model a representative firm chooses capital and other inputs to maximise profits subject to the capital accumulation identity, $K_t = (1-\delta_t)K_{t-1} + I_t$, where K_t and I_t denote the capital stock and investment respectively. The first-order condition from this problem (using a constant elasticity of substitution (CES) production function) implies that the optimal capital stock, K^*, is as follows:

$$K^* = \frac{aY}{C^{\sigma}} \tag{1}$$

where: C is the cost of capital; and σ is the elasticity of substitution between factors of production (for the Cobb-Douglas production function, $\sigma = 1$). If there are no frictions (real or financial) impeding adjustment, then the capital-to-output ratio should have an inverse relationship with the cost of capital. Even in the presence of frictions that delay adjustment of the actual stock to the optimal level given by Equation (1), the same inverse relationship should exist over the long run.

The cost of capital is measured according to the standard Jorgenson (1963) and Hall and Jorgenson (1967) formula, with the debt-equity split and present value of depreciation calculation (using the exponential method) similar to the approach in La Cava (2005). That is,

$$C_t = \left[\frac{P_{I,t}}{P_{Y,t}}\right]\left[\alpha_t\left((1-\tau_t)i_t - \pi_{Y,t}\right) + (1-\alpha_t)\left(\frac{E}{P}\right)_t + \delta_t\right]\left[\frac{1-\tau_t Z_t}{1-\tau_t}\right] \tag{2}$$

where: capital costs increase with the purchase price investment goods (relative to GDP prices) ($P_{I,t}/P_{Y,t}$); the cost of funds to the firm; the physical rate of depreciation (δ_t) and the taxation of corporate profits (τ_t is the corporate tax rate). The latter is offset to some extent by the tax deductibility of the present value of depreciation expenses (Z_t). The cost of funds to the firm is measured as a weighted average of the real after-tax business interest rate ($(1-\tau_t)i_t - \pi_{Y,t}$)

– which depends on the nominal interest rate on debt, i_t, and expected inflation (assumed to be actual inflation $\pi_{Y,t}$) – and the cost of equity, as measured by the earnings-price ratio $\left(E/P\right)_t$.[6] α_t is the share of debt financing used relative to the total of debt and equity. Naturally, there are many ways to measure these variables, and different assumptions can lead to a wide dispersion of possible measures, some of which are discussed further below. See Dews, Hawkins and Horton (1992) for an earlier discussion of issues related to the cost of capital with particular reference to Australia.

3.2 The Q Model

An alternative approach traditionally used in the investment literature is the Q model, attributable to Tobin (1969). It has since been recognised to be a variant of the neoclassical model in which costs of adjusting the capital stock are explicitly incorporated in the firm's maximisation problem (Hayashi 1982). In its modern form, the Q theory suggests a positive relationship between the investment rate and marginal Q, defined as the value of an additional unit of capital relative to its replacement cost. Q operates as a summary variable that incorporates expectations about the future returns on a firm's capital. When Q is high, firms have an incentive to invest as the expected return on capital is greater than its cost, whereas a low Q will discourage investment. In practice, marginal Q is not observable and therefore average Q – measured as the value of existing capital to its replacement cost – is typically used in its place.

3.3 Empirical Literature

There were concerted efforts to apply the neoclassical and Q models to Australian data throughout the 1970s, 1980s and early 1990s, though with mixed results.[7] A

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[6] The value of a firm (*P*) is equal to the sum of its future earnings (*E*), discounted by the cost of its equity capital (k_e); that is, $P = \sum_{t=0}^{\infty} E_t / \left(1 + k_e\right)^t$. Assuming a constant growth rate of earnings (γ) and rearranging implies $k_e = (1+g)E_0/P_0 + \gamma$. If γ is constant, k_e will move in line with *E/P*. According to Miller and Modigliani (1961), the value of the firm does not depend on whether the firm pays out earnings as dividends, or reinvests them at k_e.

[7] See Hawkins (1979) for a review of the early Australian literature. The RBA and Commonwealth Treasury worked in this area in the context of their in-house macroeconometric models (see, for example, Edey, Kerrison and Menzies 1987 and Simes 1987).

common feature of the models estimated from the early 1990s onwards was the inclusion of cash-flow variables (usually profits) (aggregate studies include Debelle and Preston 1995, (firm-level) panel data studies include Mills, Morling and Tease 1994 and La Cava 2005). Work over the past decade has been relatively scarce, particularly with regards to aggregate investment. The more recent work includes Bond and Hernandez (2003), who estimate an error-correction model based on the neoclassical framework, Swift (2006), who investigates the role of the exchange rate on manufacturing investment but does not incorporate more traditional variables, and Andersen and Subbaraman (1996), who estimate a traditional Q model.

The common theme across the literature is that output is generally an important driver of Australian investment. Cash-flow variables, where included, have also been found to be important; these are included to account for financial frictions that may inhibit the firm's ability to adjust its capital stock optimally. While significant effects have been found for price variables – mainly the real user cost of capital or Q – the size of these effects is generally small and the results are not overly robust, and they depend on issues related to the measurement of these variables. The findings of the Australian literature are overall similar to the findings from Chirinko's (1993) survey of the US literature that quantity variables are generally more important than price variables for understanding investment.

The traditional neoclassical and Q models remain the basis of most empirical papers. Their use is justified by Oliner *et al* (1995) who show that these traditional models outperform some more modern alternatives, in particular, Euler equation models. Even so, Chirinko's (1993) survey of the US literature concludes that 'the Q model's empirical performance has been generally unsatisfactory' (p 1891), while for Australia, Debelle and Preston (1995) suggest that 'Q-related variables do not appear to be good explanators of investment' (p 23). Other papers argue the importance of correctly measuring Q (which might be distorted by speculative movements in share prices, for example) in order to estimate its relevance for investment, although obtaining 'correct' measures is not easy.[8] Hence, the models in this paper are based on the traditional neoclassical model.

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[8] Andersen and Subbaraman (1996) have more success using Q models for Australia by separating fundamental movements in the value of firms from speculative movements.

3.4 Computing Equipment

Recent empirical literature highlights problems that can arise when modelling investment when it includes computing equipment. In addition to the problems created by computing equipment investment already mentioned in Section 2, Bakhshi, Oulton and Thompson (2003) show that the neoclassical equilibrium relationship, described by Equation (1), is misspecified when capital is made up of two types of goods whose prices have shifted relative to each other. Earlier work by Tevlin and Whelan (2003) also highlighted misspecification in the estimated model, but from the perspective that it was no longer correct to assume that the depreciation rate for total equipment investment is constant, as is typically the case.[9] See Appendix B for further discussion.

4. Results

4.1 The Traditional Neoclassical Long Run

The relationship between the capital-to-output ratio and the cost of capital suggested by the traditional neoclassical model is estimated separately for non-computing equipment and structures capital.[10] The exact specification is based on taking the natural log of Equation (1) and transforming it so that the dependant variable is $(k-y)$ (that is, the log difference between the real capital stock and real GDP). Structures capital is not split further into the engineering and buildings sub-components owing to data limitations. The cost of capital (also logged, c_t) is measured as described by Equation (2). With some evidence that most of the series are non-stationary (see Appendix C), these long-run relationships are modelled using cointegration techniques. Table 1 shows regression results using both OLS and DOLS, the latter being recommended by Caballero (1994) who shows that the coefficient on the cost of capital is biased towards zero when OLS is used.[11]

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[9] While the assumption of a constant depreciation rate is made explicitly in the traditional formulation of models for the investment-to-capital ratios, it is also important in the approximation made in Equation (3).

[10] Capital stock data are only available for combined public and private sectors.

[11] Using quarterly US data, Caballero (1994) finds a coefficient of –0.4 on the cost of capital when estimated by OLS, but this falls to –0.9 when estimated by DOLS using 25 lags.

Table 1: Traditional Long-run Equation

Dependant variable: $(k-y)_t$, 1975:Q2–2003:Q4

	Equipment (excluding computing)		**Structures**	
	OLS	DOLS	OLS	DOLS
Cost of capital (c_t)	0.23*** (0.05)	0.63*** (0.08)	0.12** (0.06)	0.34*** (0.06)
Number of leads	0	10	0	10
Number of lags	0	20	0	20
Cointegration tests:				
ADF	–1.90	–1.89	–0.77	–4.13***

Notes: ***, ** and * denote significance at the 1, 5 and 10 per cent levels respectively. Newey-West corrected standard errors are in parentheses. All variables are in logs. Data available until 2006:Q2, with earlier end-date allowing for leads in the DOLS regressions. ADF denotes Augmented Dickey-Fuller tests which have a null hypothesis of no cointegration. Results are compared with MacKinnon (1991) tables.

In contrast to theory, the results suggest a positive relationship between the capital-to-output ratio and the cost of capital across all models,[12] although for aggregate investment most models do not appear to be cointegrated, with the exception of the DOLS model for structures. An inverse relationship is apparent only in a few brief periods, with the capital-to-output ratio and the cost of capital otherwise positively related (Figure 6). One possible explanation for the positive coefficient is that the models are tracing out a relatively fixed upward-sloping supply curve for capital, rather than the downward-sloping demand curve; the latter being subject to substantial fluctuations as firms respond to changing expectations about the future profitability of investment (see Schaller 2006). An alternative explanation is that the capital stock is poorly measured, leading to biases in the estimation of the traditional neoclassical long run. Difficulties in finding an inverse relationship for aggregate investment are not uncommon in the literature.

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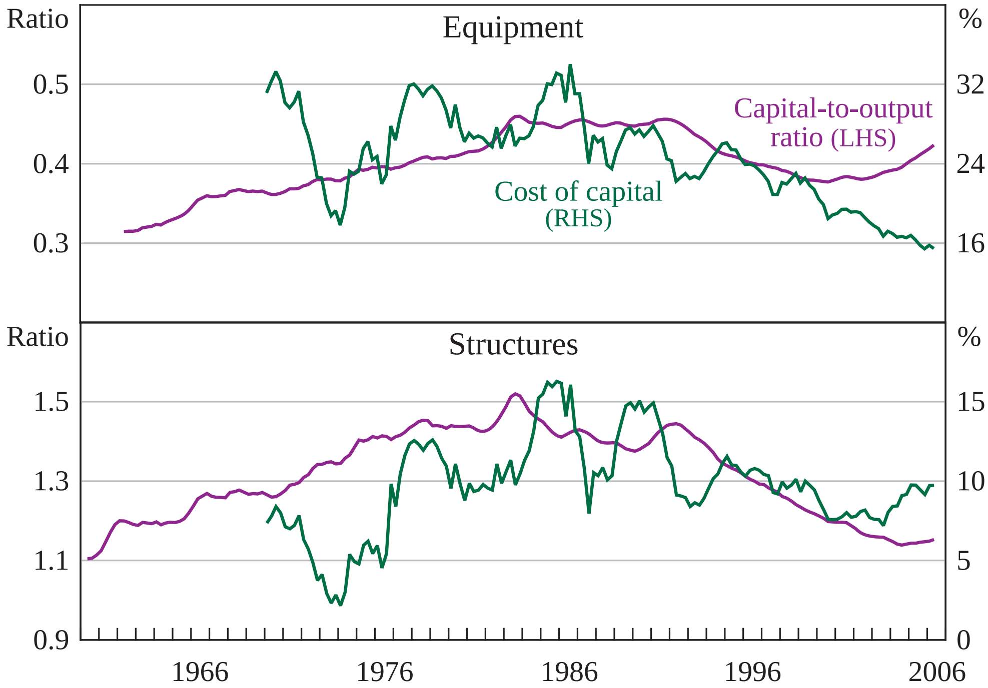
[12] These results are in contrast to La Cava (2005), who estimates a coefficient of –0.6 using Australian firm-level data.

Figure 6: Capital-to-output Ratio and Cost of Capital



Notes: Equipment excludes computing. Capital-to-output ratios are for private and public sectors combined.

Sources: ABS; authors' calculations

4.2 An Alternative Neoclassical Model

Another approach, which is adopted below and is commonly used in the literature, is to modify the traditional model so as to look for an inverse relationship between the investment-to-output ratio and the cost of capital (see, for example, Bean 1981, Bakhshi *et al* 2003 and Bond and Hernandez 2003). This transformation is due to Bean and is justified by an approximate relationship that should exist between the capital-to-output ratio and the investment-to-output ratio:

$$k - y \approx i - y - \ln\delta - \frac{g}{\delta} \tag{3}$$

where lower case variables k, i and y are logs of capital, investment and output. This approximation holds as long as growth in the capital stock (g) is small relative to the depreciation rate (δ).[13] Furthermore, if movements in δ and g are small relative to changes in $i - y$ and $k - y$, then a roughly proportionate

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[13] This assumption is likely to hold more closely for equipment investment, where the depreciation rate is large.

relationship should exist between the investment-to-output ratio and the capital-to-output ratio. This approach has the advantage that investment may be considered to be measured more reliably than capital, which is not directly observed but rather derived from the former.

Using models based on investment rather than capital allows a further disaggregation of structures investment into building and engineering investment. Unit root tests are presented in Appendix C and suggest either the presence of a unit root or an ambiguous result for investment shares and their respective cost-of-capital measures. To allow for the potential non-stationarity of the series, error-correction models (ECMs) of the following form are estimated:

$$\Delta i_t = \alpha_0 + \alpha_1 (i - y)_{t-1} + \alpha_2 c_{t-1} + \sum_{j=1}^{J} \boldsymbol{X}'_{\boldsymbol{t-j}} \boldsymbol{B_j} + \varepsilon_t \tag{4}$$

This formulation places growth in investment as the dependant variable, in contrast to the common alternative of using the investment-to-capital ratio. This is desirable as the investment growth rate is often the variable of interest to macroeconomists. However, it comes at a cost of a more volatile dependant variable, making modelling more difficult.

A vector of short-run variables, $\boldsymbol{X_t}$, is included to help explain deviations (of the level of investment) from the long-run equilibrium, which are often attributed to frictions that restrict a firm's ability to adjust immediately (such as financial frictions or physical constraints).[14] In the first set of regressions below, $\boldsymbol{X_t}$ includes only lags of investment growth, GDP growth, and changes in the cost of capital (though only from the second year to avoid potential endogeneity) as implied by the standard neoclassical model.[15]

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[14] Also, there may be an option value of waiting if investment is irreversible and future returns are uncertain (Pindyck 1991).

[15] It is possible that a spike in the price of investment goods reflects increased orders of investment goods to be delivered over coming quarters. This would lead investment and the cost of capital to be positively related, as the data trace out the supply curve rather than the demand curve. A simple way of getting around this is to only include longer lags of (changes in) the cost of capital – the approach taken here. The key results are robust to extra lags (long and short) of Δc_t.

A broader list of factors for $\boldsymbol{X_t}$ is then also investigated, including business confidence, and first differences in the real exchange rate, the terms of trade and Q. These additional variables are intended to make up for some potential difficulties associated with measuring the cost of capital, and to better capture the short-run dynamics. For example, difficulties in measuring the cost of engineering capital might lead to a role for the terms of trade in explaining engineering investment. This arises because output prices for firms undertaking engineering investment (such as mining firms) are approximated by the GDP deflator and are therefore likely to understate the fall in the relative cost of capital in the export-oriented sector when the terms of trade rises.

Lags of real corporate profit growth (as a proxy for cash flows) were also included in the short-run specification in an attempt to control for the possible dynamic impact of financial frictions. These variables are neither statistically nor economically significant (and hence not reported), in contrast to a number of existing studies (including Debelle and Preston 1995 and La Cava 2005). This might be because other investment models use a levels measure of cash flows (as a proportion of the capital stock),[16] which is not as noisy as the growth rate measure tested here.

As before, the cost of capital for equipment and engineering is measured according to Equation (2). For building, however, a term for the expected financial gain from holding capital ($E\pi_{K,t}$) is also included as follows:

$$C_t = \left[\frac{P_{I,t}}{P_{Y,t}}\right]\left[\alpha_t\big((1-\tau_t)i_t - \pi_{Y,t}\big) + (1-\alpha_t)\left(\frac{E}{P}\right)_t + \delta_t - E\pi_{K,t}\right]\left[\frac{1-\tau_t Z_t}{1-\tau_t}\right] \qquad (5)$$

This is consistent with the original Hall and Jorgenson (1967) formulation, but they assumed expectations to be static. In contrast, Tevlin and Whelan (2003) and Bakhshi *et al* (2003) model expectations as a moving average of growth in actual relative investment prices over three years and two years respectively. In Australia, expectations of capital gains appear to have been an important driver of building

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[16] The ratio of cash flows to the capital stock is used in these studies so as to be consistent with the dependant variable (the investment-to-capital ratio). However, the growth rate of cash flows is more likely to explain quarterly investment growth, which is the dependant variable used in this paper.

investment (particularly during the late 1980s commercial property boom) and so should be included in the cost of capital. However, the absence of a second-hand market in mines, ports or purpose-built equipment suggests a less important role for capital gains in motivating other types of investment. For this reason, a measure of capital gains is included only for buildings.[17]

Such a measure can be constructed in a similar way to Bakhshi *et al* (2003) and Tevlin and Whelan (2003), as an 11-quarter-centred moving average of year-ended real office price growth. However, office price growth was so rapid in the late 1980s that the implied building cost of capital becomes negative. This may reflect the omission of prices for other assets in this class of investment (factories or shopping malls for example), as well as the difficulty of capturing investors' true beliefs regarding capital gains from a measure of prices of buildings that sold in a given period. Either way, arbitrage conditions suggest that such extreme movements in office prices would not necessarily be the best measure of expected capital gains or losses.[18] To deal with this, it is assumed that half of people hold these expectations, while the other half expect real office prices to grow at their long-run average rate (which is around zero). The resulting building cost of capital is always positive and peaks much lower during the office market downturn in the early 1990s. The results of the following regressions are qualitatively similar to the alternative (11-quarter moving average) formulation.

As mentioned above, one difficulty in estimating the specification in Equation (4) is the volatility of the dependant variable. The standard deviations of quarterly growth in investment are around 6 percentage points for non-computing equipment and buildings, and around 7½ percentage points for engineering. This compares to around 1 percentage point for quarterly GDP growth. There are two potential problems as a result: the coefficients may not be very precisely estimated, but more worryingly, the coefficient estimates may be susceptible to influential observations.

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[17] Even if firms were able to sell their equipment or engineering capital, these assets are so heterogeneous, illiquid and subject to considerable adjustment costs that it is difficult to measure these prices. Cost-of-capital measures that include a measure of financial gain for equipment and engineering were examined and produced broadly similar results. The significance of the cost of capital in the equipment equation, however, was reduced.

[18] If the expected capital gain had been that high, it seems likely that investors would have bid up building prices until the expected capital gains were more reasonable.

To combat this problem, the DFFITS outlier testing methodology of Belsley, Kuh and Welsch (1980) is used.[19] For the parsimonious specifications, between 5 and 10 per cent of each sample is found to be influential and is removed from the estimated models.[20] This seems reasonable as some movements may reflect measurement error while others may be difficult to explain with a relatively parsimonious model. Models that excluded the influential observations were found to be more robust to variations in sample periods and specifications than those including all observations.[21]

4.3 Error-correction Model Results

As a prelude to the main results, Table 2 presents the results of the error-correction models based on the narrow form of $\boldsymbol{X_t}$, which includes only the variables implied by the neoclassical model. For all models, the coefficient on the cost of capital in the long run is negative (although it is not always statistically significant and its size is somewhat sensitive to alternative dynamic specifications (not reported)). An Engle-Granger test implies cointegration between investment shares and the relevant cost of capital for building and engineering investment. Significant *t*-statistics on the error-correction terms imply cointegration for equipment and engineering investment. The fit of the model is acceptable for building and

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[19] The DFFITS statistic is: $[h_t/(1-h_t)]^{0.5}e_t^*$, where $h_t = x_t(X'X)^{-1}x_t'$, x_t is t^{th} row of the X matrix of explanatory variables and $e_t^* = e_t/\left[s(t)\sqrt{1-h_t}\right]$ is the Studentised residual. Belsley *et al* (1980) recommend that an observation be treated as influential if the DFFITS statistic is greater than $2(k/T)^{0.5}$ (for k variables and T observations). However, since there is no underlying theory that justifies a particular cut-off, thresholds 20 per cent above and below the recommended cut-off were also investigated. For all parsimonious models, the size and significance of coefficients were largely unchanged using the alternative thresholds. Hence, the standard cut-off was applied. A selection of outliers using Cook's (1977) distance (a very similar methodology to DFFITS) selected similar influential observations when using the cut-off of $4/(T–K)$ as described in Fox (1991).

[20] Although an observation may be excluded from the estimation, this does not affect the long-run relationship as the investment share of GDP in following periods still includes the effects of the excluded short-run change. For example, a once-off 10 per cent spike in investment growth in an excluded period will still lead the investment share of GDP to be 10 per cent higher in the following periods.

[21] A less statistical approach would be to identify relevant events that might justify the exclusion of particular observations, for example, to account for lumpy investment items, such as aircraft.

engineering investment. The rather poor fit for equipment investment reflects the large number of insignificant coefficients in this unrestricted model.

Table 2: Investment ECM – Narrow Specification

	Equipment (1) 1974–2006	Building (2) 1986–2006	Engineering (3) 1979–2006
	Long run (dependant variable: *i*–*y*)		
Cost of capital (c)	–0.46 (–1.57)	–0.59 (–1.24)	–1.61 (–3.16)
ADF *t*-statistic[(a)]	(–2.68)	(–3.44)	(–3.99)
	Short-run results (dependant variable: Δi_t)		
Error-correction term	–0.12 (–2.74)	–0.06 (–1.55)	–0.10 (–2.67)
$\sum_{i=1}^{4} \beta_i \Delta i_{t-i}$	0.15 (0.62)	0.52 (2.45)	0.51 (3.71)
$\sum_{i=5}^{8} \beta_i \Delta c_{t-i}$	0.36 (1.70)	–0.07 (–1.05)	0.30 (2.31)
$\sum_{i=1}^{8} \beta_i \Delta gdp_{t-i}$	0.78 (0.54)	–0.21 (–0.09)	3.06 (1.96)
Adjusted R-squared	0.17	0.37	0.42
Included/total observations	119/129	71/80	103/109

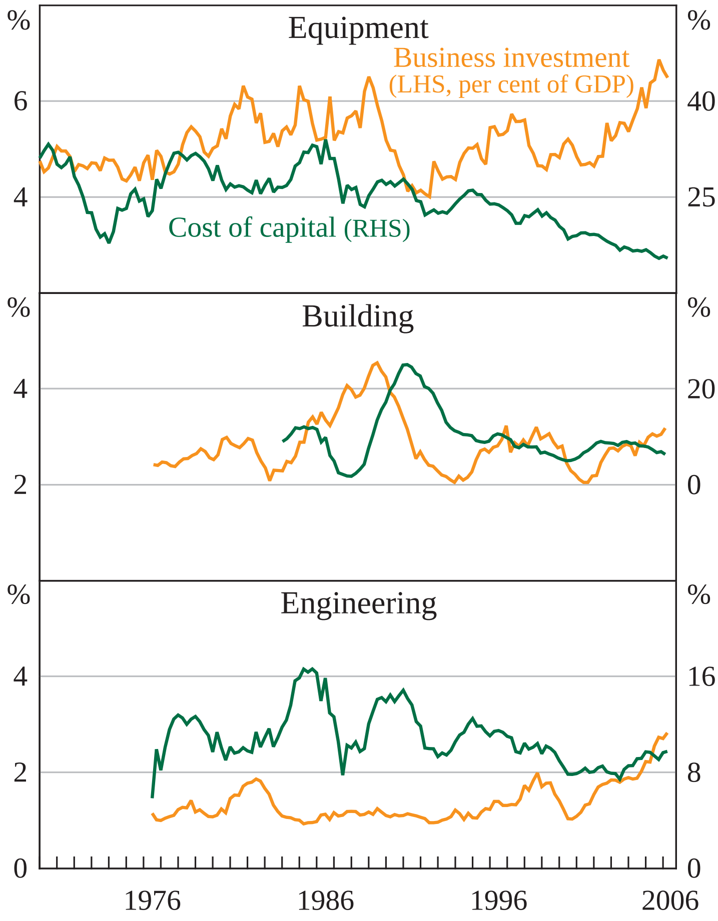
Notes: Figures in parentheses are Newey-West *t*-statistics. Sums of coefficients and associated *t*-statistics are reported. Joint tests on the sum of coefficients are significant at 10 per cent for all variables except lagged investment in Model 1.

(a) The 10 per cent critical value for the Engle-Granger cointegration test is about –3.1 (MacKinnon 1991)

Figure 7 compares investment shares of GDP with the cost of capital for the three types of investment. A loose inverse relationship is apparent for equipment. The relationship is more obvious for building investment during the boom/bust period of the later 1980s and early 1990s. The relationship for engineering is less obvious.

The results based on the broader form of $\boldsymbol{X_t}$ are presented in Tables 3, 4 and 5 for equipment, building and engineering investment respectively. The most parsimonious (and generally preferred) models are displayed on the left of each table. These are restricted forms of the more general models on the right, which are presented to illustrate the robustness of the results. The adjusted R-squared values are reported excluding the identified influential observations, rather than assuming that those observations have been perfectly predicted.

Figure 7: Investment-to-output Ratio and Cost of Capital



Notes: Investment is in chain volumes; and equipment excludes computing equipment

Sources: ABS; authors' calculations

For equipment investment (excluding computing equipment, Table 3), cointegration is found only in the shorter sample period (based on *t*-statistics for the coefficient on the error-correction terms), so the parsimonious specification for the full-sample period includes only variables in difference form (with the exception of business confidence).[22] Nevertheless, for the long sample there is a

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[22] For all investment types, the results for cointegration are not as strong when based on the Augmented Dickey-Fuller (ADF) tests on the error-correction residuals (an Engle-Granger test), but are still statistically significant for parsimonious models of building and engineering over the full sample. The stronger results of cointegration based on the significance of the coefficient on the error-correction term might suggest that any trend in the error-correction term is being compensated for by an offsetting trend in a short-run variable in the regression. Alternatively, it could reflect the low power of such tests. Also, it should be noted that distribution of the *t*-statistic for the error-correction term is uncertain, but is distributed somewhere between a Normal and Dickey-Fuller.

Table 3: Equipment (Excluding Computing) ECM – Broad Specification

	Parsimonious model (1)		Common (2)		With RER (3)		With GDP (4)	
	74–06	90–06	74–06	90–06	74–06	90–06	74–06	90–06
Long run (dependant variable: *i–y*)								
Cost of capital (c)		–0.60 (–3.25)	0.22 (0.79)	–0.77 (–2.52)		–0.35 (–4.06)		–0.24 (–2.59)
ADF *t*-statistic[(a)]		(–2.61)	(–2.04)	(–2.63)		(–2.13)		(–1.80)
Short-run results (dependant variable: Δi_t)								
Error-correction term		–0.14 (–2.94)	–0.08 (–2.64)	–0.11 (–2.04)		–0.26 (–4.35)		–0.23 (–4.52)
ΔRER_{t-2}	0.48 (6.23)	0.55 (4.62)	0.53 (7.22)	0.53 (4.85)				
$\sum_{i=1}^{8} \beta_i \Delta RER_{t-i}$					0.02 (0.07)	1.00 (2.96)	0.06 (0.23)	0.86 (3.06)
Business confidence$_{t-1}$	0.07 (9.87)	0.04 (4.36)	0.07 (9.06)	0.06 (4.65)	0.06 (6.80)	0.04 (5.51)	0.06 (6.11)	0.05 (3.25)
Δc_{t-8}	–0.16 (–2.11)		–0.17 (–2.33)	0.00 (0.00)	–0.17 (–2.34)		–0.20 (–2.52)	
Δi_{t-1}	–0.22 (–3.64)		–0.18 (–2.85)	–0.18 (–1.80)	–0.25 (–3.45)		–0.25 (–3.34)	
$\sum_{i=6}^{7} \beta_i \Delta gdp_{t-i}$	1.08 (2.44)	1.69 (2.56)	1.14 (2.91)	1.55 (2.33)	0.84 (2.21)	1.55 (2.31)		
$\sum_{i=1}^{8} \beta_i \Delta gdp_{t-i}$							–0.48 (–0.45)	1.75 (1.49)
$\sum_{i=2}^{5} \beta_i \Delta q_{t-i}$					0.06 (0.77)	0.34 (2.86)	0.11 (1.30)	0.46 (3.99)
Adjusted R-squared	0.43	0.39	0.49	0.42	0.48	0.59	0.46	0.67
Included/total observations	123/129	63/66	121/129	62/66	117/129	59/66	118/129	55/66

Notes: Figures in parentheses are Newey-West *t*-statistics. Sums of coefficients and associated *t*-statistics are reported for multiple lags. All multiple lags are jointly significant at the 10 per cent level except Q over the full sample.

(a) The 10 per cent critical value for the Engle-Granger cointegration test is about –3.1 (MacKinnon 1991)

statistically significant negative relationship between investment and the cost of capital in the short run (Model 1). In the shorter sample, the long-run coefficient on the cost of capital is close to –0.6 and is within the range suggested by international studies (see Ellis and Price 2004 and Barnes, Price and

Sebastia-Barriel 2007). Model 2 presents a common formulation for both sample periods. All of the models imply a significant role for the real exchange rate and business confidence in the short-run dynamics. The role for changes in Q is less robust across the specifications. The results with up to eight lags of GDP growth, changes in Q and the real exchange rate (Model 4) suggest possible over-fitting of the data (especially for the shorter sample period, for which the adjusted R-squared value rises substantially). Finally, the fit of the parsimonious equipment model in Table 3 is substantially better than the model presented in Table 2.

For building investment (Table 4), the extra variables of the broader specification for $\boldsymbol{X_t}$ were not found to be significant. The parsimonious Model 1 includes only a cointegrating relationship and a lagged investment term. It provides a reasonable fit of the data given the lack of short-run dynamics, with evidence of a

Table 4: Building ECM – Broad Specification

	Parsimonious model (1)		**Including Δc_t (2)**		**General (3)**	
	86–06	90–06	86–06	90–06	86–06	90–06
	Long run (dependant variable: *i–y*)					
Cost of capital (c)	–0.65 (–2.02)	–0.46 (–1.91)	–0.54 (–1.74)	–0.23 (–1.11)	–0.59 (–1.24)	0.13 (0.62)
ADF *t*-statistic[(a)]	(–3.58)	(–2.69)	(–3.72)	(–2.96)	(–3.44)	(–2.19)
	Short-run results (dependant variable: Δi_t)					
Error-correction term	–0.06 (–2.10)	–0.08 (–3.04)	–0.05 (–1.86)	–0.09 (–1.58)	–0.06 (–1.55)	–0.11 (–1.99)
Δi_{t-2}	0.26 (2.94)	0.30 (3.02)	0.22 (2.19)	0.33 (3.92)		
$\sum_{i=1}^{4} \beta_i \Delta i_{t-i}$					0.52 (2.45)	0.77 (3.25)
$\sum_{i=5}^{8} \beta_i \Delta c_{t-i}$			–0.09 (–1.77)	–0.04 (–0.41)	–0.07 (–1.05)	–0.08 (–0.91)
$\sum_{i=1}^{8} \beta_i \Delta gdp_{t-i}$					–0.21 (–0.09)	1.36 (0.58)
Adjusted R-squared	0.26	0.34	0.35	0.42	0.37	0.55
Included/total observations	76/80	62/66	72/80	61/66	71/80	61/66

Notes: Figures in parentheses are Newey-West *t*-statistics. Sums of coefficients and associated *t*-statistics are reported for multiple lags. All multiple lags are jointly significant at the 10 per cent level.

(a) The 10 per cent critical value for the Engle-Granger cointegration test is about –3.1 (MacKinnon 1991) cointegrating relationship (over the full-sample period). The coefficient on the cost of capital is around –0.5 (again consistent with a number of international studies). The speed-of-adjustment coefficient appears relatively modest, though is statistically significant. The long-run coefficient on the cost of capital is similar to that presented in Table 2, though is more significant. Additional lags of the cost of capital, investment growth and GDP growth are often not statistically significant and do not add much to the fit of the regression.

For engineering investment (Table 5), a robust cointegrating relationship is found for all of the specifications and both sample periods (based on the *t*-statistics on the

Table 5: Engineering ECM – Broad Specification

	Parsimonious model (1)		With RER (2)		With Q (3)		General (4)	
	79–06	90–06	79–06	90–06	79–06	90–06	79–06	90–06
Long run (dependant variable: i–y)								
Cost of capital (c)	–0.83	–0.81	–0.61	–0.74	–0.70	–0.78	–0.81	–1.01
	(–5.07)	(–3.62)	(–4.63)	(–3.70)	(–4.18)	(–4.26)	(–4.17)	(–2.78)
ADF *t*-statistic(a)	(–3.57)	(–2.70)	(–2.15)	(–1.46)	(–3.37)	(–2.66)	(–3.54)	(–2.96)
Short-run results (dependant variable: Δi_t)								
Error-correction term	–0.15	–0.15	–0.17	–0.19	–0.15	–0.18	–0.13	–0.15
	(–5.60)	(–5.38)	(–5.87)	(–7.38)	(–4.66)	(–6.54)	(–5.24)	(–5.63)
$\sum_{i=2}^{3}\beta_i \Delta i_{t-i}$	0.57	0.48	0.76	0.77	0.70	0.79	0.66	0.70
	(5.49)	(3.58)	(7.36)	(5.04)	(6.28)	(5.33)	(5.87)	(4.93)
$\sum_{i=5}^{8}\beta_i \Delta TOT_{t-i}$	2.59	3.52	2.76	3.06	2.16	2.31	2.07	1.88
	(6.04)	(7.82)	(6.50)	(5.55)	(3.99)	(4.42)	(4.02)	(2.39)
$\sum_{i=5}^{8}\beta_i \Delta RER_{t-i}$			0.09	1.19	–0.01	0.85	0.24	0.92
			(0.26)	(2.96)	(–0.02)	(2.23)	(0.59)	(2.29)
$\sum_{i=7}^{8}\beta_i \Delta q_{t-i}$					0.13	0.33	0.17	0.21
					(2.18)	(2.66)	(2.72)	(1.75)
$\sum_{i=1}^{8}\beta_i \Delta gdp_{t-i}$							–0.64	–1.65
							(–0.52)	(–1.07)
Adjusted R-squared	0.44	0.48	0.57	0.60	0.56	0.69	0.66	0.69
Included/total observations	99/109	61/66	100/109	64/66	101/109	61/66	97/109	57/66

Notes: Figures in parentheses are Newey-West *t*-statistics. Sum of coefficients and associated *t*-statistics are reported for multiple lags. All multiple lags are jointly significant at the 10 per cent level (except for Q over the shorter sample).

(a) The 10 per cent critical value for the Engle-Granger cointegration test is about –3.1 (MacKinnon 1991) error-correction coefficient). The long-run coefficient on the cost of capital is not significantly different from –1, the value implied by a Cobb-Douglas production function. The coefficients on the terms of trade are positive and robust across the various specifications. The fit of the models rise substantially as more short-run dynamic terms are added to the specification, but with little change in the long-run relationship or the coefficient on the error-correction term. The fit of the parsimonious model is similar to that of the model in Table 2 (measured by the adjusted R-squared), as is the significance of the cost of capital and error-correction terms (though the estimated coefficient on the cost of capital is somewhat smaller).

The coefficients on the real exchange rate are positive (but less robust), which might seem surprising given the relatively high export orientation of these firms (with an appreciation in the exchange rate reducing export revenue, other things equal). Further, it is unlikely that the exchange rate would reduce the cost of engineering investment because it has a relatively small imported component. Hence, it is likely that the positive coefficient on the real exchange rate reflects multicollinearity between the terms of trade and the real exchange rate.

Figure 8 shows the estimated dynamic response of each type of investment to a shock to the level of the respective cost of capital (equivalent to one standard deviation of the change in that cost of capital). These are based on the parsimonious models over the 1990:Q1–2006:Q2 sample.[23] The results illustrate the importance of the cost of capital for engineering investment, reflecting its relatively high long-run coefficient. The role of the cost of capital is also important for building investment, in part due to the fact that a one standard deviation shock to the building cost of capital is relatively large.[24] In contrast, the response of equipment investment to its cost-of-capital term appears relatively modest. The

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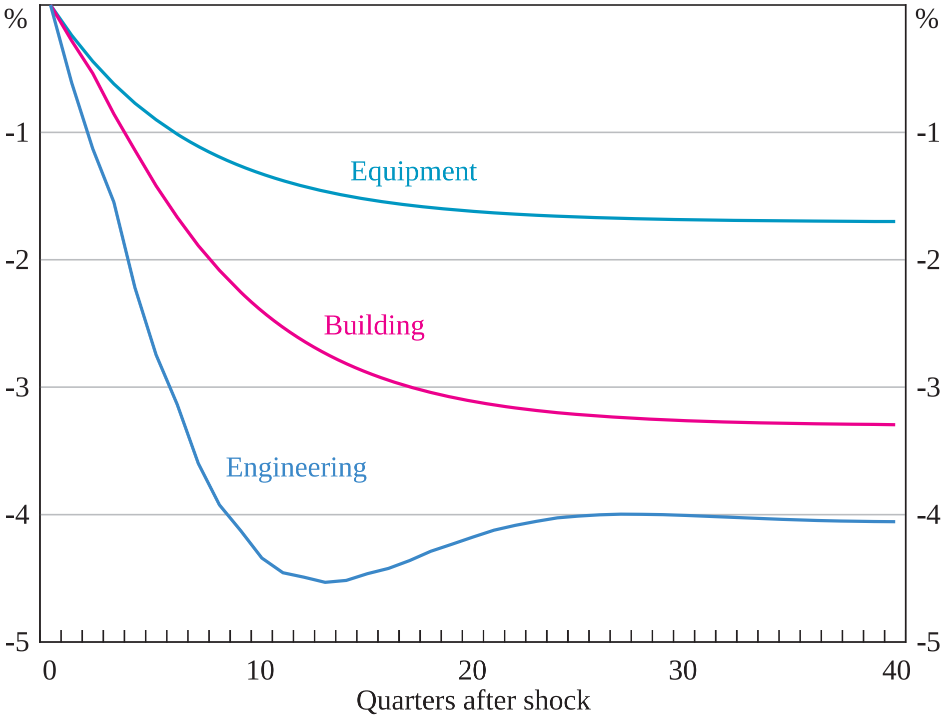
[23] Over 1990–2006, one standard deviation shocks are 2.8, 7.2 and 5.0 per cent changes in the cost of capital for equipment, building and engineering, respectively.

[24] The explanatory power of the cost of capital in the building equation in the long run is largely due to movements in expected capital gains (although it only has a 50 per cent weight). Removing the capital-gains term makes the cost of capital insignificant in the long run. This is to be expected given that the anticipation of large capital gains appears to have been one of the main factors driving the late 1980s commercial building boom. Likewise, falling property prices in the early 1990s worked to deter building investment.

adjustment of equipment and engineering investment towards long-run equilibrium is relatively rapid, compared with the adjustment of building investment.

Figure 8: Response of Investment to a Rise in the Cost of Capital

1990:Q1–2006:Q2 parsimonious models

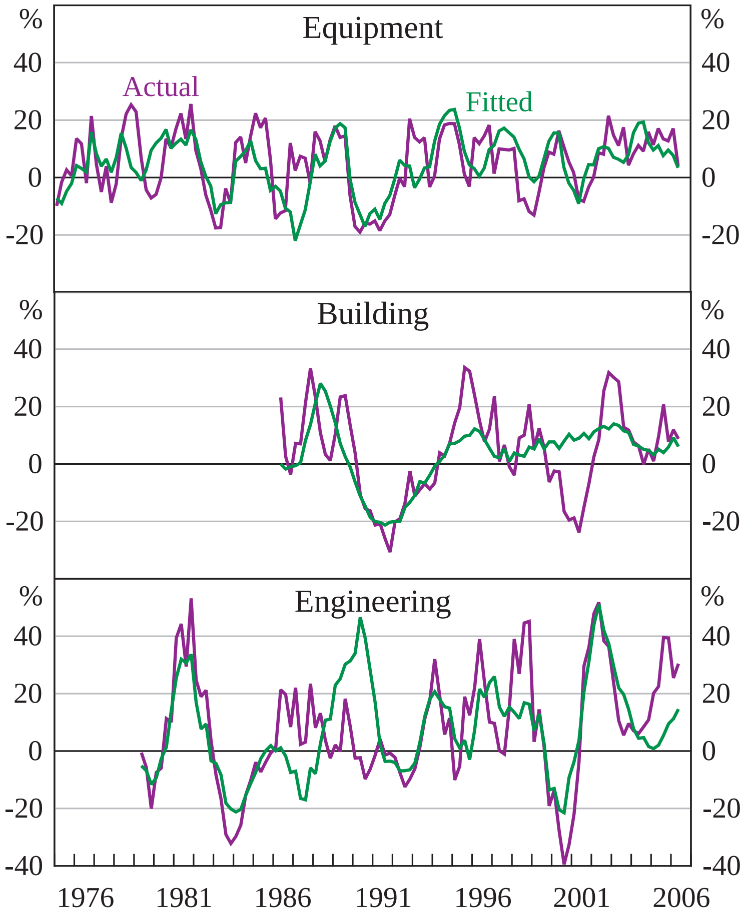


Note: Shows the deviation in levels from a shock to the cost of capital equal to one standard deviation in the change in the cost of capital

The reasonable fit of the models is shown in Figure 9, which presents year-ended percentage changes in investment along with the implied fitted values for each full-sample regression. Fitted values for the influential observations are calculated as if the general regression results hold for these observations (rather than assuming these observations are perfectly predicted). This leads to some divergences between fitted and actual values, which generally persist for four quarters given the plots are on a year-ended basis. The largest discrepancy seems to be the fall and subsequent recovery in building investment following the Sydney Olympics and the introduction of the GST. Given the one-off nature of these events, such a miss was also unlikely to be captured by standard economic factors. The relatively poor fit of engineering investment in 2005 probably reflects the large amount of road construction undertaken by the private sector on behalf of the public sector. Naturally, the model cannot explain this behaviour.

Figure 9: Actual and Fitted Values

Year-ended percentage change, full-sample parsimonious models



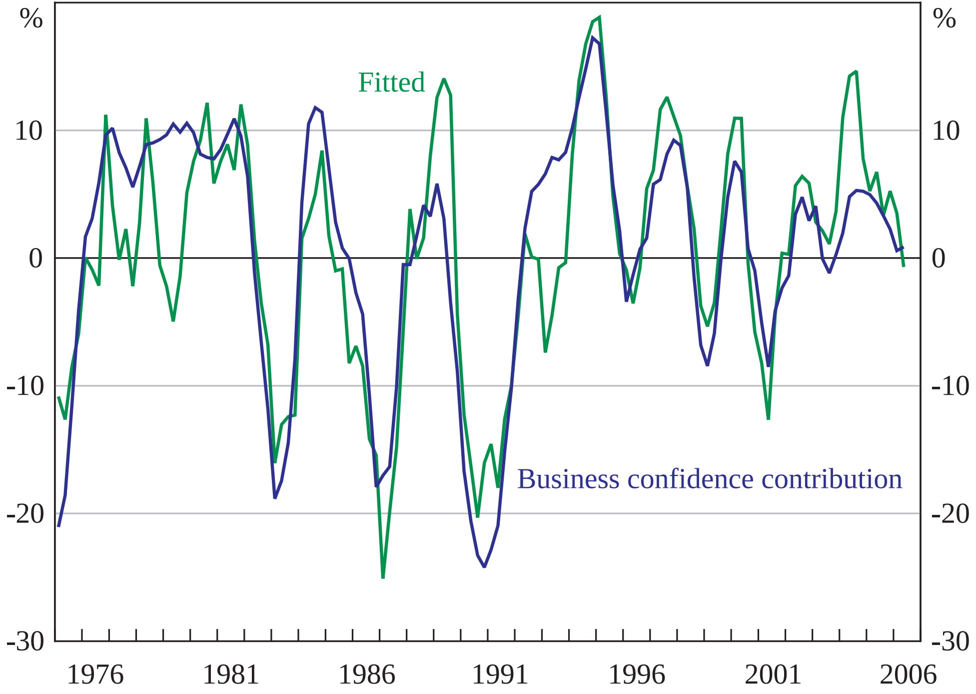
Sources: ABS; authors' calculations

The variables included to capture the short-run dynamics generally have the expected signs. Notably, for equipment investment, the models identify a powerful role for business confidence across all specifications (Figure 10 shows contributions for the full-sample parsimonious model). Business confidence appears to be capturing broader cyclical factors and taking explanatory power away from other variables.

The results also provide some evidence of a positive relationship between the real exchange rate and non-computing equipment investment. This is consistent with the possibility that when the exchange rate appreciates, firms benefit from lower prices of imported equipment, but it is worth noting that an appreciation implies tougher international competition for exporters and import-competing firms (other things equal). The results suggest that the former effect is more important, and tends to have its maximum impact after six months, with evidence of an unwinding of the effect after two years over the full sample.[25]

Figure 10: Equipment Investment

Year-ended percentage change, deviation from mean, full-sample parsimonious model



For engineering investment, all specifications identify an important role for the terms of trade in the short run (Figure 11). A 10 per cent increase in the terms of trade is estimated to increase investment by around 25 per cent within eight quarters.[26] There is also a small role for increases in Q.

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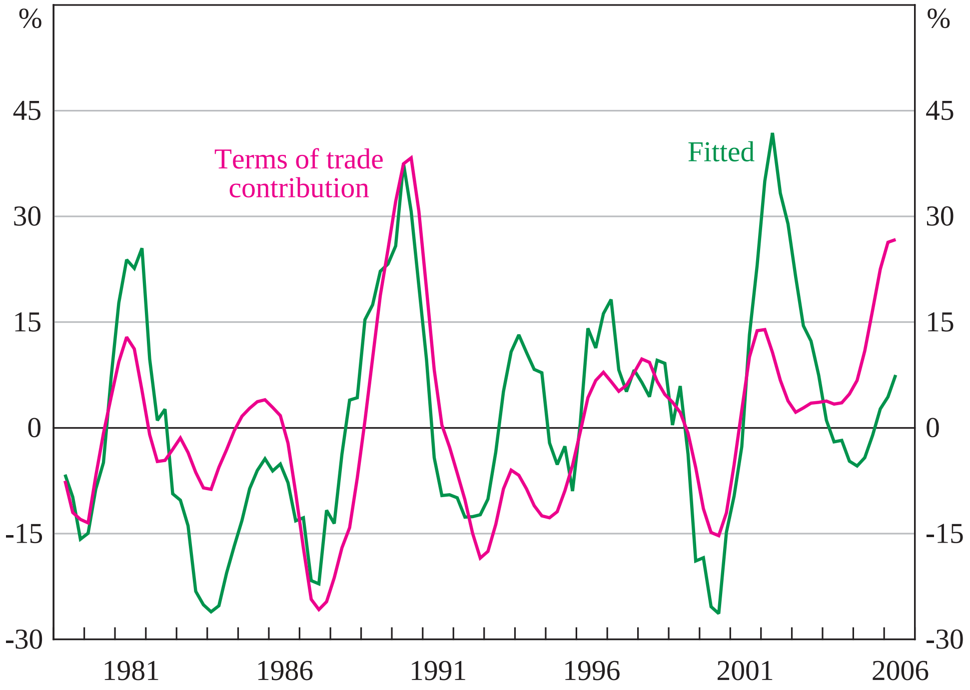
[25] This result is in contrast to Swift's (2006) finding of an overall negative effect of an exchange rate appreciation on aggregate manufacturing investment. However, she does find both positive and negative responses when looking at individual manufacturing subdivisions.

[26] Although the terms of trade makes an important contribution to the engineering equation, the estimated elasticity on the cost of capital is robust to the exclusion of this variable over the full sample.

Figure 11: Engineering Investment

Year-ended percentage change, deviation from mean,
1979:Q2–2006:Q2 parsimonious model



4.4 Further Robustness Tests

Four further tests of the robustness of the results were examined. First, the parsimonious models for each investment type were estimated including identified influential observations. For equipment, all of the key variables (such as the cost of capital, business confidence and the real exchange rate) are significant at the 1 per cent level, with largely unchanged coefficients. Similarly, key variables in the engineering equation (the cost of capital and the terms of trade), have largely unchanged coefficients and remain highly significant. Over the full sample, the coefficient on the cost of capital in the building equation falls by less than one standard error, and is still significant at the 10 per cent level. This suggests that the main results of the paper are robust to the inclusion of influential observations. Nonetheless, excluding influential observations is important for avoiding spurious relationships when testing various specifications of the model.

Second, in an unrestricted model, with up to 8 lags of each variable in the short-run dynamics, there may be a lack of degrees of freedom and a risk of over-fitting the data. One way around this is to consider regressions with coefficients on adjacent lags of the same variable restricted to be equal (as in Gordon 1997). The key results discussed above are generally robust to these restrictions being placed on lags of GDP, the cost of capital, Q, terms of trade and the real exchange rate.

The third extension was to consider the potential role of the privatisation of former government trading enterprises in driving the estimated relationships for private investment considered in Section 4.3. The reclassification of the investment of these public enterprises might cause the long-run private investment share to trend up during the 1990s, a period of considerable privatisation. To test this, the cumulative value of privatisations as a share of stock market capitalisation can be included as part of the long-run relationships in each of the preferred models. In all models, this variable is statistically insignificant and the size of the estimated coefficients on the cost-of-capital variables did not change substantially.

A fourth extension was to examine results including a time trend in the long-run relationship. As well as being an alternative means of controlling for trends such as privatisation, this could also help to control for possible trends in investment in non-computing equipment (as a share of GDP), in light of the rise in the prominence of computers in a wide range of business activities over this period (which could have led to substitution away from non-computing investment, for example). This inclusion does not affect the size or significance of the cost of capital and error-correction term in the building and engineering models over the full sample, with some of the shorter sample results being less robust. For equipment, the coefficient on the cost of capital is still negative, but smaller and statistically insignificant (reflecting collinearity between the cost of capital and a time trend in the post-1990 sample). Nonetheless, the time trend is statistically insignificant for all models.

5. Conclusions

The modelling work in this paper shows that it is possible to explain a sizeable proportion of the variation in aggregate Australian business investment using models that make economic sense. However, this has only been possible by introducing two innovations. The first has been to recognise the special nature of computing equipment and to exclude it when estimating models of equipment investment. The second has been to exclude outlying or influential observations from the estimation, recognising that regression models may not be able to explain all the extreme short-term movements in the data.

The modelling work makes two key points about the determinants of Australian business investment. First, there is a significant negative long-run relationship between the investment share of GDP and the cost of capital for all types of investment. In contrast, the traditional neoclassical long-run model – based on an inverse relationship between the capital-to-output ratio and the cost of capital – fails for Australian data over the sample periods considered.

Second, the other determinants of investment vary considerably across different types of investment. For equipment investment, measures of business confidence are important. For engineering investment, the terms of trade are a key driver of investment expenditures. Building investment is more difficult to explain, but it is responsive to the cost of capital, particularly when expected capital gains and losses are taken into account.

Appendix A: Data Sources

Business confidence: Taken from the ACCI-Westpac survey of manufacturers, expected business conditions, next six months. Net balance (percentage improve minus percentage deteriorate). In order to take logs, the series was transformed by dividing the net balance by 2 and adding 50. The resulting series is between 0 and 100 with net balance being 50.

Business investment: ABS Cat No 5206.0, chain volumes (Table 2) and current prices (Table 3), private, seasonally adjusted (sa). Prior to 1985:Q3, chain volumes series is constructed from component series using chain-linking methodologies.

Business investment excluding computing and livestock: Chain volumes and current prices, private, sa. Chain volumes constructed by removing livestock and computing using chain-linking methodologies. Component data available from ABS Cat No 5204.0, Table 69 (total) and Table 62 (private).

Building investment: ABS Cat No 5206.0 Table 2, chain volumes, private, sa.

Capital stock: ABS Cat No 5204.0 Table 39, total (since public and private are not available separately).

Computing equipment capital stock: ABS Cat No 5204.0, Table 94, public and private.

Computing equipment consumption of fixed capital: ABS Cat No 5204.0, Table 98, public and private.

Computing equipment investment: ABS Cat No 5204.0, Table 96, public & private and ABS special request, private.

Computing equipment prices: ABS unpublished data.

Cost of capital: constructed, see below.

Engineering investment: ABS Cat No 5206.0, Table 2, chain volumes, private, sa.

Equipment investment: ABS Cat No 5206.0, Table 2, chain volumes, private, sa.

Ex-computing equipment investment: constructed, see below.

GDP: ABS Cat No 5206.0, Table 2, chain volumes, sa.

Real trade-weighted index: RBA.

Terms of trade: ABS Cat No 5206.0, Table 1, sa.

Tobin's Q: stock market index divided by the implicit price deflator (IPD) for investment. Equipment numerator is ASX200 Industrials Index post-2000, All Industrials Index pre-2000 and denominator is ex-computing IPD. Engineering numerator is ASX200 Resources Index post-2000, All Industrials Index pre-2000, and denominator is engineering IPD.

Cost of capital: Calculated using Equation (2) (ex-computing equipment and engineering investment) and Equation (5) (building investment), where:

- $P_{I,t}$ and $P_{Y,t}$ are the investment and GDP IPDs respectively;
- τ is the corporate tax rate, taken from University of Michigan Tax Database (<http://www.bus.umich.edu/OTPR/otpr/introduction.htm>);
- α is the debt share of financing, calculated as total debt divided by total debt plus equity. Total debt and equity are taken from the *Financial Accounts*, ABS Cat No 5232.0, Table 2;[27]
- r is the real interest rate, and is calculated as the weighted-average credit outstanding large business interested rate (post-1994) or business indicator rate

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[27] Data in the *Financial Accounts* are only available since 1988. Before this we assume a constant debt share.

(pre-1994), deflated by the year-ended growth rate of the GDP IPD. The interest rates are taken from Reserve Bank of Australia (RBA) *Bulletin* Table F.5;

- *E/P* is the cost of equity capital as proxied by the equity earnings yield (assuming a constant expected growth rate of earnings), see Dews *et al* (1992) for further discussion. *E/P* is the inverse price-earnings ratio from the ASX200. Source: RBA *Bulletin* Table F.7 (post-1982);

- *Z* is the present value of depreciation allowances, calculated using the exponential method as discussed in La Cava (2005). The nominal interest rate in this calculation is the 10-year Treasury bond rate. Source: RBA;

- δ is the depreciation rate, calculated by dividing consumption of fixed capital (ABS Cat No 5204.0, Table 93) by the capital stock for ex-computing equipment and structures. Computing is removed from equipment COFC and capital stock using chain-linking methodologies; and

- expected capital gain (building) is the 11-quarter-centred moving average of year-end growth rate of real office prices. Real office prices are taken as nominal office prices (source: JLW/JLL Property Digest, prime CBD \$/m^2, weighted average of capital cities), deflated using the GDP deflator.

Ex-computing equipment investment: Quarterly ex-computing real equipment investment data are calculated using a two-step procedure. First, the annual growth rate of chain volumes ex-computing equipment investment is calculated using Equation (A1), (where *Q* represents chain volumes, *p* represent the IPD, *E* represents equipment (including computing) and *C* represents computing equipment). Levels are calculated by setting the chain volumes measure equal to the current price measure in the reference year (2004/05). Second, quarterly movements from the chain volumes equipment measure including computing equipment are applied to the annual data excluding computing equipment to give a quarterly series. The new quarterly series are benchmarked to add to the annual ex-computing data using the procedure developed in Denton (1971).

$$g = \frac{p_{E,t-1}Q_{E,t} - p_{C,t-1}Q_{C,t}}{p_{E,t-1}Q_{E,t-1} - p_{C,t-1}Q_{C,t-1}} \tag{A1}$$

Nominal ex-computing investment is also calculated annually and benchmarked using movements from quarterly nominal aggregate equipment investment. Computing is removed from the capital stock and consumption of fixed capital using the first step above.

Historical Data

Private business investment, dwelling investment, public investment, private capital stock, labour, GDP: 1890–1901: Butlin (1962); 1901–1949/50: Butlin (1977); 1949/50–1959/60: Foster (1996).

Net capital inflow: 1900/01–1948/49: apparent capital inflow from Vamplew (1987), Tables ITFC 101–106 and ITFC 200–210; 1949/50–1958/59: Foster (1996); 1959/60 onwards: ABS Cat No 5302.0.

Non-farm share of GDP (for calculation of non-farm GDP): Vamplew (1987).

Wage rates: 1901–1974: Butlin (1977); 1974–2006: average compensation per employee (adjusted for hours worked), ABS Cat No 5204.0, Table 41.

Hours worked: 1901–1972: Butlin (1977); 1972–2006, ABS Cat No 1364.0.15.003.

Labour force: 1901–1969: Butlin (1977); 1969–2006: ABS Cat No 6203.0.

Depreciation rates (total and by industry): Unless otherwise indicated, a weighted average of depreciation rate by type of capital using data from ABS Cat No 5204.0. Depreciation rates by type of capital are calculated as the real consumption of fixed capital as a ratio to the previous period's real capital stock. Weights are constructed from the previous period's capital stock, rescaled such that the weights sum to one (which otherwise does not hold owing to chain-linking).

Appendix B: Chain-linking and Investment

The real investment and capital stock data used in this paper are constructed by the ABS using a chain-linking approach. Formally, these series are chained Laspeyres volume indices. Chain-linking is used because it arguably produces better estimates of real growth rates, but problems exist with chain-linked levels estimates. In particular, the real levels estimates may suffer from 'non-additivity' – that is, aggregates will not necessarily be equal to the sum of their components. This non-additivity means that levels estimates many years ago may not have an intuitive interpretation – a point raised in Section 2.2.1. Non-additivity tends to become particularly significant where there have been large relative price shifts between the components of a series. For Australian investment data, large relative price shifts are evident in computing equipment and livestock investment, thereby creating problems for investment series that include these components (Table B1).

Table B1: Business Investment Prices

Relative to GDP deflator, 1965/66 = 100

	Relative investment prices			Number of times relative prices have halved between 1985/86 and 2005/06
	1965/66	1985/86	2005/06	
Computing equipment	100.0	1.1	0.02	30.9
Computer software	100.0	65.0	16.9	1.9
Livestock	100.0	24.3	19.6	0.6
Business investment	100.0	82.6	52.2	0.8
Business investment excluding computing equipment	100.0	90.1	78.7	0.6
Business investment excluding computing equipment & livestock	100.0	104.8	92.8	0.6

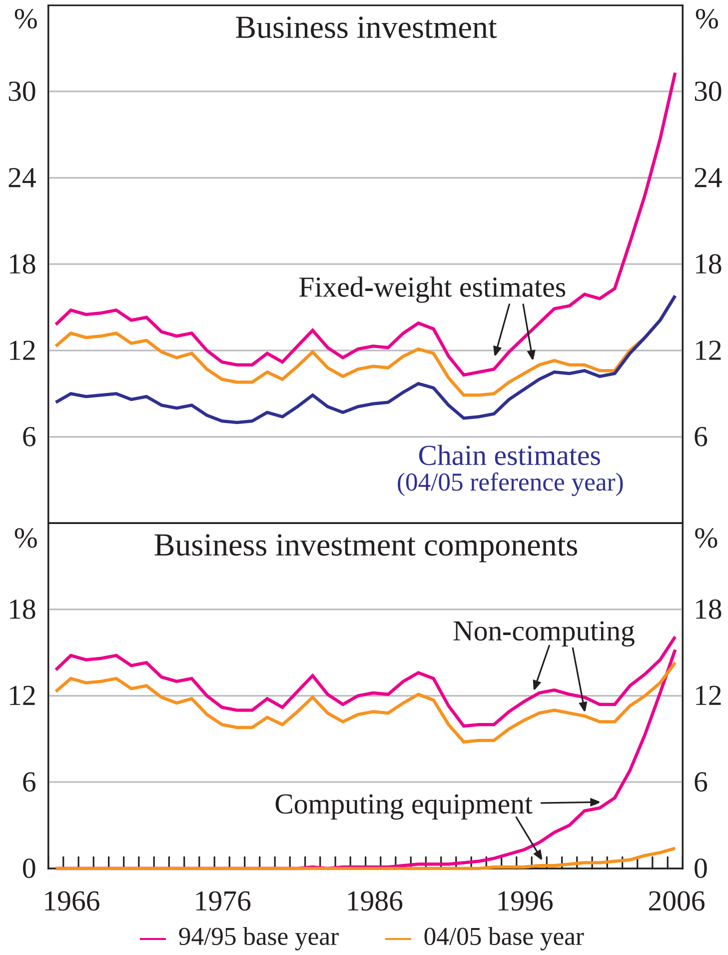
Sources: ABS, authors' calculations

Some of the advantages and disadvantages of chain-linking can be illustrated by a comparison with alternative fixed-weight estimates. Additivity always holds for fixed-weight indices (by definition), but relative price changes mean that the weight of sub-components (such as computing) can vary substantially with different base years. This means that the level of investment can change significantly if a different base year is chosen (Figure B1, top panel). Chain-linked series do not face this problem (an advantage) as their *growth rate* is a compromise between fixed-weight series with different base years. This reflects the fact that the chain series allows the weight given to the components to vary over time.

The loss of additivity of chain-linked series (a disadvantage) is evident in Figure B1 (bottom panel) as the sum of the non-computing and computing components of investment do not add to the chain estimates in the top panel. Also, the level of the aggregate chain series is difficult to interpret, being not only below the two fixed-weight estimates but also below the series for just non-computing investment for most of the sample (top versus bottom panels).

Figure B1: Business Investment – Chain versus Fixed-weight Volume Indices

Per cent of GDP



Sources: ABS; authors' calculations

B.1 Depreciation Rates

In this paper, we solve most additivity problems by removing computing from investment and depreciation. In part, this is important because non-additivity can greatly distort measures of depreciation rates in ways discussed below.

Many investment models make use of the capital accumulation identity (as in Equation (B1)) and assume that the depreciation rate can be treated as a constant. However, because of non-additivity, the capital accumulation identity need not hold in practice and therefore the assumption of a constant depreciation rate might be flawed when the model is taken to the data. As such, the capital accumulation identity should be not be used for deriving depreciation rates, as illustrated by Tevlin and Whelan (2003) using US data.

$$\delta_{1,t} = \frac{I_t - \Delta K_t}{K_{t-1}} \tag{B1}$$

Instead, depreciation rates at their most disaggregated level should be measured by taking the ratio of the consumption of fixed capital (COFC, otherwise known as depreciation) during a period to the stock of capital at the beginning of the period, as follows:

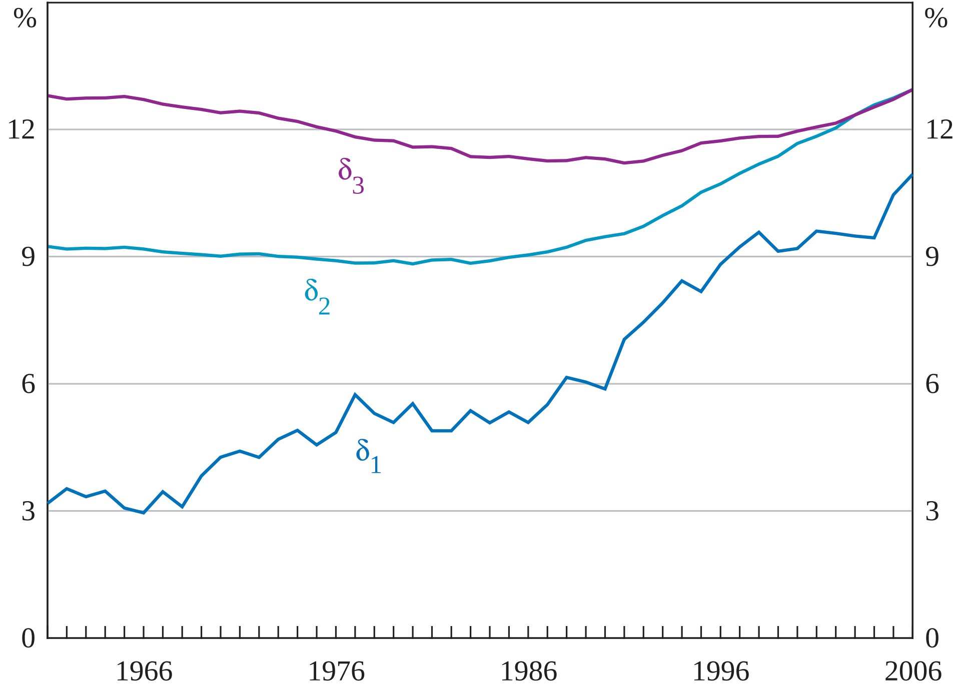
$$\delta_{2,t} = \frac{COFC_t}{K_{t-1}} \tag{B2}$$

However, non-additivity means that aggregate measures of depreciation (as calculated by Equation (B2) at the aggregate level) are not necessarily a weighted average of the depreciation rates of their sub-components. If non-additivity exists, then the average depreciation rate calculated in this way may have weights on sub-components that do not sum to one. As such, a correction is needed to force the weights to sum to one.

The differences between these possible measures are illustrated in Figure B2 for equipment capital (including computing). δ_1 is measured indirectly using the capital accumulation identity (Equation (B1)). δ_2 is the depreciation rate constructed in the fairly standard fashion of taking the ratio of depreciation of equipment capital during the period to the capital stock at the beginning of the period as in Equation (B2). δ_3 is also based on Equation (B2) (but at a disaggregated level) and includes the correction to weight the depreciation rates of the components with weights that sum to one. The difference between the measures is stark, and highlights the importance of calculating depreciation rates correctly.

Figure B2: Estimates of Depreciation Rates for Equipment Capital

Private non-dwelling and public capital stocks



Notes: δ_1 is a measure that makes use of the capital accumulation identity, δ_2 is flow of real depreciation as a proportion of beginning period capital, while δ_3 corrects δ_2 for weights that do not sum to one.

Sources: ABS, authors' calculations

Appendix C: Unit Root Tests

This Appendix shows unit root test results for the main series used in the modelling work. Two tests have a null hypothesis of a unit root (Augmented Dickey-Fuller (ADF) and Phillips-Perron tests) while an alternative has the null hypothesis of no unit root (the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test).

These tests suggest either the presence of a unit root or provide ambiguous evidence of a unit root for all variables except the cost of capital for structures. The clearest evidence of a unit root is found for the capital-to-output ratios for equipment and structures, the investment-to-output ratio for engineering and building and the cost-of-capital measures for equipment and engineering. The results are more ambiguous for the investment-to-output ratio for equipment and the cost-of-capital measure for building.

Many of these series are highly persistent, and these tests for a unit root may be picking up some form of non-stationarity rather than a unit root *per se*. An inspection of many of these series – particularly the investment-to-output ratios – seems to indicate some mean-reverting characteristics, bringing into doubt some of the conclusions drawn from the results above. As is typical with these tests, their low power limits the strength of conclusions that can be drawn.

Table C1: Unit Root Tests

	ADF	Phillips-Perron	KPSS
Equipment investment			
Capital-to-output ratio	–0.63	–0.90	0.42*
Investment-to-output ratio	–2.54	–2.50	0.13
Cost of capital	–0.92	–0.87	0.93***
Structures investment			
Capital-to-output ratio	1.17	1.06	0.98***
Cost of capital	–3.46**	–3.19**	0.27
Building investment			
Investment-to-output ratio	–1.37	–1.77	0.40*
Cost of capital	–4.27***	–2.12	0.15
Engineering investment			
Investment-to-output ratio	–0.87	–0.91	0.59**
Cost of capital	–2.25	–2.40	0.60**

Notes: ***, ** and * denote significance at the 1, 5 and 10 per cent levels respectively. All variables are in logs. The capital-to-output ratios and cost-of-capital measures for equipment and structures are tested over 1975:Q2–2003:Q4. All other tests correspond with the samples used in the error-correction models shown in Table 2, namely 1974:Q2–2006:Q2 for equipment, 1986:Q3–2006:Q2 for building and 1979:Q2–2006:Q2 for engineering.

Appendix D: Investment by Industry

The aggregate investment share (Figure 4) depends on both investment shares within each industry and the distribution of output across industries. Table D1 looks at how these have changed over the past 20 years. Data limitations mean that public and private investment have to be combined, as do the property & business services and the finance & insurance industries (referred to as 'property & finance').[28]

Table D1: Decomposing the Investment-to-output Ratio by Industry

Changes between five-year averages for 1976–1980 and 2002–2006, current prices

	Average investment-to-output $(I_i/Y_i)_t$			**Average industry output share** $(Y_i/Y)_t$			**Contributions from changes in:**	
							$(I_i/Y_i)_t$	$(Y_i/Y)_t$
	76–80 (%)	02–06 (%)	Change (% pts)	76–80 (%)	02–06 (%)	Change (% pts)	(% pts)	(% pts)
Agriculture	48.4	32.8	–15.5	6.8	3.5	–3.2	–0.8	–1.3
Mining	29.6	43.1	13.5	4.8	5.5	0.7	0.7	0.3
Manufacturing	12.7	19.0	6.3	20.6	12.0	–8.6	1.0	–1.4
Property & finance	19.8	14.6	–5.2	10.9	20.3	9.4	–0.8	1.6
Other market	22.4	19.0	–3.4	35.6	36.9	1.3	–1.2	0.3
Other non-market	15.2	11.6	–3.6	21.3	21.8	0.5	–0.8	0.1
Total	20.6	18.3	–2.3	100.0	100.0		–1.9	–0.5

Notes: 'Other market' includes electricity, gas & water supply; construction; wholesale trade; retail trade; accommodation, cafes & restaurants; transport & storage; communication services; and cultural & recreational services. 'Other non-market' includes government administration & defence; education; health & community services; and personal & other services.

Sources: ABS; authors' calculations

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[28] The private sector represented between 65 and 80 per cent of total investment over most of this period, and the private sector dominates the behaviour of the four main industries identified for total investment above. On a separate issue, the aggregate investment share can be decomposed as follows: $\Delta\left(I_t/Y_t\right)=\sum_i\left[w_{1i}\cdot\Delta\left(I_{i,t}/Y_{i,t}\right)+w_{2i}\cdot\Delta\left(Y_{i,t}/Y_t\right)\right]$. There are a number of choices for weights; here, $w_{1i}=\left(Y_{i,t}/Y_t+Y_{i,0}/Y_0\right)/2$ and $w_{2i}=\left(I_{i,t}/Y_{i,t}+I_{i,0}/Y_{i,0}\right)/2$ are used, where 0 denotes the base period.

Between 1976–1980 and 2002–2006, the aggregate nominal investment share has declined modestly (by 2.3 percentage points), though this probably reflects to some extent the period being considered, with the general trend over time being fairly flat. Some key industry trends are apparent – namely, the decline in the output shares of the agriculture and manufacturing industries, while the property & finance industry has expanded. The effects of these compositional changes on the aggregate investment share have largely been offsetting (accounting for only 0.5 percentage points of the fall).

The industries using computers relatively intensively – namely property & finance, other market and other non-market industries – have all recorded falls in ratios of nominal investment to output, probably reflecting the effects of falling computing equipment prices (consistent with this conclusion, equivalent ratios of real investment to output for these industries have risen). The falls in nominal (gross) investment-to-output ratios occurred despite these industries recording the largest increases in their depreciation rates (Table D2), also reflecting an increased use of computing equipment with its relatively high depreciation rate.[29] The fall in the investment-to-output ratio for agriculture largely reflects falls in the price of livestock investment.[30] Against these trends has been a rise in the nominal investment-to-output ratios in the mining and manufacturing industries. While most industries have reported an increase in the capital intensity of production (over the period as indicated by the capital-to-labour ratio; Table D2), these increases have been greatest for mining and manufacturing. With regards to its overall importance for investment, the decline in the size of the manufacturing industry has largely been offset by its trend towards using more capital-intensive techniques.

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[29] The depreciation rate for computing equipment is 40 per cent compared to around 11 per cent for non-computing equipment (in 2005/06).

[30] The depreciation rate for agriculture reflects the declining share of livestock investment, with livestock having a depreciation rate of around 27 per cent compared to 7.7 per cent for other types of agricultural investments (in 2005/06).

Table D2: Industry Ratios

	Capital-to-labour ratios, real, 1975/76 = 100			
	1975/76	1985/86	1995/96	2005/06
Agriculture	100.0	108.5	105.8	146.6
Mining	100.0	131.4	226.5	228.1
Manufacturing	100.0	134.3	178.8	246.6
Property & finance	100.0	121.7	140.3	159.7
Other market	100.0	124.3	122.3	137.2
Other non-market	100.0	100.1	97.8	100.8
Total	100.0	122.6	129.8	149.4

	Depreciation rates (real, annual, per cent)			
	1975/76	1985/86	1995/96	2005/06
Agriculture	13.1	11.8	12.2	10.1
Mining	6.6	6.8	7.2	7.8
Manufacturing	10.1	10.4	11.0	12.0
Property & finance	3.3	4.0	4.2	6.0
Other market	5.0	5.3	5.6	6.3
Other non-market	3.4	3.5	4.2	5.8
Total	5.8	5.8	6.1	6.9

Note: For industries included in ‘other market’ and ‘other non-market’, see notes to Table D1.

Sources: ABS; authors’ calculations

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