ESSAYS ON INVESTMENT AND HOUSE PRICES

A Thesis Submitted for the Degree of
Doctor of Philosophy

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Abstract

This thesis is a collection of four related chapters that examine investment activities in the Australian economy. Chapter 2 investigates the key drivers of aggregate business investment in Australia. A Tobin's *q* model of investment is augmented to account for the impact of demand constraints and allow for the effect of economic uncertainty on the investment decision. Using quarterly data over the period 1967 Q3 to 2010 Q4, the impacts of Tobin's *q*, income, cash flow and uncertainty on the aggregate investment rate are then determined and disentangled. Distinct from the majority of similar studies in the literature, most with respect to US investment, Tobin's *q* is found to be highly influential for investment over the long run and its impact is twice that of investment's corresponding relationship with cash flow. Uncertainty and demand constraints are revealed to be highly significant for investment over business cycle frequencies. These results are consistent with the theory of investment under uncertainty and echo recent findings of the importance of uncertainty for investment in the US economy.

Chapter 3 examines the key drivers of fixed firm investment of listed non-financial companies in Australia over the period from 1987 to 2009. A Tobin's *q* model of investment is augmented to account for the effect of economic uncertainty on the investment decision. The effects of Tobin's *q*, sales and cash flow on firm investment rate are also analysed and discussed. Consistent with existing literature, this research finds clear evidence of negative effects of both macroeconomic and firm idiosyncratic uncertainty on Australian firm investment. However, evidence also shows that firm specific uncertainty is more important in explaining firm investment than macroeconomic uncertainty.

Chapter 4 analyses the dynamics of the Australian housing market during the last three decades using a housing behavioural economic model based on nominal variables and the behaviour of house buyers. There is evidence that short-run nominal house prices are driven by nominal variables, including buyers' inter-temporal disposable incomes and interest rates. There exists a long-run co-integrated

relationship at both the state and national levels between house prices and house acquisition costs. The empirical evidence shows that the nominal behavioural model is equivalent or even better than other conventional models in explaining house price dynamics in Australia.

In Chapter 5, the key drivers of private residential investment in Australia since the 1980s are investigated. A Tobin's *q* model of investment is augmented to account for the impact of demand factors and the effect of economic uncertainty on the house investment decision. Using quarterly data over the period from 1981 Q1 to 2012 Q4, the impact of Tobin's *q*, income, land prices and financial constraints on the house investment rate are then determined and examined. A long-term co-integration relationship between Tobin's *q* and the investment ratio, as posited by *q* theory is not found, while changes in *q* have an impact on investment in the short-term. The determinants extracted from the stock-flow model explain the movement of housing investment. Uncertainty and construction costs are revealed not to be highly significant for investment. There is evidence of a positive correlation between investment and business cycles.

General Declaration

In accordance with Monash University Doctorate Regulation 17/ Doctor of Philosophy and Master of Philosophy (MPhil) regulations the following declarations are made:

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes one original paper accepted and published in a peer reviewed journal and unpublished three papers. The core theme of the thesis is the interaction between investment and its determinants in Australian context. The ideas, development and writing up of all the studies in the thesis were the principal responsibility of myself, the candidate, working within the Department of Economics within the Faculty of Business and Economics under the supervision of Professor Jakob B. Madsen.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of Chapter 2, 3 and 4, my contribution to the work involved the following:

Thesis Chapter	Title	Publication status	Nature and extent of the candidate's contribution
2	What determines investment in Australia: The role of the stock market, uncertainty and market imperfections?	Returned for revision	I contribute 50 percent to the research paper
3	Uncertainty and investment: Evidence from Australian firm panel data	Published by the *Economic Record*, June 2014	I contribute 100 percent to the research paper
4	A Behavioural Model for House Price Dynamics in Australia	Submitted for review	I contribute 100 percent to the research paper
5	What Drives Residential Investment in Australia?	Submitted for review	I contribute 100 percent to the research paper

I have renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed: ………………………………………………….

Date:

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Chapter 1

Introduction

This thesis comprises of four related papers that examine investment activities in the Australian economy. Specifically, investment dynamics in Australia are examined at the national, state and firm levels, as well as in the housing sector. Each paper focuses on Tobin's q, making it the main theoretical framework used throughout the thesis.

The following is a brief description of the four main chapters. The focus of Chapter 2 is on the relationship between aggregate investment and macro-economic variables in Australia. Chapter 3 examines Australian firm investment; specifically, the relationship between investment and firm characteristics. Moreover, by using various measures for uncertainty, the effects of uncertainty on investment are considered. Using a model based on debt repayment capabilities, the determinants of Australian house price dynamics are studied in Chapter 4. Lastly, Chapter 5 examines the driving forces of residential investment in Australia.

1.1 Motivation

Understanding investment is of major importance for policy makers as fluctuations in investment lead to significant consequences for the economy. In order to stimulate investment, it is important to ascertain the factors that influence investment at both the economy-wide and firm levels. Although there is a vast literature on the factors that affect investment, the role of some factors are so far inconclusive; in particular, the role of uncertainty is still a subject for debate. Furthermore, the persistent decline in Australian investment activity during and after the Global Financial Crisis 2007-2008 reinforces the need to better understand the factors that drive private business investment.

While theoretical considerations appear to support the conjecture that uncertainty is related to investment, the sign and magnitude of the relationship is not explained in a satisfactory manner in both theoretical and empirical literature. From a theoretical point of view, the effect of uncertainty on investment is ambiguous and dependant on the relationships amongst the variables as well as the assumptions of the model parameters such as firm's attitude toward risk, the cost function, market competitiveness and the shape of the marginal productivity of capital. Given the theoretical ambiguities on the effects of uncertainty on investment, empirical analysis is needed to investigate the effects further. However, empirical research on uncertainty and investment to date (for example, McDonald and Siegel, 1986; and Bertola and Caballero, 1994) is even less conclusive on the role of uncertainty on investment.

A large body of literature claims relationships amongst investment and specific variables, however in a large number of these studies one cannot distinguish the cause from the effect by merely glancing at the data. While, observing data does provide us with some useful insights, observing patterns in data is not enough. For example, the cause of the recent decline in the value of the stock market that led to the fall in investment rates is far from obvious. Therefore, the use of sophisticated econometric modelling techniques is imperative when analysing complex topics, such as investment.

The next subsections will discuss gaps in specific areas of investment literature and the motivation to address these gaps in this thesis.

Australian aggregate and firms' investment

Published research investigating the determinants of aggregate Australian private business investment over the decades since the 1980s is extremely limited. Even amongst the limited existing studies of Australian investment, there is scant confirmation of the key drivers of investment. With investment rates continuing to deteriorate over many quarters over 2008 Q4 to 2009 Q3, the demand for a thorough examination of the determinants of investment is clear.

In contrast to research pertaining to the U.S economy where both theoretical and empirical studies with respect to investment, have continued to give insights into the behaviour of U.S. firm investment activity, research investigating the determinants of Australian private firm investment since the 1980s is extremely limited. For example, Mills, Morling and Tease (1995), La Cava (2005) and Chang, and Tan, Wong, and Zhang (2007) are the only studies that analyse the drivers of firm investment in Australia; however, their focus is mainly on financial determinants. In addition, notable findings with respect to investment determinants, such as financial constraints and the fundamental value of investment opportunities are subject to specific caveats or objectives when applied to Australian data. To my knowledge, there is no study that examines uncertainty and its effect on firm investment in Australia where its main focus is something other than financial determinants. This however could be due to the difficulties associated with finding and modelling data on investment determinants.

In addition, an investigation on Australian firms is needed because there are fundamental differences between the Australian and the US markets, one being the composition of the listed firms on the two stock markets. For example, a larger proportion of Australian listed firms are in the energy and material sectors, thus they have more tangible assets, are more likely to be transparent and less subject to market imperfections (Chang *et al.*, 2007) and their investments may be irreversible and large. As a result of all of this, the impact of uncertainty on the Australian market may be different from the US market.

House prices dynamics

The housing sector plays an important role in the economic development of Australia, as it accounts for a very large proportion of Australian household wealth, while housing expenditures account for a large proportion of GDP and household expenditures. Fluctuations of house prices lead to consequences for other economic variables. Houses are the households' main assets, while mortgage debt is the main liability. Changes in house prices have profound implications on the rest of the economy, as large house price movements affect households' net wealth and their capacity to borrow and spend. Understanding the movement of house prices is therefore of major importance for economic policy makers.

In the house user-cost based conventional models, house prices are predominantly driven by fundamental variables such as income, demographics, the house user-cost of capital and the inelastic house supply (Girouard, Kennedy, van den Noord and Andre, 2006). However, the sharp increase in house prices in Australia over the last three decades cannot be explained sufficiently by these fundamental variables. In fact, the remarkable survival of the Australian housing market out of the Global Economic Crisis compels one to question what actually determines the dynamics of this market. To date, empirical studies show that the roles of factors determining house price movements in Australia are unclear.

The behavioural model developed by Madsen (2012) claims that nominal variables are important in house price dynamics. For example, a large percentage of houses payments are financed by loans, as such, the ability of households to re-pay these loans plays a decisive role in house price dynamics. Given financial renovations, higher incomes and lower mortgage interest rates, the household affordability increases, leading to higher demand for house buying. In addition, house buyers have short-sighted views and are influenced by money illusion. Therefore, given the implications of the nominal interest rate and nominal income in house price dynamics, the importance of other nominal variables in house price dynamics cannot be ignored and needs to be examined.

Residential investment

Residential investment is associated with the production of new dwellings, therefore, it adds to the existing stock of housing. Residential investment is an important driver of economic development since residential construction is an economic activity with large multiplier effects. Houses are the households' main assets (wealth), while mortgage debt is the main liability. Residential housing investment has averaged about a third of total private fixed investment in Australia and 5.6 per cent of real Australian GDP during the 1959 to 2012 period, as calculated from the Australian Bureau of Statistics (ABS) data. As house wealth accounts for an enormous percentage of total wealth, an increase of this housing stock has an important impact on economic growth. Given this, it is vital to understand the drivers of residential investment in Australia.

1.2 Structure of the Thesis

The thesis has six chapters, including four empirical chapters, one introduction chapter and one concluding chapter. Each empirical chapter follows the usual sequence of introduction and motivation, literature review, theoretical and empirical models, data, empirical results and conclusions. The conclusion chapter provides concluding remarks on findings in the four empirical studies, their implications, limitations and directions for future research. The structure of the four empirical chapters is as follows:

Chapter 2

This chapter revisits Australian private investment and undertakes an examination of the key factors that affect private investment activity; specifically, the chapter attempts to identify whether these key factors impact the level or the change in the investment rate over time. Tobin's *q* model of investment is augmented to account for the impact of demand constraints on investment (following Blanchard, 1983) and to allow for the costs of uncertainty as proposed by Dixit and Pindyck (1994). The theory is then tested using quarterly data over the period 1967 Q3 to 2010 Q4. Factors that are commonly found to be important for investment rates in the U.S. are incorporated into the empirical analysis of Australian private firms. These factors are cash flow – included to allow for the possibility of credit constraints, income – to allow for the divergence between the market and fundamental value of capital, and uncertainty to allow for the costs of uncertainty on investment.

A major contribution of this chapter is the construction of the aggregate Tobin's *q* data for Australia using the method developed by Laitner and Stolyarov (2003) and Wright (2004). An attempt at such a thorough calculation of the aggregate Tobin's *q* ratio has not been performed using Australian data since the 1980s. The overall results indicate that, *q* is found to be a highly significant driver of long-term investment. Furthermore, the magnitude of the coefficient of *q* is large and strongly dominates, pertaining to the fundamental value of the representative firm as proxied by cash flow. Thus, abstracting from business cycle fluctuations, the Australian capital market is relatively strongly driven by the fundamental value of capital.

Specifically, results suggest that changes in the level of uncertainty in the equity market, as measured by the fluctuations in the volatility of stock prices, are revealed to be significantly associated with investment. It shows that it is the change in the level of uncertainty observed in the stock market, rather than the level of uncertainty itself, that is important in driving short-term decisions pertaining to investment. Moreover, as stock market volatility really only accelerates prior to investment downturns, uncertainty is found to be a key driver of investment downturns. The final result of Chapter 2 is income per capita significantly affects investment during business cycle fluctuations. However, it was found that persistence in the rate of growth of investment is only triggered by a continual corresponding increase in the rate of growth of income per capita. These results reveal that investment rates are likely to only increase when the economy is at the initial and accelerating phase of its cyclical upswing and that rigidities pertaining to the demand side of the economy can have a substantial impact on the timing and magnitude of investment fluctuations.

Chapter 3

This chapter undertakes a rigorous examination of the key factors proposed by theory that are expected to impact on firms' investment activities. The chapter examines *q* theory and the role of uncertainty in Australian firms, by applying different estimators, especially the Generalised Method of Moment (GMM) technique for the panel data set, 1987-2009. Moreover, unlike previous studies (e.g. Leahy and Whited, 1996; Baum, Caglayan, and Talavera, 2008; and Bloom, Bond and Van Reenen, 2007), this study employs uncertainty proxies that have been used very recently (for instance in Panousi and Papanikolaou, 2012). Although, the primary measure of uncertainty in my study is the volatility of firms' stock price returns, the chapter additionally incorporates a new CAPM based method of measuring idiosyncratic uncertainty.

The results of the chapter show that there is a negative relationship between investment and uncertainty, while its effect depends on the different proxies used and the characteristics of firms. The other explanatory variables found to be important for firms' investment decisions are, Tobin's *q*, cash flow, leverage and sales. The coefficient of the variable measuring uncertainty is consistent and significant with alternative models (static Tobin's *q* and the dynamic panel data model). It is found that the sign and strength of the relationship depends upon the market power of the firm and the degree of financial constraints it faces. The effects of uncertainty also vary with firm size. While, after controlling for fundamental variables, firm specific uncertainty is more relevant for investment decisions than macroeconomic uncertainty.

Chapter 4

This chapter develops an empirical model based on a theoretical model proposed by Madsen (2012). In the model, nominal house prices are influenced by nominal variables through a mechanism based on the affordability test imposed by banks that give mortgages to house buyers. The chapter contributes to the existing empirical literature on the dynamics of Australian house prices, by employing a new theoretical model, different from the conventional models. An empirical research linking the long-term and short-term determinants of house prices is scarce for the Australian market, while co-integration analyses on land prices are in shortage due to insufficient data. This research is the first attempt to analyse the role of nominal variables on house prices and to use land prices, proxied by agricultural land prices, in the long-term co-integration relationship of house prices and their acquisition costs in Australia. It employs a much larger database than previous studies analysing the Australian housing market.

Results suggest that a long-term relationship of house prices, land prices and construction costs exists. Also, apart from the user-cost of capital model, the employed behavioural model seems to explain price movements in Australia more effectively than the other conventional models. There is evidence that the increases in house prices are due both to the short-run effects of demand variables (for example, income, the mortgage rate and financial commitments) and long-run effects of supply variables such as, construction costs and land costs.

Chapter 5

This chapter revisits two popular models of housing investment, the *q* model and the stock-flow model, to explain housing investment in Australia. A first difference OLS regression model based on *q* theory is estimated using data at both the national and state levels. In this chapter, the Tobin's *q* model of investment is augmented to account for the effect of economic uncertainty on housing investment in Australia. Overall, findings suggest that Tobin's *q* is important in housing investment decisions in Australia. However, no co-integration relationship between Tobin's *q* and the investment ratio has been found. The traditional stock-flow approach is applied and appears to better explain the movement of investment decisions. Results show that residential investment is mainly driven by demand side variables, including income, population, user-cost of housing and financial costs. Uncertainty and construction costs are also revealed to be significant for investment but with vague signs, whereas business cycles have a very distinct impact on housing investment.

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Chapter 2

What Determines Investment in Australia: The Role of the Stock Market, Uncertainty and Market Imperfections?[1]

Abstract

This research investigates the key drivers of aggregate business investment in Australia. A Tobin's *q* model of investment is augmented to account for the impact of demand constraints and allow for the effect of economic uncertainty on the investment decision. Using quarterly data over the period 1967 Q3 to 2010 Q4, the impacts of Tobin's *q*, income, cash flow and uncertainty on the aggregate investment rate are then determined and disentangled. Distinct from the majority of similar studies in the literature, most with respect to US investment, Tobin's *q* is found to be highly influential for investment over the long run and its impact is twice that of investment's corresponding relationship with cash flow. Uncertainty and demand constraints are revealed to be highly significant for investment over business cycle frequencies. These results are consistent with the theory of investment under uncertainty and echo recent findings of the importance of uncertainty for investment in the US economy.

[1] This chapter forms the basis of a paper that was co-written by myself and Sarah Carrington, Economist, Asian Development Bank.

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2.1 Introduction

Published research investigating the determinants of aggregate Australian private business investment over the decades since the 1980s is extremely limited. With the exception of McKibbin and Siegloff (1988), contributions to the analysis of the drivers of aggregate corporate investment have been confined mainly to research papers in the public sector and institutions such as the Reserve Bank of Australia[2]. This is in contrast to the ongoing published work pertaining to the U.S economy where both theoretical and empirical studies with respect to investment have continued to give insights into the behaviour of U.S. investment activity. Furthermore, even amongst the limited existing studies of Australian investment, there is scant confirmation of the key drivers of investment; with respect to the commonly-tested variables, results are oftentimes conflicting with the exception of the finding that changes in the capital stock often move in line with fluctuations in real output. Findings with respect to credit constraints, the fundamental value of investment opportunities, uncertainty and other factors that are often the subject of scrutiny in the international investment literature, are either not upheld for Australia or are but singular findings of studies subject to specific caveats or objectives when applied to Australian data.

Persistent declines in Australian investment activity in the wake of the Global Financial Crisis, however, reinforce the need to better comprehend the factors that drive private business investment. With investment rates continuing to deteriorate over many quarters – indeed, in double-digit magnitudes, year-on-year, over 2008 Q4 to 2009 Q3; some of the most persistent falls in investment over two decades – the demand for a thorough examination of the determinants of investment is clear. In particular, with movements of the 'usual suspects' driving investment being highly

[2] Reserve Bank of Australia research papers include Debelle and Preston (1995) who conduct a study of the channel through which foreign output impacts on Australian output, Andersen and Subbaraman (1996) who examine whether speculative or fundamental changes in the value of firms impact more strongly on investment activity, La Cava (2005) who undertakes a panel data study of the differential drivers of the sub-components of private business investment, and Cockerell and Pennings (2007) who instigate the most recent investigation of the drivers of investment within a neo-classical economic framework.

correlated over the most recent investment downturn, one cannot distinguish cause from effect and correlation from causality by merely glancing at the data. While in a sequential sense, data show that the decline in the value of the stock market led the fall in investment rates, which was accompanied by a large increase in stock market volatility and uncertainty in the economy and a gradual reduction in real GDP per capita, causation is far from obvious. The ambiguity has also been present in public debate surrounding the health of the Australian financial system, the stance of monetary policy in the face of the reduced robustness of the consumption and housing investment sectors and the broader role of Government borrowing and spending in times of economic instability.

Accordingly, this chapter aims to revisit Australian private investment and undertake an examination of the key factors that are expected to impact on private investment activity. In the vein of most general equilibrium models of investment, the chapter derives a Tobin's *q* model of investment. In response to the lack of empirical validation of 'pure' Tobin's *q* models of investment, the pure *q* model is augmented to account for the impact of demand constraints on investment (following Blanchard, 1983) and to allow for the costs of uncertainty on the investment decision as proposed by Dixit and Pindyck (1994). The theory is then tested using quarterly data over the period 1967 Q3 to 2010 Q4. Factors commonly found to be important for investment rates in the U.S. are also incorporated into the empirical analysis; cash flow, income and uncertainty are included in the estimations to allow for the possibility of credit constraints, divergence between the market and fundamental value of capital, and the costs of uncertainty impacting on investment. The aim of the empirical section is essentially to disentangle and clarify the drivers of investment and identify whether they impact on the level or change in investment rates over time.

A major contribution of this chapter is the construction of the Tobin's *q* data series used in the analysis. Aggregate Tobin's *q* data for Australia has been carefully constructed in a theoretically consistent manner only prior and up to 1986 (Dews, 1986). Accordingly I construct a Tobin's *q* series at quarterly frequency for Australia from 1988 – when a consistent set of data to do this first becomes available – to present using the method developed by Laitner and Stolyarov (2003) and Wright

(2004). This entails calculating the Tobin's *q* ratio as the current market value of aggregate total private firm equity and liabilities divided by the current value of the net capital stock of private businesses. An attempt at such a thorough calculation of the aggregate Tobin's *q* ratio has not been performed using Australian data since the 1980s[3]. To the best of my knowledge, this is the first study for aggregate investment in Australia using quarterly time-series Tobin's *q* data spanning more than four decades.

The chapter proceeds as follows. The next section summarises the state of the literature regarding Australian aggregate investment in the context of the broader economic investment literature. Section 3 then derives a Tobin's *q* theory of investment augmented with demand constraints and accounting for the impact of uncertainty on the investment decision of the representative investor. The construction of the Tobin's *q* data and a general description of the data pertaining to Australian aggregate investment and its drivers are discussed in Section 4. The empirical model and the analysis and results are presented in Section 5. Section 6 comprises several robustness checks of the preceding results. The final section concludes.

2.2 Studies of Australian Investment in the Context of the Broader Literature

Although conventional economic theory suggests that Tobin's *q* should be the sole explanatory variable for investment rates, much of the empirical evidence, in the US and abroad, suggests that aggregate corporate investment is only weakly related to Tobin's *q* while income, uncertainty and, particularly, cash flow appear to be the principal force behind fluctuations in investment (see for discussion Blanchard, Rhee and Summers, 1993, and Romer, 2006, Ch. 8). While such results run counter to the predictions of the pure Tobin's *q* model of investment, several investment models

[3] Several studies have calculated proxies for aggregate Tobin's *q*: Debelle and Preston (1995) calculate *q* as equal to the gross rate of capital investment multiplied by an assumed adjustment cost factor, minus one. Anderson and Subbaraman (1996) use real share prices as a proxy for *q*. In a more recent paper Cockerell and Pennings (2007) calculate *q* as the stock market index divided by the implicit price deflator. The trouble associated with the usage of real stock prices as a proxy for Tobin's *q* is that it increases over time due to retained earnings and will, therefore, not gravitate towards a constant level as Tobin's *q*.

have been developed to explain the relationship between uncertainty, income, cash flow and investment.

A number of authors have stressed the importance of uncertainty for investment activity (Bernanke, 1983; McDonald and Siegel, 1986; Bertola and Caballero, 1994; Dixit and Pindyck, 1994, or for a survey see Carruth, Dickerson and Henley, 2002). The premise of these models is that investment – or at least some part of investment – is irreversible. When there is uncertainty about the returns to investment and it is either irreversible or incurs substantial sunk costs, then the investment decision becomes complex. The timing of the decision to invest becomes an important component of the strategy to minimise the costs of uncertainty; where investment is postponed, more information may be gained about the future which can reduce the investor's exposure to unnecessary sunk costs or excessive investment risk (Dixit and Pindyck, 1994). Ultimately, an environment of uncertainty will delay, and with some probability halt, a number of investment projects as the cost of investment relative to the expected profits in an uncertain environment will reduce or eliminate the benefits of investing altogether. Accordingly there should be a negative relationship between investment and economic uncertainty in the aggregate. A thorough investigation of this relationship remains to be undertaken for Australian aggregate investment.

Firms may also have incentives to delay or cancel investment activity in times of weak demand. One rationale is that where there is any level of price or wage inflexibility, changes in aggregate demand may engender imbalances in goods markets and conditions of excess supply. Blanchard (1983) develops a model where demand constraints play a role in constraining investment activity as these conditions deter investment activity; firms foresee that there will not be adequate demand for their planned increase in supply. Another channel through which demand constraints are likely to deter investment is through the impact of reduced demand on asset markets. In the presence of asymmetric information within financial markets, weakened demand, which impacts on the price of financial assets, can spur a spiralling contraction in credit to fund investment; reduced asset prices will decrease the value of collateral, which in turn shrinks the amount of funding willing to be lent to investors, further decreasing aggregate demand, and so on. Such models of investment fall under the category of accelerator models and emphasise the inter-linkages between real and financial markets through the relationship between demand and investment funding in the presence of asymmetric information between borrowers and lenders (see Bernanke, 1983). Evidence for the relationship between demand and investment can be found in the many empirical studies looking the association of aggregate income per capita – the proxy used for aggregate demand – and capital accumulation (See the survey by Chirinko, 1993 and for Australia specifically see Reserve Bank of Australia papers by Cockerell and Pennings, 2007, La Cava, 2005, Andersen and Subbaraman, 1996, and Debelle and Preston, 1995).

Finally, investment is also found to be sensitive to internally generated free cash flow. There is a vast literature on the relationship between investment and cash flow or profit rates; the sensitivity of investment to cash flow can be explained through either credit market frictions or divergence between the market and the fundamental value of the firm. Firstly, in the case where credit rigidities increase the effective cost of finance to investing firms, investment will become more sensitive to internally generated cash flow in the aggregate (see Hubbard, 1998, and Romer, 2006, Chapter 8, for an overview). Essentially, the Tobin's *q* based model of investment assumes total equity financing. However, firms will often use debt, a mix of debt and equity, or a combination of debt, equity and retained earnings to finance investment. Where the required preconditions of an efficient market and no taxes, agency costs, asymmetric information do not hold, the Modigliani-Miller (1958) theorem is also not applicable and the capital structure of investment can impact on the return to investment. Thus when credit market frictions exist, firms will face a higher cost of financing investment on average and may become dependent on internally generated cash flow for funding new investment. Andersen and Subbaraman (1996) investigate this relationship at the aggregate level for the Australian economy and their results support this credit market friction theory. Microeconomic level empirical research looking at investment determinants also suggests that there is a strong link between investment and cash flow or other measures of internal funds. The key study cited as supporting this theory for U.S. investment activity is Fazzari, Hubbard and Petersen (1988). For Australia, however, the evidence on the existence of credit constraints causing excessive sensitivity of investment to internal cash flow is not uniform; Debelle and Preston (1995) find a positive and significant relationship between cash flows and investment whereas Cockerell and Pennings (2007) find no significant relationship.

The second explanation regarding the excessive sensitivity of private business investment to internally generated cash flows relates to the situation where the fundamental value of the firm and the market value of the firm diverge. As considered by Blanchard, Rhee and Summers (1993, henceforth BRS), such circumstances arise when either the firm's management has information that is superior to the market with respect to the value of the firm or when the equity market is subject to rational speculation or fads that drive the market value to diverge from the underlying value of the firm. When the q variable fails to summarise all expectations that are relevant for investment behaviour, BRS postulate that a firm's valuation might differ from the market's valuation of the firm. In such cases, it is argued by BRS, the rational, optimising firm will follow the fundamental value of the firm, which is, in essence, the discounted expected present value of the firm's future cash flows. Studies including BRS, Barro (1990) and Greasely and Madsen (2006) have proxied for the fundamental value of the firm using internally generated cash flows. Thus, investment may be sensitive to cash flow due to either credit constraints or divergences between the market and the fundamental value of the firm. No explicit investigation of this phenomenon as explained through the channel of the cash flow sensitivity of investment has been undertaken for the Australian economy.

2.3 Theoretical Background

We first build up a simplified theoretical model to provide the background for the investment and q relationship. This model is based on a general investment model that is common to the literature and incorporates demand constraints and uncertainty. It is therefore distinguished from models such as those developed by Benge (1997, 1998) that focus on specific taxation conditions prevailing to Australian corporations and instead focuses on elements that have been shown to be important for investment behaviour more globally. The representative firm's objective is to choose the level of investment to maximise the present value of real cash flows as per the following optimisation problem:

$$\max \Omega = \int_{t=0}^{\infty} e^{-\rho t}[K^{\alpha}(t)(A(t)L(t))^{1-\alpha} - I(t) - W(t)L(t) - C(I(t), K(t))]dt \tag{2.1}$$

subject to: $$\dot{K}(t) = I(t) - \delta K(t) \tag{2.2}$$

where Ω is the present value of real free cash flows, henceforth cash flows, ρ is the constant real required return to equity, K is capital stock, L is labour, A and α are fixed parameters representing technology and the labour-to-capital factor shares under Cobb-Douglas technology assumptions, respectively, I is gross investment, W is the real wage rate, $C(I)$ is the adjustment cost function for investment, with $C(0)$ =0, $C'(0)$ =0, $C''(.) > 0$, and δ is the rate of capital depreciation. A dot over a variable signifies first differences. The firm is an all equity firm and it is assumed that all the free cash flow is paid out. It is also assumed that there is no discrepancy between the market and fundamental value of the firm. Following Blanchard (1983), and given empirical evidence suggesting a strong role for income in determining investment (Chirinko, 1993, Carrington and Madsen, 2012) limitations on the demand for investment output are also considered as a constraining influence on investment. Accordingly, the investment decision is also constrained by demand for investment output as follows:

$$K^{\alpha}(t)(A(t)L(t))^{1-\alpha} = \overline{Q}(t) \tag{2.3}$$

where $\overline{Q}$ is the quantity of output demanded at time t. The adjustment cost function is $C(I(t)) = \frac{\gamma}{2}\left(\frac{I(t)}{K(t)}\right)^2$ which is convex in investment and homogenous of degree one – this insures that marginal q is equal to average q, as shown by Hayashi (1982) – and is standard in the literature. The significance of this result is that Tobin's q can be measured and, therefore, that Tobin's q theory of investment can be tested.

The current-value Hamiltonian of this optimization problem is therefore given by:

$$H = K^{\alpha}(t)(A(t)L(t))^{1-\alpha} - I(t) - W(t)L(t) - \frac{\gamma}{2}\left(\frac{I(t)}{K(t)}\right)^2 \cdot I + q[I(t) - \delta K(t)] - \mu\left(K^{\alpha}(t)(A(t)L(t))^{1-\alpha} - \overline{Q}(t)\right) \tag{2.4}$$

where q is the shadow price of capital or the value attached to an additional unit of capital stock; the price the firm is willing to pay for an additional unit of capital and

μ is the present value to the investor of the demand constraint being relaxed by one unit.

The first order conditions of other than those that restate the constraints and the transversality condition are as follows:

$$\frac{\partial H}{\partial I}=0: \qquad \frac{3\gamma}{2}\left(\frac{I(t)}{K(t)}\right)^2=q(t)-1 \tag{2.5}$$

$$\frac{\partial H}{\partial K}=-\dot{q}+\rho q \qquad \Rightarrow \dot{q}=\rho q-\left[\alpha(1-\mu)\left(\frac{A(t)L(t)}{K^{\alpha}(t)}\right)^{1-\alpha}+\gamma\left(\frac{I}{K}\right)^2\right] \tag{2.6}$$

These are the key equations determining the asset market value and the investment behaviour of the firm. Equation (2.5) specifies the no arbitrage equilibrium and shows that the marginal cost of investment, $1+C_I'$ is equal to the marginal benefit of investment, q, in equilibrium; investors have no incentives to invest or disinvest when this holds. Solving equation (2.5) this with respect to the investment rate gives the equation governing the transitional dynamics of investment and that which will form the basis of the empirical investigation in Section 5 of the chapter:

$$\frac{\dot{K}(t)}{K(t)}=\left[\frac{q(t)-1}{\gamma}\right]^{1/2} \tag{2.7}$$

Equation (2.6) is the equation describing the dynamics of the price of capital and the resulting transition dynamics of the capital stock. The condition shows that the value of one unit of capital at the margin depends on the acquisition cost of capital, inclusive of the marginal adjustment costs, as well as any shadow costs associated with a demand constrained market. Thus within a demand constrained environment, the effective cost of producing another unit of capital – inclusive of the shadow costs imposed by weakened demand conditions – exceeds the market value of capital at the margin. Accordingly, as diminishing marginal returns to capital are assumed, firms have incentives to disinvest until the market value of capital and its cost of production are again equivalent. Were these demand constraints relaxed, the impetus to disinvest would disappear as the market value of capital and the cost of producing capital are again brought into line.

Uncertainty and Investment

To augment this theoretical model with uncertainty regarding the investment decision, Dixit and Pindyck's (1994) option value approach to the determination of investment is applied. As described in Section 2, where investment is, at least in part, irreversible, and there is uncertainty surrounding the expected return to the investment decision, any leeway the investor has with respect to the timing of their investment becomes of important value. In essence, the option to delay an investment decision so as to wait for any new information to arrive that may reduce the uncertainty surrounding the expected return on the investment is of value, and increasingly so the more uncertain the environment faced by the investor. Thus when a firm actually undertakes investment inclusive of some irreversible components, it loses its option to wait for new information.

Therefore, under uncertainty, the cost of using up the option value of being able to postpone the project must be deducted from the value of the project, where the option value is a positive function of uncertainty and the variance of uncertainty. It follows that when the firm makes an investment, the value of the firm increases by the value of the project, *Q*, minus the option value of delaying the project, *F(Q),* when the project is installed. Hence, under uncertainty, Tobin's *q* becomes:

$$q = \frac{Q - F(Q)}{AC} \tag{2.8}$$

where *AC* is the cost of additional capital. Effectively, where the net expected value of the project after considering the lost option value is greater than the cost of acquiring the capital anew, then the firm is expected to undertake the investment. Equation (2.8) presents the wedge between the payoff necessary to induce the investor to exercise the option to invest and the present value of the cost of the investment. The size of the wedge increases as uncertainty increases. So if uncertainty increases, the higher threshold requires firms to delay their investment and wait for more information such that the level of uncertainty decreases or drop the project altogether. Higher uncertainty therefore has negative impacts on firms' investment.

Using some boundary conditions, Dixit and Pindyck (1994, p. 146) show that the threshold value at which the firm should invest is given by:

$$q = \frac{\beta}{\beta - 1} > 1 \qquad (2.9)$$

where $\beta = 1/2 - (r-\delta)/\sigma^2 + \sqrt{[(r-\delta)/\sigma^2 - 1/2]^2 + 2r/\sigma^2}$, r is the risk free interest rate, δ is a positive parameter; r-δ is the mean of share returns, and σ^2 is the variance of share returns. The equation defines the threshold value which q has to exceed in order to make new investment profitable. This threshold value exceeds the conventional value of 1 and is an increasing function of uncertainty, the discount rate, and the expected growth in the return to the asset.

The theoretical part shows that investment should be driven by the fundamental value of the firm in the long run – which theoretically is reflected by Tobin's *q*. In addition, it is also influenced by uncertainty, which lead to the threshold *q* higher than that in a certain condition. Based on this theoretical foundation as above, empirical models will be developed, which will be discussed further in Section 5.

2.4 Data

The chapter focuses on the quarterly data over 1967 Q3 to 2010 Q2. It is of interest to take a preliminary glance at the data for Australian investment and its potential drivers – Tobin's *q*, profit rates, income and uncertainty – over the last four decades. Accordingly, a discussion of the construction and main features of the data is followed by graphs of the data series are presented in Figures 2.1 and 2.2.

Aggregate business investment, or total private business investment, is defined by Australian Bureau of Statistics as total of "non-dwelling construction plus machinery and equipment plus cultivated biological resources, plus intellectual property products", measured as fixed capital investment of non-financial private business. Following literature on investment (e.g. Dixit and Pindyck, 1994), private business investment is proxied by the investment ratio, which is the ratio of fixed capital investment of non-financial private business over total non-residential corporate capital stock at the beginning of period, measured at quarterly frequency. Quarterly fixed capital investment of non-financial private business is measured by private non-dwelling gross fixed capital formation, available directly from net private corporate capital stock recorded in the Australian National Accounts (Australian Bureau of Statistics, cat. 5206.0 Table 3). Total non-residential non-financial corporate capital stock is from ABS cat. 5204.0 Table 57. Prior to 1980, original capital stock data is only available as annual data (from 1959 and up to 1980). Accordingly, quarterly capital stock data are interpolated following Ferderer's (1993) process of interpolation. The investment series was used to construct weights following

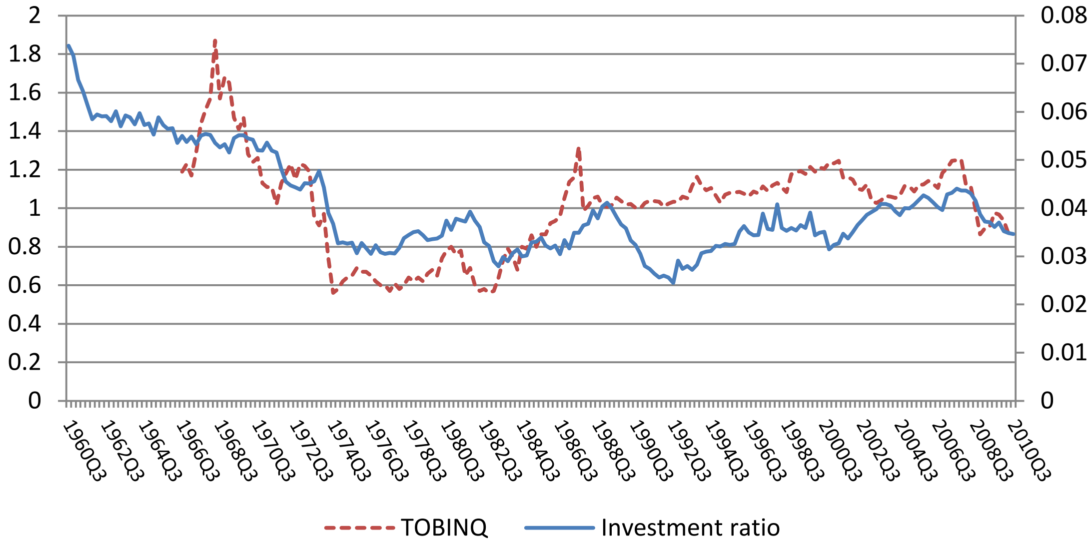
$$K_{i,j} = [\sum_{z=1}^{j} I_{i,z} \,/\, \sum_{z=1}^{4} I_{i,z}]\,(K_{i,4} - K_{i-1,4}) + K_{i-1,4}\,, \quad (2.10)$$

where j =1 to 4 refers to quarters, and i refers to years. The current price series of investment and capital stock are converted into real values using the gross fixed capital formation deflators**.** See the data appendix for the parameters used in this calculation. From 1980, capital stock data is available as quarterly data.

Due to data availability, the profit rate is measured as the ratio of private gross surplus over the value of private non-residential non-financial firms' capital stock; both are deflated by the GDP implicit deflator and the Gross Fixed Capital Formation deflator respectively.

The data show that the rate of accumulation of fixed capital has varied over time and looks to have two succinct phases, as seen in Figure 2.1. Over the 1960s and early 1970s, the investment rate steadily declined from over 7.0% to just over 4.2% in December 1973, averaging 5.2% per annum over the period from June 1960 to December 1973. This decline in investment reflects the winding down of the mining boom and the post WWII golden-growth era and the beginnings of the stagflation era of the 1970s. Post 1973 the rate of investment largely steadied and maintained an average rate of 3.2% per annum. There were, however, significant falls in investment rates in the economic downturn of 1982-83, when unemployment rose to almost ten percent, its highest level since the Great Depression, and the recession of 1991 that resulted from financial sector turbulence proceeding the 1980s boom and 1987 stock market crash. Strong investment rates were observed over the growth periods in the years coinciding with financial liberalisation in the mid to late 1980s, the long upswing of the 1990s and the most recent pre-GFC boom over 2002 – 2007. The decline in investment rates from 2008 to 2011 reflects the poor stock market performance over this period and is due to the recent Global Financial Crisis taking momentum in Australia in 2008. In total, the data span covers four major cyclical phases of investment.

Figure 2.1: Australian Tobin's *q* and Investment ratio during 1960 -2010



Note: The left axis is for Tobin's *q*, the right axis is for investment ratio (I/K).

Tobin's *q* for Australian aggregate investment

One of the contributions of this chapter is the construction of an updated Tobin's *q* data series for Australia. As prefaced, there have been scarce studies of aggregate investment for the Australian economy and the last relatively rigorous calculation of aggregate Tobin's *q* was completed in 1986. The first panel compares the investment rate with Tobin's *q* as constructed for Australia. Tobin's *q* is calculated as the current market value of total private firm equity and liabilities divided by the current value of the net capital stock of private business. In this chapter we have constructed the series of aggregate Tobin's *q* from 1967 Q3 to 2010 Q2 for Australia which is comprised of pre-existing as well as newly generated data sets. With respect to newly calculated data, within the literature, a number of methods have been used to calculate aggregate Tobin's *q* data for various economies[4]. The methodology used to

[4] Some widely used methods that have initially been used for U.S. data include Summers (1981) *q* and tax-adjusted *q* series, Bernanke, Bohn and Reiss' (1988), Blanchard, Rhee and Summers' (1993). Detailed working papers exist to explain the construction of these series. In general, these researchers have constructed *q* by summing their estimations of the market value of equity and debt and divided this sum by the balance sheet value

construct the series in this study is based on that used by Laitner and Stolyarov (2003) and by Wright (2004) for the U.S. economy. This method is the most thorough of those used to calculate Tobin's *q* and has been replicated as closely as possible on a quarterly basis for the Australian economy over the period for which data are available to do this; from 1988 Q1 onwards.

There are some distinctions between the methodology used by Laitner and Stolyarov (2003) and by Wright (2004)[5], however, because the level of data detail required to distinguish each *q* series is not observable in any Australian data set, the methodologies as applied to Australian data are in practical terms, analogous. The numerator of the Tobin's *q* ratio, total market value of private corporate capital can be measured by the net claims of all other economic agents in an economy on the private corporate sector. The equilibrium principle of national financial accounts claims that the sum of net financial assets of all economic agents in an economy (including households, private corporate sector, government sector, monetary authority and foreign investor) should be equal to zero. Therefore, the numerator of Tobin's *q* can be expressed as:

$$\begin{aligned}&\text{Implied total market value of private corporate capital} =\\&\qquad\text{Net domestic financial household assets} +\\&\qquad\text{Net domestic financial assets held by governments} +\\&\qquad\text{Net domestic financial assets of the monetary authority} +\\&\qquad\text{Net capital investment from abroad}\end{aligned}$$

The quarterly data is taken principally from the Financial Accounts data from Australian Bureau of Statistics (ABS cat. 5232.0).

The numerator is then divided by the replacement value of capital as per the quarterly series of net private corporate capital stock recorded in the Australian National Accounts (Australian Bureau of Statistics, cat. 5206.0 Table 57). Note that

of tangible assets. Specifically, Summers (1981), Bernanke *et al*. (1988) and BRS have based their estimation of the numerator of the aggregate *q* measure as follows:

$$\begin{aligned}&\text{Total market value}\\&= \text{market value of equity plus the market value of debt}\\&= \frac{\text{Dividend payment}}{\text{dividend yield}} + \frac{\text{Total interest payment}}{\text{medium term corporate bond yield}}\end{aligned}$$

The value of the denominator is constructed as the nominal capital stock plus inventories. Note that this method requires assumptions and discretion in selecting a representative measure of the dividend yield ratio and aggregate bond yield ratio.

[5] A discussion of the relative merits or otherwise of these measures can be found in Wright's (2006) working paper addressing this.

this construction of *q* entails a direct calculation of the total value of assets, based on actual statistics, and accounts for both tangible and intangible assets[6].

Prior to 1988, due to the shortage of adequate data, the calculation of quarterly *q* is divided into two further periods (see the Data Appendix for more specific details). From 1966 Q3 to 1986 Q4, the Tobin's *q* ratio used in this chapter is taken directly from Nigel Dews' (1986) research conducted while employed by the Reserve Bank of Australia. In Dew's paper a representative sample of listed companies is selected and the total market value of this sample is calculated and scaled up by the appropriate factor to obtain the total market value of entire business economy. Alternative data sources to construct a more representative measure of Tobin's *q* are not available for the Australian economy prior to 1988 and Dews' series is used in other major studies regarding Australian investment such as McKibbin and Siegloff (1988). Over the period from 1986 to 1988 over which neither Dew's series nor the relevant Financial Accounts data exists, the *q* ratio is estimated using the market value of capital stock as per the value of the share market over the period in question. Further detail on the data construction can be found in the data appendix. The rounded estimated *q* series can be found in Table 2.A.3 in the appendix.

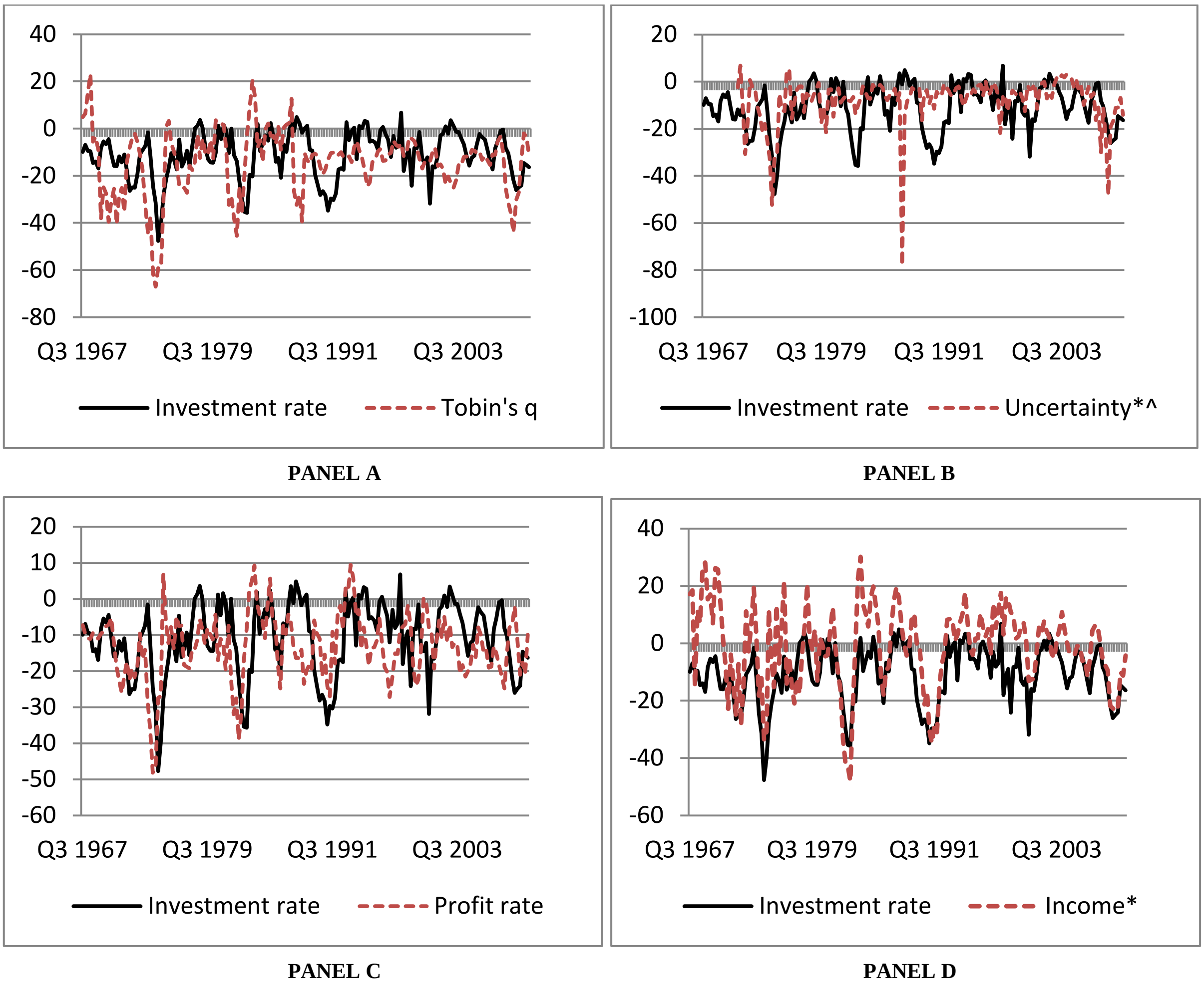
As can be seen in Figure 2.1 and panel A of Figure 2.2, Tobin's *q* shows some strong correlation with the rate of investment. As with investment prior to 1974, Tobin's *q* was also at an above average level; between 1966 Q1 and 1973 Q3, the average value of *q* measured 1.32. Over the period 1973 Q4 to 1986 Q3, *q* fell to below the value of 1 and averaged only 0.71. After a brief spike in the value of *q* in the late 1980s – reflecting the 1980s stock market boom – *q* again fell and stayed below 1 until 1993 Q2 when market and acquisition costs again reached parity. With few exceptions, *q* remains at or above the investment level until 2008 Q3. This coincides with the strong investment and indeed, economic, upswing seen in the Australian economy over the last 2 decades until the GFC most recently. However, as with investment, the value of *q* falls quite substantially since 2008 and has only

[6] According to McGrattan and Prescott (2001), intangible assets may account for one quarter of the total market value of firms in the US, which is a very important proportion of total assets. It might be surmised that the Australian economy comprises a similarly significant proportion of intangible assets.

recovered slightly since. Notably, in all major investment downturns – 1974, 1982, 1989 and 2008 – Tobin's *q* leads investment by between 2 to 3 quarters. Investment upturns, however, seem to respond to *q* more tentatively and after evidence of more persistence in the path of *q*. Given that these upturns proceed more turbulent periods of market uncertainty it is not surprising that there is a longer lag in the response of investment to movements in *q*.

Panel B in Figure 2.2 portrays the relationship between investment and uncertainty over the period 1967 Q3 to 2010 Q2 with uncertainty data becoming available only in 1971 Q1. Uncertainty here reflects uncertainty in returns to investment and is measured as the standard deviation of the daily AllOrds Index stock return data over each quarter following Greasley and Madsen (2006) (see also Wilson *et al.,* 1990). Specifically, the efficient market hypothesis posits that the current price of stocks represents the expected future value of discounted cash flows of the underlying firms (Schwert, 1990). Accordingly, volatility of stock price returns is reflective of uncertainty in future cash flows and reflects an uncertain investment environment. In the graph this series has been scaled and multiplied by negative one such that the two series are more easily comparable; investment should decline when uncertainty increases. Initial visual inspection suggests that with respect to large increases in uncertainty, investment does appear to respond negatively, particularly in the 1970s and most recently in the period post 2008.

Figure 2.2: Changes in the rate of investment, Tobin's *q*, profit rate, income and uncertainty



Note*:* The investment rate, Tobin's *q*, uncertainty, the profit rate and income are measure quarterly. There series are normalised to mean of 0. * signifies that the series has been scaled to be proportionate to the investment rate series for comparison purposes. ^ signifies that the series has been multiplied by negative one, again for ease of comparison.

Panel C of Figure 2.2 compares investment rates with company profit rates. Profit rates are commonly used to give an indication of how responsive firms are to internal cash flow (Blanchard, Rhee and Summers, 1993, Barro, 1990, Greasely and Madsen, 2006, Madsen and Carrington, 2012). Due to data availability, the profit rate is measured as private gross surplus over the value of private non-financial firms' capital stock which are deflated by the GDP implicit deflator**,** and the Gross Fixed Capital Formation deflator, respectively. The relationship between investment and profit rates in Panel C is, on visual inspection, remarkably tight. While the close relationship between investment and profit is clear, it is notable that more often than not, both in upturns and downturns, large swings in investment are led by swings in profit rates initially. Exceptions to this are the fall in investment in the 1991 recession and the most recent dip as a result of the GFC. Both of these economic downturns were preceded by crises initiated primarily in the financial sector.

The final panel compares investment rates and real income per capita. As has been found in other papers looking at the drivers of aggregate investment for Australia, real income growth and investment growth appear visually to be highly positively correlated; although whether a leading or lagging relationship holds is hard to distinguish from the figure. The falls in investment in the mid 1970s, 1990, 2000 and 2008 appear to lead income changes whereas those in 1971 and 1981 appear rather to lag declines in income. With respect to investment upswings, income appears to lead or at least coincide with investment in nearly every instance except the late 1970s.

The visual comparison of the major suspected drivers of investment reveals that investment rates are likely to have a very strong, lagged relationship with profit rates and a generally consistent and positive relationship with Tobin's q and real income per capita. While the visual depiction of the correlation between investment and uncertainty is not unquestionably consistent, there does appear to be a negative correlation between the two series on balance, and strong falls in investment look to correspond with large spikes in uncertainty.

2.5 Empirics

2.5.1 Empirical model

From the theory section it is seen that investment depends on Tobin's q and uncertainty in the long run. It is also assumed that the fundamental value of the firm and the market value of the firm do not diverge; the q variable summarises all expectations that are relevant for investment behaviour. As reflected in equations 2.6 – 2.8, investment should be driven by the market value of the firm in the long run – which theoretically is reflected by Tobin's q – and investment will fluctuate around its long-term equilibrium due to demand side disturbances in the short run. According Blanchard, Rhee and Summers (1993), in case where the market and the fundamental value of the firm are not equal, the fundamental value of the firm measured by the firm managers themselves is an important variable driving investment decisions. The estimation method to be used therefore requires the following two equations to be estimated:

$$\ln(I/K)_t = \alpha_0 + \alpha_1 \ln q_t + \alpha_2 \ln q_t^* + \alpha_3 Var_t + \varepsilon_t, \tag{2.11}$$

$$\Delta \ln(I/K)_t = \alpha_5 + \tau\hat{\varepsilon}_{t-1} + \sum_{i=1}^{k} \beta_i \Delta \ln q_{t-i} + \sum_{i=1}^{k} \lambda_i \Delta \ln q_{t-i}^* + \sum_{i=1}^{k} \gamma_i \Delta Var_{t-i} + v_t, \tag{2.12}$$

where Δ is the one-quarter difference operator, ε and v are stochastic error terms, I is non-residential private firm fixed investment, K is the beginning-of-period non-residential private capital stock, q is Tobin's q as measured by the capitalized value of the capital stock divided by the acquisition cost of capital at current costs, Var is uncertainty and q^* is a measure of the fundamental value of the firm using profit rate. Similar to BRS, we use the current profit rate as proxy for the unobservable q* and assume that firms are using their *ex post* profit rate to predict their future profit. According to q theory, the I/K ratio being regressed in an equation where q is main explanatory variable comes directly from the derivation of the investment function, as seen Eq. 2.1 to 2.7 of this chapter. Similar to other cointegration researches, the estimation procedure here includes two steps. Equation 2.11 will be estimated first. Then the first lag of the Error Correction Term ε_t produced from the levels regression result of Equation 2.11 is used as an explanatory variable in Equation 2.12 which is estimated latter. More in-depth discussion could also be found in Madsen and Carrington (2012).

To investigate the relationship between investment and uncertainty, we need to choose a proxy for uncertainty that is pervasive enough to have an impact on all firms and is readily and frequently observable within the measurement period. The main proxy used for uncertainty in this study is the standard deviation of the daily All Ordinaries Index returns during each quarter. This is consistent with the standard in the literature (see Wilson *et al*., 1990; and Greasley and Madsen, 2006)..

The long-run relationship between the variables – reflected in Equation 2.11 – will be estimated using the Dynamic Ordinary Least Squares (DOLS) estimator of Stock and Watson (1993), where the first differences of the lags and leads and concurrent values of the explanatory variables are included as additional regressors to allow for the dynamic path around the long-run equilibrium and to account for endogeneity. The addition of leads and lags removes the deleterious effects that short-run dynamics of the equilibrium process have on the estimate of the cointegrating vector of explanatory variables (Kao and Chiang, 2001). All the variables are based on one quarter differences; data of quarterly frequency have the advantage of capturing richer information regarding the impetus and timing of fluctuations in the investment rate around the long-run equilibrium rate of investment.

The Error Correction Term (ECT) produced from the levels regression result of Equation 2.11 is used as an explanatory variable in Equation 2.12. It permits us to capture the long-run dynamic adjustment process between variables on an adjustment path. It allows for shifts in investment resulting from adjustment to its equilibrium long-run level, as defined by the co-integrating relationship in Equation 2.11, as well as from transitory fluctuations due to demand side disturbances. The sign of the coefficient of the ECT should be negative. As the theoretical section established, increases in income should result in reduced demand constraints and therefore higher expected returns to investment, promoting investment. While the level of uncertainty should theoretically be a key determinant of investment decisions, it may be the case that *changes* in uncertainty are more important for firms' investment decisions. In such circumstances, an increase in uncertainty – here measured as an increase in the level of volatility in expected returns to equity – will lead to a reduction in capital investment. Similarly, while the levels of q and $q*$ are predicted to impact on the level of investment, it is also possible that the *change* in these variables could have an impact on the *rate of change* in investment in excess of the effect already captured from these variables in the error-correction term. These variables are included in the difference regression accordingly.

2.5.2 Empirical analysis and results

Equation 2.11 is a model showing the possible cointegration amongst the variables claimed by the above literature section. Before running the model, it is necessary to test for stationary of the concerning variables. Therefore, unit root tests have been undertaken and the results are displayed in Appendix 1 of this chapter. Accordingly, $\ln q_t$, $\ln q_t^*$ and $\ln(I/K)_t$ are I(1) series, while uncertainty is stationary. Then due to I(1) charateristics of the series, cointegration vector tests based on the Johansen (1988) methodology are used to examine the relationship between Tobin's q (q), investment (I/K) and profit rates (all in natural logarithm format). Although theoretically, uncertainty should be included in the cointegration test, but in fact, it is not included because of its stationary nature. A trace test and a maximum Eigen value test are used to test for cointegration (Johansen, 1988). The results displayed in Table 2.1 show that both test statistics of trace and max eigen tests reject the null of zero cointegrating vectors. On the other hand, the hypothesis that there is one cointegrating vector cannot be rejected. Based on the evidence in Table 2.1, we could conclude that there exists a cointegration relationship amongst the variables of interest. In the other words, the level of the investment ratio moves with that of both Tobin's q and the profit rate over the sample period from 1967 Q3 to 2010 Q2.

Table 2.1: Johansen test for number of cointegration vectors

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**Max-Eigen Statistic**
None	0.125710	36.18234**	22.97259***
At most 1	0.049438	13.20975	8.670080
At most 2	0.026199	4.539674	4.539674

Note: *, ** and *** indicate 10%, 5% and 1% significance, respectively.

Given the clue of a long-run relationship from Johansen test, Equation 2.11, the long-run relationship between the variables is estimated using the Dynamic Ordinary Least Squares (DOLS) estimator of Stock and Watson (1993) due to advantages of this estimator. The DOLS estimator being used means the following equation is now estimated:

$$\ln(I/K)_t = \lambda_0 + \lambda_1 \ln q_t + \lambda_2 \ln q_t^* + \sum_{s=-n}^{m} [\beta_s' \Delta \ln q_{t+s} + \tau_s' \Delta \ln q_{t+s}^*] + \varepsilon_{1t} \quad (2.13)$$

where m and n are number of lags and leads and are chosen automatically by the Schwarz information selection criterion and t refers to the period and measured in quarters. The theoretical model predicts that both q and $q*$ will be positively related to the investment rate. VAR_t is not presented in the equation as it is a stationary and in fact the inclusion of VAR_t in the equation regression showed that it was not significant. The result of the DOLS estimation of Equation (2.13) is:

$$ln\left(\frac{I}{K}\right)_t = 0.378996 * \ln(q_t) + 0.172486 * \ln q_t^* - 2.964097$$

(6.27) (3.02) (-20.94)

where the figures in parentheses are the t-statistics. In this reduced-form regression, all coefficients are significant at the 1% level. The full estimations results with all lags and leads of variables can be found in Table 2.A.2 in the appendix. The residuals of the regression are extracted as a new time series to be used latter. The augmented Dickey–Fuller (ADF) test statistic for I(1) of the residuals series is -2.27, which means the series is stationary. Again, similar to the Johansen test result above, the null hypothesis of no cointegration amongst the three variables in the above equation is rejected at conventional significance levels (with 5% significance). The signs of the coefficients of the variables are positive and are consistent with the literature. The coefficients of lags and leads of differences can be found in the appendix section of this chapter. The results of this estimation reveal that both Tobin's q and the profit rate are highly correlated with investment and reinforce the visual impression in Figure 2.2 that Tobin's q and profitability are determinants of long-run investment dynamics. Here the magnitude of the coefficient of Tobin's q is twice the size of that pertaining to profitability. This echoes the findings by Greasley and Madsen (2006) using annual U.S. data. However the magnitude of the coefficient of the q variable is even higher for Australia. The estimates in this chapter are also much higher than the corresponding estimates made by Summers (1981) in his investigation of investment for the U.S. economy.

Augmenting Equation 2.12, the following equations are regressed:

$$\Delta \ln(I/K)_t = \alpha_5 + \tau\hat{\varepsilon}_{t-1} + \sum_{i=1}^{4} \beta_i \Delta \ln q_{t-i} + \sum_{i=1}^{4} \lambda_i \Delta \ln q^*_{t-i} + v_t, \quad (2.14)$$

$$\Delta \ln(I/K)_t = \alpha_5 + \tau\hat{\varepsilon}_{t-1} + \sum_{i=1}^{4} \beta_i \Delta \ln q_{t-i} + \sum_{i=1}^{4} \lambda_i \Delta \ln q^*_{t-i} + \sum_{i=1}^{4} \gamma_i \Delta Var_{t-i} + \sum_{i=1}^{4} \gamma_i \Delta \ln Y_{t-i} + v_t, \quad (2.15)$$

where Equation 2.14 is a baseline model - looking only at the impact of the change in Tobin's q and q* on the change in investment rates - and Equation 2.15 is augmented by the variables predicted to drive fluctuation in the level of the investment rate around its long-run equilibrium. Here we add Var denoting for uncertainty and Y denoting for real GDP per capita as proxy for the total level of output of the economy. Output has been claimed by investment literature as an important driver of investment (see Caballero, 1999, for the review). The lagged terms added in the equation reflect the information set available to firms when the investment decision is made. Including lagged terms also avoids some of the problems associated with possible simultaneity in investment and capital structure decisions.

We use the general-to-specific model reduction method where the variable with the most insignificant coefficient is deleted in each regression round until all coefficients are significant at the 5% level, excluding the constant term. Results of both the unrestricted and restricted models are presented in Table 2.2.

Table 2.2: Parameter estimates of Equations 2.14 and 2.15

Dependent variable $\Delta ln\frac{I}{K_t}$	**(1)**	**(2)**	**(3)**	**(4)**
Constant	0.00	0.00	0.00	**0.02****
	(0.42)	(0.99)	(0.06)	**(2.25)**
Δlnq_{t-1}	0.04		0.04	
	(0.93)		(0.67)	
Δlnq_{t-2}	**0.10***	**0.11***	**0.12****	
	(1.89)	**(1.90)**	**(1.99)**	
Δlnq_{t-3}	0.04		0.01	
	(0.71)		(0.24)	
Δlnq_{t-4}	0.04		0.07	
	(0.79)		(1.28)	
Δlnq^*_{t-1}	0.08		0.04	
	(1.27)		(0.50)	
Δlnq^*_{t-2}	0.1		0.05	
	(0.97)		(0.46)	

Δlnq^*_{t-3}	**0.15****	**0.13*****	0.04	
	(2.23)	**(2.66)**	(0.46)	
Δlnq^*_{t-4}	-0.01		-0.00	
	(-0.19)		(-0.02)	
Var_t			-0.77	
			(-1.11)	
Var_{t-1}			**-1.45***	**-1.80****
			(-1.92)	**(-2.00)**
Var_{t-2}			1.22	
			(1.34)	
Var_{t-3}			**-2.38*****	**-2.21*****
			(-2.63)	**(-2.96)**
Var_{t-4}			1.23	**1.11****
			(1.70)	**(2.02)**
ECT_{t-1}	**-0.09****	**-0.09****	**-0.33*****	**-0.34*****
	(-2.13)	**(-2.1)**	**(-3.36)**	**(-3.86)**
ΔlnY_{t-1}			0.41	**0.69****
			(1.01)	**(2.42)**
ΔlnY_{t-2}			-0.29	
			(-0.70)	
ΔlnY_{t-3}			0.70	**0.85****
			(1.63)	**(2.54)**
ΔlnY_{t-4}			**-1.00****	**-1.08*****
			(-2.54)	**(-3.19)**
R-squared	0.13	0.09	0.27	0.24
DW	2.30	2.24	2.16	2.09
AIC	-3.21	-3.25	-3.13	-3.22
BIC	-3.02	-3.18	-2.74	-3.08

Note: p-values are indicated in parentheses.*, ** and *** indicate 10%, 5% and 1% significance, respectively. Δlnq is growth rate of the Tobin's *q* ratio. Δlnq^* is the growth rate of the profit ratio. *Var* is uncertainty. ΔlnY is growth rate of real GDP per capita. ECT_{t-1} is error correction term produced from Equation 2.13 regression. The standard errors are based on the Newey-West autocorrelation and heteroscedasticity consistent covariance matrix. AIC is Akaike info criterion and BIC is Schwarz criterion.

The results of the unrestricted, baseline regression – looking only at the impact of the change in Tobin's *q* and *q** on the change in investment rates – are shown in Column 1. Similar to BRS' results, both Tobin's *q* and *q** are positive and significant determinants of investment. Consistent with the level regression results, the dependent variable is more strongly responsive to *q* than *q**, when the sum of the coefficients are considered. The implication is that while *q* and *q** may differ in their behaviour some of the time – during market fads or bubbles for example – they are likely to move in step for a substantial amount of time. In this case it appears that *q* dominates in terms of influence over investment. This is consistent with the theory that *q* encapsulates all relevant information relating to the value of the firm whereas current profit rates are only a proxy for expected discounted value of future cash flows. With respect to timing; the second lag of Tobin's *q* are significant, showing that the information embodied in q two quarters earlier is important to the current quarter's investment decision. Fundamental q^* is revealed to be significant after being lagged three quarters. All of these results hold in the restricted regression which can be seen in Column 2. Thus, in general, changes in both q and q^* are associated with changes in the rate of investment after a lag of 2 to 3 quarters. Importantly the error-correction terms are significant at the 1% level in both the general and specific model regressions and are negatively signed. This means that the investment ratio in the long-run converges towards its long-run equilibrium which is consistent with the predictions of the model.

The augmented regression's results are displayed in Column 3. The regression results of the restricted model (obtained by using the general-to-specific procedure) are displayed in Column 4. The first result to be remarked is that by augmenting the model with the additional variables, the change in both q and q^* cease to be of significance for changes in the investment rate. Their influence is now felt solely through the error-correction term. In the unrestricted model the first and third lags of uncertainty and the fourth lag of income per capita are all significant and correctly signed according to the theoretical model's predictions. Crucially the *ECT* remains negative, significant and even of the same magnitude. Refining the model as per the general-to-specific methodology confirms and strengthens these results with the number and sum of coefficients increasing for the income variable; all of the first, third and fourth lags are now significantly associated with the change in investment rates. The signs of the coefficients of income variable (ΔlnY) switch from positive to negative then back to positive; this signifies that it is the acceleration, rather than the change in income, that is important for influencing investment rates. Thus a change in the rate of growth of income per capita has a strong effect on investment rates; however sustained and steady growth in income is only predicted to maintain rather than increase the level of the investment rate. The general result that income is an important determinant of investment is consistent with the capital stock adjustment principle as well as previous studies specific to Australian investment using neo-classical models showing that output has significant role on private investment (McKenzie, 2007). The high economic and statistical significance of the income variable is also consistent with the conclusion of Chirinko's (1993) survey of the US investment literature that income remains a very important determinant of investment regardless of which variables are included in estimates.

Two criteria for model comparison Akaike info criterion and Schwarz criterion are reported at the end of Table 2.2. The comparison rule here is the smaller these criteria the better the model is. As seen, results of AIC and BIC seems to be equivalent. These criteria information shows that the models of Columns 2 and 4 be better in term of relative quality than those of Columns 1 and 3 respectively, although the values of R-squared say the opposite in term of goodness of fit.

The test of the relationship between uncertainty and investment can be viewed as a test of whether larger than usual movements in stock prices will be associated with greater uncertainty about one's prediction of future returns to investment. Theory predicts that increased uncertainty should initiate a downward adjustment in investment spending. While the unrestricted estimates imply that the level of uncertainty has a dampening impact on the investment rate, the restricted estimates reveal that as well as the expected level effect, like income, the second derivative of the standard deviation of the expected returns to capital (proxying for uncertainty) impacts on investment as well. In other words when there is movement between one level of uncertainty to another – when there are changes in the volatility of expectations as reflected by the stock market – investment rates are expected to change, and do so in a negative manner. This is in addition to the expected negative impact of the level of uncertainty being negatively associated with investment. In general, the results justify the significant negative impact of uncertainty on investment, after controlling for Tobin's *q* and profitability. When uncertainty is added in the model, the short-run impact of changes in Tobin's *q* and the profit rate on the investment rate diminish. When income per capita is added to the regression, uncertainty remains significant. However, *q* and *q** maintain their significant impact on investment over the long run as these variables assert a converging influence on investment rates through the *ECT*.

2.6 Robustness Check

In this section, the robustness of the relationships of the above variables for the investment regressions is tested. First, we note the strong cyclical fluctuations in investment apparent in Figure 2.2 and account for the business cycle by adding a new variable proxying for the cyclical divergence of GDP from trend GDP. We then use other proxies for uncertainty to test for the strength of these key results.

We account for business cycle impacts by using a measure of the GDP gap which is defined as the difference between real GDP and potential GDP, scaled by potential GDP. The GDP gap also arguably proxies for expectations regarding the overall economic outlook as explained in previous empirical studies (Sundararajan and Thakur, 1980; and Ang, 2009). Thus the larger the differential between potential GDP growth and observed GDP growth, the greater the expectation there will be an increase in GDP growth in the future, and vice-versa. To the extent that these expectations impact on business investment decisions and investment is a forward looking decision making process, this variable should be positively signed. The trend level of output is taken to be the potential level of output and it is obtained using the Hodrick-Prescott filter method with a smoothing parameter of 1600 (see Hodrick and Prescott, 1997, for the calculation method).

Previous empirical researchers (Episcopos (1995) and Serven (1998)) find evidence of relationships between investment and macroeconomic uncertainties. Accordingly, we use measures of macroeconomic volatility, proxied by the conditional standard deviation of different aggregate variables, to verify the robustness of the impact of uncertainty on investment; macroeconomic uncertainty should strongly increase the option value of delaying investment. The proxies utilised include conditional standard deviations obtained from a univariate GARCH (p,q) specification (following Bollerslev, 1986) of the following macroeconomic series: (i) the forward looking Westpac Economic Index (published quarterly by Westpac Bank's Research and Australian Chamber of Commerce and Industry); (ii) Australian real interest rates; (iii) the inflation rate; (iv) the real Australian dollar exchange rate; and (v) the Australian terms of trade. A GARCH specification computes the conditional variance of the residual precipitated from a regression of the variable on its lagged values. Using maximum likelihood techniques, it is possible to estimate simultaneously an AR process for the variable and an ARM process for the conditional variance of the error term. Uncertainty is assumed to be the fitted series of this conditional variance and is essentially a forecast of the variance of the variable based on its past observations. The mean equations of GARCH models for the real interest rate and inflation rate series are in the ARMA form while those for the other three series are in the ARIMA form as these series have a unit root. Thus the dependent variables of the mean equations are first-deference series in these cases. The data was obtained from ABS, RBA and Datastream Economic data and further details regarding the data can be obtained in the data appendix. The explicit illustration of these measures can be found in Figure 2.A.1 at the appendix.

Here we examine how the various uncertainty measures are correlated. According to Table 2.3 and Figure 2.A.1 there is a strong correlation amongst the groups of uncertainty: a group of Westpac Index uncertainty, stock market uncertainty, real interest uncertainty, inflation uncertainty and real interest uncertainty, and another group including terms of trade uncertainty and real exchange rate uncertainty. Uncertainty within a group match the behaviour of the other group members. However, the correlation statistics show that uncertainty are not totally correlated to one another, but they are independent at a considerable level. It is therefore worthy to find out whether different uncertainty influence investment differently and if the baseline investment equation is sensible to different uncertainty measures.

Table 2.3: Correlation Matrix of Various Uncertainty Measures

	Inflation	Real exchange rate	Terms of trade	Real interest rate	Westpac Indicator	AllOrds returns
Inflation	1.00					
Real Exchange rate	0.08	1.00				
Terms of Trade	-0.02	0.34	1.00			
Real Interest rate	0.58	0.18	-0.16	1.00		
Westpac Indicator	0.07	0.23	0.14	0.42	1.00	
AllOrds returns	0.04	0.07	0.24	0.22	0.46	1.00

The results obtained under the robustness checks are displayed in Table 2.4. Adding the GDP gap variable and restricting the insignificant variables to zero yields the estimates in Column 1. As seen in Column 1, the business cycle has a strong correlation with investment. The coefficients of the output gap variable are significant at the 1% level and are positively signed as expected. With the inclusion of the variable accounting for business cycles, Tobin's *q* becomes insignificant, but the coefficient of uncertainty continues to be significant and remains negatively signed. Further, it appears to dominate income, profit and business opportunity variables in its explanatory power in the regressions. This suggests that profit rates, demand constraints and other expectation capturing variables are simply proxies for the accelerator process that drives the investment component of business cycle movements. These results do not give information as to which variables instigate the cyclical process however. Remarkably, uncertainty, as measured in the previous section, remains significant even when business cycle fluctuations are captured in the regressions indicating the unique importance of uncertainty to the investment decision beyond those associated with cyclical volatility.

The results obtained using the constructed proxies for different indicators of macroeconomic uncertainty are displayed in columns 2 – 6 in Table 2.4. The main thrust of the results reinforce the significant role of uncertainty as well as that of income in determining business investment; the coefficients of uncertainty are largely significant and negative and support the fundamental results in section 5, while the other variables being researched also have significant coefficients with the expected signs. With specific focus towards the uncertainty proxies, the results suggest that there is a lagged relationship between changes in the level of uncertainty of the real interest rate, the terms of trade and the real exchange rate. In particular, an increase in the level of the conditional standard deviations of these variables is associated with a decrease in the rate of growth of investment after a lag of two quarters for the interest rate variable and three quarters for the international terms of trade and exchange rate variables. The results reinforce those presented in Table 2.2 where there is a strong lagged relationship between uncertainty and investment behaviour.

Table 2.4: Sensitivity Analysis for Investment Equation

Dependent variable $\Delta ln\frac{I}{K_t}$	**(1) VAR: Unconditional SD of stock index**	**(2) VAR: Conditional SD of Westpac Economic Leading indicator**	**(3) VAR: Conditional SD of real interest rate**	**(4) VAR: Conditional SD of Terms of trade**	**(5) VAR: Conditional SD of real exchange rate**	**(6) VAR: Conditional SD of inflation**
Constant	0.01	0.09***	0.01	-0.01	0.00	0.01
	(1.42)	(3.43)	(1.35)	(-0.69)	(0.73)	(0.84)
Δlnq_{t-1}						
Δlnq_{t-2}				0.13**	0.11**	0.11**
				(2.27)	(2.02)	(2.07)
Δlnq_{t-3}		0.08*		0.12**	0.14***	0.12**
		(1.70)		(2.55)	(2.88)	(2.60)
Δlnq_{t-4}						
Δlnq^*_{t-1}			0.13*	0.12*		
			(1.81)	(1.68)		
Δlnq^*_{t-2}						
Δlnq^*_{t-3}						
Δlnq^*_{t-4}						
Var_t		-7.65***	-0.02***			-8.35**
		(-5.57)	(-3.14)			(-2.3)
Var_{t-1}						6.38*
						(1.73)
Var_{t-2}			0.01**			
			(2.25)			
Var_{t-3}	-2.59***			-3.46**	-0.94***	
	(-2.59)			(-2.23)	(-3.14)	
Var_{t-4}	0.85*			4.06**	0.69**	
	(1.72)			(2.03)	(2.12)	
ECT_{t-1}	-0.26***	-0.32***	-0.29***	-0.30***	-0.32***	-0.27***
	(-3.23)	(-4.03)	(-3.65)	(-3.83)	(-3.55)	(-3.36)
ΔlnY_{t-1}	0.73***					
	(2.83)					
ΔlnY_{t-2}						
ΔlnY_{t-3}		0.71**	0.99***	0.79**	0.74**	0.84**
		(2.04)	(3.09)	(2.1)	(2.04)	(2.32)
ΔlnY_{t-4}	-0.65*	-0.83**	-0.59*	-0.61**	-0.70**	-0.64**
	(-1.78)	(-2.63)	(-1.84)	(-2.03)	(-2.21)	(-2.18)
$\Delta GDPgap_t$	2.03***					
	(5.85)					
R-squared	0.33	0.24	0.22	0.20	0.21	0.21
DW	2.28	2.19	2.21	2.13	2.07	2.15
AIC	-3.41	-3.33	-3.26	-3.27	-3.19	-3.26
BIC	-3.29	-3.21	-3.16	-3.14	-3.02	-3.16

Note: t-values are indicated in parentheses.*, ** and *** indicate 10%, 5% and 1% significance, respectively. The general-to-specific method is implemented in all columns. The standard errors are based on the Newey-West autocorrelation and heteroskedasticity consistent covariance matrix. The same notation as in Table 2.2 is used. $\Delta GDPgap$ is the change in the GDP gap.

With respect to the combined leading indicator variable in Column 2 and the inflation based variable in the last column of Table 2.4, changes in the level of uncertainty are found to be associated contemporaneously with investment activity. While these results give no information about causation between these variables and investment, as there is some lag between investment decisions and recorded investment, it may be the case that an upturn in investment sentiment creates conditions for improved business outlook and reduced inflation uncertainty. Thus, from the combined results is could be surmised that reduced uncertainty with respect to the initial costs of investment stimulates increased investment activity, and that, that activity, in turn, increases the general business outlook sentiment and reduces uncertainty regarding demand and price outcomes. Such results are consistent with an accelerator theory of investment where increases in funding access due to diminished cost uncertainty finances investment. New investment then stimulates improved expectations and valuations of investment assets, in turn reducing overall credit constraints and the impact of informational asymmetries in the financial sector on real capital accumulation. While verifying this hypothesis is outside the scope of this chapter, the continued significance of the acceleration of the income variable in all of the regressions excluding the GDP gap regressions corroborates this mechanism. The findings are consistent with previous studies (e.g. Goldberg, 1993), which find negative effects on average of macroeconomic uncertainty proxies with aggregate investment.

AIC and BIC information criteria are calculated and reported to provide comparison amongst the models. Accordingly, the results of AIC and BIC amongst the model seem to be not much different. With the inclusion of the GDP gap, both the explanation power and quality of the model is better (as in Column 1 values of AIC/BIC of is smaller than other column’s while its R-squared is higher).

While the results are not displayed, the robustness of the results in Section 5 is also tested by applying an alternative method of calculating capital stock series. Instead of the actual series obtained from ABS, I use the perpetual inventory method starting from the first observation of capital stock K_0, basing on investment series and average depreciation rate of 8%, we obtain another series of capital stock. Using the new series, the result is not different. My result on the importance of q is consistent to an important research by McKibbin and Siegloff (1988), in which they claim the *q* role in explaining investment when they adjusted capital stock data to be consistent with the *q* theory. In summary, the robustness tests confirm that the results pertaining to the main variables in my models – uncertainty, Tobin's *q*, profitability and output – after controlling for business cycles, using different capital stock measures and adopting alternative proxies for uncertainty – remain valid and significant.

2.7 Conclusion

This chapter derived an augmented Tobin's *q* model of investment incorporating demand constraints and allowing for the costs of uncertainty for aggregate investment activity. The implications of this model were then tested using Australian macroeconomic economic data over 1967 Q3 – 2010 Q2. This is the first study to investigate aggregate private investment using quarterly data spanning over four decades for Australia and follows only one published study on this topic since 1986.

There are three major findings of the empirical investigation and they have important implications for the understanding of investment and for the modelling of business cycle fluctuations within Australia more generally. Firstly, as distinct from results pertaining to the US, *q* is found to be a highly significant driver of long-term investment. Further, the magnitude of the coefficient of *q* is large and strongly dominates that pertaining to the fundamental value of the representative firm as proxied by cash flow. Thus, abstracting from business cycle fluctuations, the Australian capital market is relatively strongly anchored to the fundamental value of capital.

Secondly, changes in the level of uncertainty in the equity market – as measured by fluctuations in the volatility of stock prices – are revealed to be significantly associated with investment at business cycle frequencies. The interpretation is that it is the fluctuation in the level of uncertainty seen in the stock market, rather than the level of uncertainty itself, that is important in driving more short-term decisions pertaining to investment. Moreover, as stock market volatility only really accelerates prior to investment down turns, uncertainty is found to be a key driver of investment downturns.

The final result of note corroborates previous studies relating to investment behaviour in the US as well as in Australia: income per capita significantly impacts investment over business cycle frequencies. In the estimations for Australian investment it was found that persistence in the rate of growth of investment can only be triggered by a continual corresponding increase in the rate of growth of income per capita, however. The inferences of this result are that increases in investment rates are only likely to be delivered when the economy is at the initial and accelerating phase of its cyclical upswing and that rigidities pertaining to the demand side of the economy can have a substantial impact on the timing and magnitude of investment fluctuations. While either goods market rigidities or accelerator models of investment and credit market behaviour are possible explanations for this result, identifying the exact mechanism through which demand constraints affect investment, however, falls outside of the scope of this chapter and is left for future research.

The chapter provides some relevant implications to government policies on promoting private investment. While private investment plays important roles in economic development, increasing and stabilizing investment should be one of priorities of government jobs. This chapter empirical results show that to enhance investment, there should be policies to reduce uncertainty, at least for types of uncertainty which can be reduced by government policies. Political and macroeconomic policy uncertainty are types of controllable uncertainty and can be reduced through the increased stability and transparency of the governments, in particular Australian government.

2A.1. Data Appendix

Private Investment
Private Non-residual Fixed Investment: Private Gross Fixed capital formation (excluding gross fixed capital formation in Dwellings) at a quarterly frequency, seasonally adjusted at current prices from ABS 5206.0 - Australian National Accounts: National Income, Expenditure and Product. The current price series is deflated using the gross fixed investment (GFCF) deflators (also from ABS).
Capital stock
The annual series of net private corporate capital stock is from ABS, data category number 5206.0 Table 57 and 5204.0. The estimates of capital stock are calculated as the summation of year-end net capital stock of non-financial corporations. The quarterly figures are interpolated from annual data based on annual data following Federer (1993), where the private investment series was used to construct weights in the following linear interpolation: $K_{i,j} = [\sum_{z=1}^{j} I_{i,z} / \sum_{z=1}^{4} I_{i,z}](K_{i,4} - K_{i-1,4}) + K_{i-1,4}$, when j =1 to 4 standing for quarter, *i* stands for year.
Investment ratio
The private business investment divided by the net private capital stock at the end of the previous period. Both are real series. The real capital stock series is obtained by deflating the current capital stock series using the gross fixed investment deflators.
Profit rate
It is calculated as gross surplus of private business at current prices divided by the current value of net capital stock. The gross surplus is from ABS cat. 5206. The current value of net capital stock is from ABS and interpolated for missing quarterly data as explained above.
Income
Income is taken as real income per capita. This measure is the seasonally adjusted quarterly real Gross Domestic Product divided by total population. All original data was obtained at quarterly frequencies from the Australian Bureau of Statistics Database.
Tobin's q
Tobin's *q* is calculated as the current market value of total private non-financial firm equity and liabilities divided by the current value of the net capital stock of private non-financial business. In this chapter we have constructed the series of aggregate Tobin's *q* from 1967 Q3 to 2010 Q2 for Australia which is comprised of pre-existing as well as newly generated data sets. With respect to newly calculated data, within the literature, a number of methods have been used to calculate aggregate Tobin's *q* data for various economies. The method used to construct the series in this study is based on that used by Laitner and Stolyarov (2003) and by Wright (2004) for the U.S. economy. The method is based on the fact that the total net financial assets/liabilities of all economic agents (i.e. households, Federal government, local and state governments, the rest of the world, private non-financial corporates, central bank and financial intermediates) must equal to zero. Therefore the total market value of private non-financial corporates must equal to the total net claims of the counter agents on this sector. The denominator of Tobin's *q*, the replacement cost of private non-financial business capital stock, is the net capital stock calculated above, of the same period. Both nominator and denominator of Tobin's *q* are at current price. This method has been replicated as closely as possible on a quarterly basis for the Australian economy over the period for which data is available to do this; from 1988 Q1 onwards.

The applied method used for calculating the numerator of the Tobin's *q* ratio entails summing the market value of the business sector as measured by the non-residential net financial assets of the personal sector and the net claims of the governments and the monetary authority on the private sector. The data is taken principally from the Financial Accounts data from Australian Bureau of Statistics (ABS cat. 5232.0).

Specifically, the numerator of Tobin's *q* can be expressed as:

$$\begin{aligned}&\text{Total market value of capital} =\\&\text{Net domestic financial household assets} +\\&\text{Net domestic financial assets held by governments} +\\&\text{Net domestic financial assets of the monetary authority} +\\&\text{Net capital investment from abroad}\end{aligned}$$

The numerator is then divided by the replacement value of capital as per the annual series of net private corporate capital stock recorded in the Australian National Accounts (Australian Bureau of Statistics, cat. 5206.0 Table 57). Note that this construction of *q* entails a direct calculation of the total value of assets, based on actual statistics, and accounts for both tangible and intangible assets.

Prior to 1988, due to the shortage of adequate data, the calculation of quarterly *q* is divided into two further periods From 1966 Q3 to 1986 Q4, the Tobin's *q* ratio used in this chapter is taken directly from Nigel Dews' (1986) research. In Dew's paper a representative sample of listed companies is selected and the total market value of this sample is calculated and scaled up by the appropriate factor to obtain the total market value of entire business economy. Over the period from 1986 to 1988, over which neither Dew's series nor the relevant Financial Accounts data exists, the numerator *q* ratio is estimated by using a weighted average index of financial asset values. Assuming that the composition of aggregate financial assets is 0.3 debt and 0.7 equity (the average over this period obtained from RBA Bulletin June 1993), the equity component is presumed to fluctuate according to the movements of the AllOrds share market index and the value of the debt component with that of the value of corporate bonds.

Deflators

Series of GDP and GFCF deflators are from ABS cat. 5206.0 Australian National Accounts: National Income, Expenditure and Product Table 5.

Westpac leading indicator index of economic activity

Melbourne/Westpac leading index of economic activity or Westpac Leading index is provided monthly by Westpac Melbourne Institute Indexes of Economic Activity reports. The data is from *Datastream*, beginning from January 1960. A GARCH(1,1) model of for the monthly annualized growth rate was estimated. The estimated variance used as uncertainty in the investment model is the average of conditional variances estimated from a GARCH model of the respective months. My method is similar to Episcopos (1995).

Real interest rate

The series is obtained from Datastream from 1969Q2.

Terms of trade

ABS cat. 5206.0, Table 1, seasonally adjusted.

Real exchange rate

Real trade-weighted index from Reserve Bank of Australia, as can be found from:
http://www.rba.gov.au/statistics/tables/index.html#exchange_rates

Australian Inflation rates

The series is obtained from Datastream from 1971Q1.

2A.2. Appendix 1

Unit root tests are necessary before performing any cointegration test. Three different unit root tests, namely the Augmented Dickey Fuller test (ADF), the Phillips–Perron test (PP) and the Zivot-Andrews test (ZA), are carried out for each variable, where the last test accounts for one endogenous structural break in the series over time. Unit root test results are displayed in Table 2.A.1 and suggest that the Tobin's q, profit rate and investment series are integrated of order one according to ADF and PP tests. The investment series is a borderline case; ADF and PP tests show it as having a unit root while it is shown to be stationary according to the Zivot-Andrews test. Graphing these variables suggests that the investment and profit variables are not stationary, even after considering structural breaks of means and trends.

Table 2.A.1: Unit root test results

Variable	**ADF**		**PP**		**Zivot-Andrews**		**Results**
	Level	**1st Difference**	**Level**	**1st Difference**	**Level**	**1st Difference**	
ln q	-1.81	-13.35***	-1.97	-13.37***	-3.911	-14.681	I(1)
	(0.37)	(0.00)	(0.29)	(0.00)	(1983Q2)	(1974Q4)	
$\ln(I/K)$	-2.30	-5.35***	-2.36	-16.07***	-5.24**	-5.21***	I(1)/I(0)
	(0.42)	(0.00)	(0.39)	(0.00)	(BP=1974Q1)	(1975)	
lnq*	-2.51	-6.11***	-2.15	-6.07***	-4.49	-6.69***	I(1)
	(0.32)	(0.00)	(0.50)	(0.00)	(BP=1973Q2)	(0.00)	
VAR	-4.50***						I(0)
	(0.00)						

Note: p-values for the ADF and PP tests are indicated in parentheses.*, ** and *** indicate 10%, 5% and 1% significance, respectively. ADF and PP tests for all variables allowing for intercept and trend. Zivot-Andrews test. For the Zivot–Andrews tests in levels, the 1%, 5% and 10% critical values are –5.57, –5.08 and –4.82, respectively, allowing for trend and mean breaks. In first differenced form, the values are –5.43, –4.80 and –4.58, respectively. The endogenously determined break point (BP) for each series is indicated in parentheses.

Table 2.A.2: Dynamic Ordinary Least Squares regression results

Variable	Coefficient	Std. Error	t-statistics	Prob.
constant	-2.96	0.14	-20.94	0.00
lnq^*_t	0.17	0.06	3.02	0.00
lnq_t	0.38	0.06	6.27	0.00
Δlnq^*_{t-4}	-0.53	0.21	-2.53	0.01
Δlnq^*_{t-3}	-0.69	0.24	-2.80	0.01
Δlnq^*_{t-2}	-0.80	0.25	-3.19	0.00
Δlnq^*_{t-1}	-0.81	0.24	-3.41	0.00
Δlnq^*_t	-0.84	0.23	-3.66	0.00
Δlnq^*_{t+1}	-0.67	0.26	-2.59	0.01
Δlnq^*_{t+2}	-0.76	0.26	-2.95	0.00
Δlnq^*_{t+3}	-0.68	0.27	-2.46	0.02
Δlnq^*_{t+4}	-0.61	0.29	-2.11	0.04
Δlnq^*_{t+5}	-0.45	0.30	-1.51	0.13

Δlnq^*_{t+6}	-0.49	0.27	-1.80	0.07
Δlnq^*_{t+7}	-0.45	0.27	-1.66	0.10
Δlnq^*_{t+8}	-0.34	0.21	-1.66	0.10
Δlnq_{t-4}	-0.06	0.11	-0.54	0.59
Δlnq_{t-3}	0.04	0.14	0.27	0.79
Δlnq_{t-2}	0.15	0.18	0.86	0.39
Δlnq_{t-1}	0.02	0.18	0.12	0.90
Δlnq_{t}	-0.11	0.18	-0.61	0.54
Δlnq_{t+1}	0.10	0.19	0.54	0.59
Δlnq_{t+2}	-0.02	0.19	-0.08	0.94
Δlnq_{t+3}	0.09	0.19	0.46	0.65
Δlnq_{t+4}	0.19	0.18	1.02	0.31
Δlnq_{t+5}	0.31	0.18	1.71	0.09
Δlnq_{t+6}	0.23	0.18	1.29	0.20
Δlnq_{t+7}	0.18	0.15	1.19	0.24
Δlnq_{t+8}	0.08	0.14	0.55	0.59

Note: The standard errors are based on the Newey-West autocorrelation and heteroskedasticity consistent covariance matrix. Number of lead and lags are indentified based on SIC criteria.

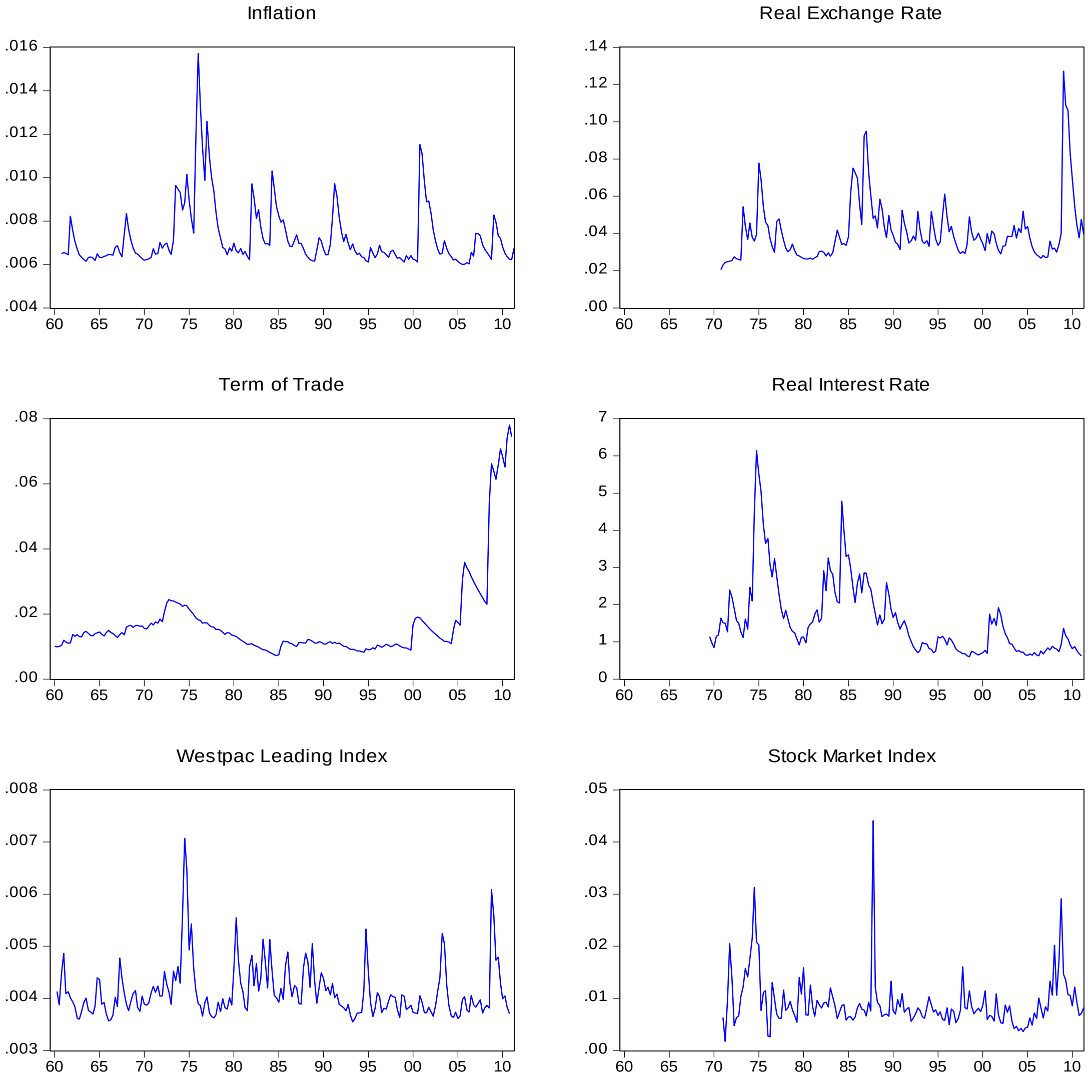
Table 2.A.3: Estimated Australian Tobin's *q* during 1966Q3 – 2010Q2

Quarter	q	Quarter	q	Quarter	q	Quarter	q	Quarter	q	Quarter	q
1966Q3	1.19	1974Q1	0.97	1981Q3	0.65	1989Q1	1.01	1996Q3	1.06	2004Q1	1.06
1966Q4	1.23	1974Q2	0.74	1981Q4	0.69	1989Q2	1.02	1996Q4	1.09	2004Q2	1.05
1967Q1	1.17	1974Q3	0.56	1982Q1	0.60	1989Q3	1.05	1997Q1	1.08	2004Q3	1.07
1967Q2	1.29	1974Q4	0.58	1982Q2	0.57	1989Q4	1.04	1997Q2	1.11	2004Q4	1.12
1967Q3	1.44	1975Q1	0.62	1982Q3	0.58	1990Q1	1.02	1997Q3	1.09	2005Q1	1.11
1967Q4	1.51	1975Q2	0.64	1982Q4	0.56	1990Q2	1.02	1997Q4	1.12	2005Q2	1.09
1968Q1	1.57	1975Q3	0.65	1983Q1	0.57	1990Q3	1.00	1998Q1	1.13	2005Q3	1.12
1968Q2	1.87	1975Q4	0.69	1983Q2	0.64	1990Q4	1.00	1998Q2	1.11	2005Q4	1.12
1968Q3	1.57	1976Q1	0.67	1983Q3	0.73	1991Q1	1.03	1998Q3	1.08	2006Q1	1.14
1968Q4	1.68	1976Q2	0.67	1983Q4	0.79	1991Q2	1.04	1998Q4	1.18	2006Q2	1.13
1969Q1	1.65	1976Q3	0.65	1984Q1	0.75	1991Q3	1.04	1999Q1	1.19	2006Q3	1.10
1969Q2	1.47	1976Q4	0.62	1984Q2	0.68	1991Q4	1.03	1999Q2	1.19	2006Q4	1.18
1969Q3	1.41	1977Q1	0.60	1984Q3	0.80	1992Q1	1.01	1999Q3	1.18	2007Q1	1.21
1969Q4	1.47	1977Q2	0.60	1984Q4	0.79	1992Q2	1.02	1999Q4	1.21	2007Q2	1.25
1970Q1	1.28	1977Q3	0.57	1985Q1	0.86	1992Q3	1.03	2000Q1	1.19	2007Q3	1.25
1970Q2	1.24	1977Q4	0.61	1985Q2	0.80	1992Q4	1.03	2000Q2	1.21	2007Q4	1.25
1970Q3	1.26	1978Q1	0.58	1985Q3	0.86	1993Q1	1.06	2000Q3	1.20	2008Q1	1.12
1970Q4	1.13	1978Q2	0.60	1985Q4	0.86	1993Q2	1.05	2000Q4	1.24	2008Q2	1.11
1971Q1	1.11	1978Q3	0.64	1986Q1	0.92	1993Q3	1.12	2001Q1	1.23	2008Q3	0.99
1971Q2	1.11	1978Q4	0.62	1986Q2	0.93	1993Q4	1.16	2001Q2	1.25	2008Q4	0.86
1971Q3	1.02	1979Q1	0.64	1986Q3	0.96	1994Q1	1.12	2001Q3	1.16	2009Q1	0.90
1971Q4	1.13	1979Q2	0.62	1986Q4	1.05	1994Q2	1.09	2001Q4	1.16	2009Q2	0.90

1972Q1	1.18	1979Q3	0.66	1987Q1	1.14	1994Q3	1.10	2002Q1	1.15	2009Q3	0.98
1972Q2	1.23	1979Q4	0.68	1987Q2	1.16	1994Q4	1.06	2002Q2	1.10	2009Q4	0.97
1972Q3	1.15	1980Q1	0.65	1987Q3	1.32	1995Q1	1.03	2002Q3	1.10	2010Q1	0.94
1972Q4	1.23	1980Q2	0.74	1987Q4	0.99	1995Q2	1.07	2002Q4	1.12	2010Q2	0.87
1973Q1	1.22	1980Q3	0.78	1988Q1	1.01	1995Q3	1.08	2003Q1	1.04		
1973Q2	1.19	1980Q4	0.80	1988Q2	1.05	1995Q4	1.08	2003Q2	1.03		
1973Q3	0.95	1981Q1	0.76	1988Q3	1.06	1996Q1	1.08	2003Q3	1.04		
1973Q4	0.91	1981Q2	0.78	1988Q4	1.02	1996Q2	1.07	2003Q4	1.06		

Note: *q* values are rounded up to two decimal places.

Figure 2.A.1: Different uncertainty measures



Note: Uncertainty measures calculated based on conditional standard deviations obtained from a univariate GARCH (p,q) specification of: inflation rate, real Australian dollar exchange rate, Australian terms of trade, real interest rates, Westpac Economic Leading Indicators; except the last uncertainty measure is from standard deviation of AllOrds Stock Index returns.

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Chapter 3

Uncertainty and Investment: Evidence from Australian Firm Panel Data

Abstract

This chapter investigates the key drivers of fixed firm investment of listed non-financial companies in Australia over the period from 1987 to 2009. A Tobin's *q* model of investment is augmented to account for the effect of economic uncertainty on the investment decision. The effects of Tobin's *q*, sales and cash flow on firm investment rate are also analysed and discussed. Consistent with existing literature, this research finds clear evidence of negative effects of both macroeconomic and firm idiosyncratic uncertainty on Australian firm investment. However, evidence also shows that firm specific uncertainty is more important in explaining firm investment than macroeconomic uncertainty.

3.1 Introduction

Understanding investment is of major importance for policy makers as fluctuations in investment lead to significant consequences for the economy. In order to stimulate investment, it is important to find out the factors that influence investment at both the economy-wide and firm levels. Although there is a vast literature on the factors that affect investment, the role of some factors are so far inconclusive; in particular the role of uncertainty is still a subject for debate.

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While theoretical considerations appear to support the conjecture that uncertainty is related to investment, the sign and magnitude of the relationship is not explained in a satisfactory manner in both theoretical and empirical literature. From a theoretical point of view, the effect of uncertainty on investment is ambiguous and dependant on the relationships amongst the variables as well as the assumptions of the model parameters such as firm's attitude toward risk, the cost function, market competitiveness and the shape of the marginal productivity of capital. The early Hartman (1972) model claims that an increase in uncertainty leads to an increase in investment. Models with adjustment costs developed by Pindyck (1982) and Abel (1983) find that the sign of the investment-uncertainty relationship depends on the variations of the model conditions. For example, under the conditions of perfect competition an increase in uncertainty stimulates investment if the marginal product of capital is a convex function of wages and output prices, whose evolution is uncertain. However, an increase of uncertainty may discourage investment if the marginal product of capital function is concave.

Dixit and Pindyck (1994) and Abel, Dixit, Eberly and Pindyck (1996) propose option-based models which emphasize important characteristics of investment that affect the decision to invest - irreversibility and uncertainty. Their approach draws similarities between an investment decision and a call option (that is, invests now or waits later). When irreversibility and uncertainty are taken into account, the behavior of firms will be different and the option to delay investment becomes valuable; that is, firms could decide whether to immediately invest or to wait for upcoming information (Bernanke, 1983). If uncertainty increases, the value of the option to delay the investment can be substantial. Firms will only invest now if the return of the investment exceeds the return of the delayed investment plus the option value to wait. So uncertainty may cause a decline in investment due to irreversibility. However, this theory, the real option theory, does not always predict a negative relationship, as for example in Abel and Eberly (1999) it is shown that irreversibility may positively affect investment in the long run due to the hang over effect.

As a result of theoretical ambiguities on the effects of uncertainty on investment, many have conducted empirical analyses to clarify the effects further.

However, empirical research on uncertainty and investment (for example, McDonald and Siegel, 1986; and Bertola and Caballero, 1994) is even less conclusive on the role of uncertainty on investment. Recent publications such as Baum, Caglayan and Talavera (2008), Baum, Caglayan, and Talavera (2010), Bond, Moessner, Mumtaz and Syed (2005) have used more precise and updated data, new proxies for uncertainty and have applied new econometric models to resolve the persisting issues and found a consistent negative impacts of different measures of uncertainty on investment for the US and UK firms.

In contrast to the research pertaining to the U.S economy where both theoretical and empirical studies with respect to investment have continued to give insights into the behaviour of U.S. firm investment activity, the research investigating the determinants of Australian private firm investment since the 1980s is extremely limited. For example, Mills, Morling and Tease (1995), La Cava (2005) and Chang, and Tan, Wong, and Zhang (2007) are the only studies that analyze the drivers of firm investment in Australia; however, their focus is mainly on financial determinants of investment. The main theme of the existing research on firm investment in Australia is on how financial constraints drive investment. In addition, notable findings with respect to investment determinants, such as financial constraints and the fundamental value of investment opportunities are subject to specific caveats or objectives when applied to Australian data. For instance, Mills *et al.* (1995) using a small sample of 66 listed companies during an 11-year period find that certain financial factors had a significant impact on investment decisions of Australian companies. However, their study is subject to small sample size and possible selection bias.

The recent persistent decline in Australian investment activity in the wake of the Global Financial Crisis has reinforced the need to better understand the factors that drive private business investment, especially uncertainty. This chapter aims to revisit the topic of Australian firm investment by undertaking a rigorous examination of key factors (dictated by their theoretical significance) thought to impact on firm investment activity. Most importantly, this is the first research that examines the effect of uncertainty on Australian firms' investment.

This chapter is motivated by previous works on uncertainty; for example, Leahy and Whited (1996) for US firms, Greasley and Madsen (2006) who test the *q* theory and the role of uncertainty in the US market, Baum *et al.* (2008) and Bloom, Bond and Van Reenen (2007) who utilise new econometric models (such as GMM techniques). In addition, as a larger proportion of Australian listed firms are in the energy and material sectors, thereby having more tangible assets, they are more likely to be transparent and less subject to market imperfections (Chang *et al.*, 2007) and their investments may be irreversible and large. As such, it is important to investigate the impact of uncertainty on Australian firm investment as fundamental differences may exist between the Australian and the US listed firms which may lead to different outcomes of uncertainty.

To my knowledge, this is the first study that examines uncertainty and its effect on firm investment in Australia where its main focus is something other than financial determinants. Tackling the difficulties associated with finding and modeling data on investment determinants, this research contributes to the existing literature as new uncertainty proxies are incorporated into a *q* based investment model, testing empirically using panel data of Australian firms from 1987-2009, the largest time period available. Although the primary measure of uncertainty in my study is the volatility of returns of firms' stock prices, the chapter additionally uses new methods of measuring uncertainty. I specifically consider the effects of two different forms of uncertainty on firms' investment, which include firm idiosyncratic (micro) uncertainty, derived from either residuals obtained from a conditional return model, or covariance between the firm stock returns and market returns, and market (macro) uncertainty measured based on either AllOrds index returns or a GARCH model of leading macro-economic indicators.

The results of this chapter suggest that a negative relationship exists between investment and uncertainty, while its effects depend on the different proxies used and the nature of the firm. The coefficient of the variable measuring uncertainty in the estimation is consistent and significant with alternative models (static Tobin's *q* and the dynamic panel data model). The sign and strength of the relationship depends upon the market power of the firm and the degree of financial constraints. The other explanatory variables, used by investment research literature including Tobin's *q*, cash flow, leverage and sales, are also found to be important to firms' investment.

The impact of uncertainty varies with firm size; and, after controlling for fundamental variables, firm specific uncertainty, rather than macro-economic uncertainty is more relevant for investment decisions.

The chapter is organized as follows. Section 2 reviews the literature on investment and uncertainty. Section 3 discusses the theoretical background of the empirical model that is utilised. Data sources and methodologies are described in Section 4. The empirical results are discussed in Section 5, while the robustness analysis is given in Section 6. The final section concludes the study.

3.2 Literature Review

The literature on investment discloses a list of factors that drive private firm investment. The traditional accelerator theory claims that current and lagged firm output is the main investment determinant. On the other hand, neo-classical theories stress on the decisive role of output and user cost of capital in determining optimal long-term capital stock and investment (Baddeley, 2002). Romer (2006) also provides a detailed discussion on the determinants of firm investment, including *q*, profitability, uncertainty and cash flow. Given space limitations and since my model is based on *q* theory incorporated with uncertainty, investment determinants are focused on *q* theory and investment models with uncertainty.

The *q* theory, a prominent investment theory popular for its application in empirical studies, argues that firms invest only when the additional value of a one dollar investment is higher than one, or when the marginal return is higher than marginal cost. Tobin (1969) claimed that a firm invests only when *q,* the ratio between market value of the firm asset and its replacement cost, is higher than unity. Furthermore, *q* theory states that the *q* ratio (marginal *q*) can represent business opportunities of firms, and that shocks will influence firms' investment directly via *q*. The existing empirical works examine the role *q* plays in investment; some works confirming the role of *q,* while others demonstrating a weak link between *q* and investment. Nevertheless, the *q* based models are widespread in investment studies on both macro and micro levels, as the evidence of weak links between *q* and investment is claimed to be the result of miscalculating *q*. According to Leahy and

Whited (1996) if the marginal *q* is correctly calculated, it can sufficiently represent all the factors influencing investment.

Theoretical and empirical studies show that Tobin's *q* (a common proxy for marginal *q*) should not be a sole explanatory variable, and that other determinants should be included such as profitability, sales, uncertainty and cash flow (see for example, Blanchard, Rhee and Summers (1993), and Mills *et al.* (1995)). Empirically, models that incorporate these explanatory variables are widespread. According to Fazzari, Hubbard, and Petersen (1988), due to the imperfection of capital markets the cost of external funding is significantly higher than internal funding. Therefore, as many firms are constrained by the relatively high cost of external finance, an increase in *q* may not necessarily lead to a corresponding increase in investment; suggesting that firm investment is dependent on internal funding and therefore cash flow (Romer and Romer, 1996).

Many economists have stressed the importance of uncertainty on investment; however, theoretical literature is ambiguous in regards to the relationship between investment and uncertainty. Theoretical models such as Abel (1983) show that uncertainty has both a direct effect and an indirect effect (via *q*) on investment, while the specific effect of uncertainty on investment is ambiguous as it depends on the concaveness of the adjustment cost function used in the models. However, according to Abel and Eberly (1999), the relationship is non-linear, as there are different episodes with different elasticities of investment given an increase of uncertainty. However, this argument contrasts with the intuitive reasoning which claims that the relationship between uncertainty and firm investment is a linear negative one. Using country-level aggregate investment data, a vast body of empirical literature ascertains a negative relationship between aggregate business investment and uncertainty using various types of uncertainty measures that are based on volatile macroeconomic variables such as inflation, exchange rates, interest rates and the stock market index. There are forward looking measures such as the forecast economic index or the interest rates term structure that are superior to the above mentioned measures and studies that employ them also find a negative relationship (for instance, see Ferderer, 1993; Episcopos, 1995; and Carrington and Tran, 2012 for a further discussion).

At firm level, uncertainty can be classified into two types - idiosyncratic and aggregate uncertainty. Idiosyncratic uncertainty is firm-specific uncertainty and it is independent across firms. The importance of idiosyncratic uncertainty relative to aggregate uncertainty however is not conclusive. Caballero and Pindyck (1996) claim that aggregate uncertainty is more important than idiosyncratic uncertainty; while, Leahy and Whited (1996) find that aggregate uncertainty is not significant and conclude that uncertainty affects investment mainly through q for a panel of US manufacturing firms. In contrast, Dixit and Pindyck (1994) argue that idiosyncratic uncertainty is as important as aggregate uncertainty. In addition, Bo (2002) using panel data of Dutch firms finds idiosyncratic uncertainty more important than aggregate uncertainty in driving firm investment.

Also, at the firm level, Dixit and Pindyck (1994) show that when there is uncertainty and irreversibility, the behavior of firms is different. This is because investment cannot be reverted after being implemented and therefore, firms need to account for the uncertainty before they go ahead with the investment decision. The option to delay the investment decision is valuable, as firms can decide whether to invest immediately or to wait for new information. Greenwald and Stiglitz (1993) argue that risk aversion would make firms want to invest less; while, Bernanke (1983) shows that firms postpone investing due to the benefits that arise from the arrival of new information. Furthermore, Bernanke (1983) argues that from the firms' point of view, when investment projects are even partly irreversible, high uncertainty induces firms to delay investment decisions. Moreover, uncertainty can depress investment because of the increasing cost of finance, raising managerial risk-aversion (Panousi and Papanikolaou, 2012), or an increase in agency problems (DeMarzo and Sannikov, 2006).

The increase in number of empirical studies using disaggregated data, usually at firm-level is due to the increasing availability of disaggregated databases and the development of new econometric modelling techniques such as General Methods of Moments for panel data, leading to more robust empirical results in the presence of heterogeneity and endogeneity. A number of studies that examine the investment-uncertainty nexus, at the firm level, find that the negative effect of uncertainty on investment varies depending on which proxies are used for uncertainty. In addition, the majority of studies focus only on US and UK data, while only a handful of investigate non-Anglo countries. For example, Guiso and Parigi (1999) and Bontempi, Golinelli and Parigi (2010) examine Italian manufacturing firms, Fuss and Vermeulen (2008) Belgium firms, Von Kalckreuth (2003) German firms, Bo (2002) Dutch firms, Hatakeda (2002) Japanese firms and Pattillo (1998) examines firms in Ghana.

Studies examining investment decisions of Australian firms are scant, especially at the firm level, while research on uncertainty is non-existent. At the aggregate level, Cockerell and Pennings (2007) and Carrington and Tran (2012) find that aggregate private non-financial business investment is driven by Tobin's q, profit, income and uncertainty. At the firm level, using a balanced panel data of 66 Australian non-financial firms during the 1982-1992 period, Mills, Morling and Tease (1995) find evidence that financial factors including leverage, cash flow, stock of cash and liquid financial assets are important in investment behaviour, particularly for smaller highly leveraged firms and firms with high retention ratios. While Debelle and Preston (1995) find a positive and significant relationship between cash flow and investment. A recent paper by Chang, Tan, Wong and Zhang (2007), investigates the impact of financial constraints on Australian listed companies' investment decisions and demand for liquidity over the 1990–2003 time period. They find that financial constraints reduce the sensitivity of investment to the availability of internal funds. In general, the existing micro-level empirical papers only look at Tobin's q, cash-flow and financial constraints as investment determinants in Australia, disregarding the investment and uncertainty relationship.

3.3 Theoretical Model

Our theoretical model is a simplified version of the Abel (1983) investment model that provides the theoretical background for the relationship between investment and q. We start from a net worth maximization problem of a representative firm. Investment and stock prices are jointly determined from the following objective function of the representative firm, which under the Cobb-Douglas technology assumptions, given by:

$$V(K_t, p_t) = \max_{I_s, L_s} E_t \int_t^{\infty} \left[p_s L_s^{\alpha} K_s^{1-\alpha} - wL_s - \gamma I_s^{\beta} \right] e^{(-\rho(s-t))} ds \tag{3.1}$$

subject to:

$$dK_t = (I_t - \delta K_t)dt \tag{3.2}$$

$$dp_t/p_t = \sigma dz \tag{3.3}$$

where V is value of the firm, I is investment, L is labour, K is capital, p_t is output price, ρ is discount rate, $\beta > 1$ is the constant elasticity of the cost of investment and dz is a Wiener process with mean zero and unit variance. Equation 3.2 regulates capital accumulation why Equation 3.3 describes the behaviour of price of output.

The price process has the following properties, $E_t(p_s) = p_t, s \geq t$ and the variance of p_s , conditional on p_t is equal to $(s-t)\sigma^2$. The uncertainty here is in the price of the product, p_s. Solving the problem using Dynamic Programming, the Bellman equation for this problem is as follows:

$$\rho V(K_t, p_t)dt = \max_{I_s, L_s}\{\left[p_s L_s^{\alpha} K_s^{1-\alpha} - wL_s - \gamma I_s^{\beta}\right]dt + E_t[dV]\} \tag{3.4}$$

Intuitively, the left hand side of Equation (3.4) is the required rate of return, while the right hand side is the contemporary cash flow and the expected future price of the company.

Next, the expected capital gain $E_t[dV]$ is calculated. The value of the firm depends on the state variables K and p. Since p follows a Wiener process, Ito's lemma is needed to calculate dV. The second order Taylor expansion of $V(K_t, p_t)$ gives:

$$dV = V_K dK + V_p dp + \frac{1}{2}V_{KK}(dK)^2 + \frac{1}{2}V_{pp}(dp)^2 + V_{pK}(dp)(dK) \tag{3.5}$$

Substituting the two equations of motion for dK_t (3.2) and dp_t (3.3) gives:

$$E[dV] = V_K(I_t - \delta K_t)dt + V_p p_t \sigma dz + \frac{1}{2}V_{KK}\big((I_t - \delta K_t)dt\big)^2 + \frac{1}{2}V_{pp}(p_t\sigma dz)^2 + V_{pK}(p_t \sigma dz)\big((I_t - \delta K_t)dt\big) \tag{3.6}$$

According to the rules of multiplication for Wiener terms, $(dt)^2 = (dt)(dz) = E(dz) = 0$ and $(dz)^2 = (dt)$ and we obtain:

$$E[dV] = \left[V_K(I_t - \delta K_t) + \frac{1}{2}V_{pp}p_t^2\sigma^2\right]dt \tag{3.7}$$

The Bellman equation (3.4) can now be written as follows:

$$\rho V(K_t, p_t)dt = \max_{I_t, L_t}\left[p_t L_t^{\alpha} K_t^{1-\alpha} - wL_t - \gamma I_t^{\beta} + V_K(I_t - \delta K_t) + \frac{1}{2}V_{pp}p_t^2\sigma^2\right]dt \quad (3.8)$$

If dt is eliminated at both sides, we have:

$$\rho V(K_t, p_t) = \max_{I_t, L_t}\left[p_t L_t^{\alpha} K_t^{1-\alpha} - wL_t - \gamma I_t^{\beta} + V_K(I_t - \delta K_t) + \frac{1}{2}V_{pp}p_t^2\sigma^2\right] \quad (3.9)$$

The demand for labour can be derived by differentiating the right hand side of Eq. 3.9 with respect to L, which gives:

$$L_t = \left(\frac{w}{\alpha p_t}\right)^{1/(\alpha-1)} K_t \quad (3.10)$$

Substituting this demand for labour into the right hand side of Bellman equation we obtain:

$$\max_{L_t}[p_t L_t^{\alpha} K_t^{1-\alpha} - wL_t] = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\alpha/(1-\alpha)} p_t^{1/(1-\alpha)} K_t = hp_t^{1/(1-\alpha)} K_t \quad (3.11)$$

where $h = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\alpha/(1-\alpha)}$

Differentiating the right hand side of the above Bellman Equation 3.11 with respect to I, we have an investment function:

$$\gamma\beta I_t^{\beta-1} = V_K \quad (3.12)$$

Substituting the investment equation in the Bellman equation gives us:

$$\rho V(K_t, p_t) = hp_t^{1/(1-\alpha)} K_t + (\beta-1)\gamma I_t^{\beta} - \delta K_t V_K + \frac{1}{2}V_{pp}p_t^2\sigma^2 \quad (3.13)$$

Both of the above equations can be combined to form a second order partial differential equation for the value function V. Abel shows that the solution equals:

$$V(K_t, p_t) = q_t K_t + \frac{(\beta-1)\gamma\left(\frac{q_t}{\gamma\beta}\right)^{\beta(\beta-1)}}{r - \frac{\beta(1-\alpha+\alpha\beta)\sigma^2}{2(1-\alpha)^2(\beta-1)^2}} \quad (3.14)$$

where

$$q_t = \frac{hp_t^{\frac{1}{1-\alpha}}}{r + \delta - \frac{\alpha\sigma^2}{2(1-\alpha)^2}} \quad (3.15)$$

It is justified by Abel (1983) that the above q is the marginal revenue product of capital, which is the shadow price of capital.

Since $\gamma\beta I_t^{\beta-1} = V_K$ from (3.12), we have:

$$I_t = \left(\frac{1}{\gamma\beta}V_K\right)^{1/(\beta-1)} \quad (3.16)$$

or

$$I_t = \left(\frac{q_t}{\gamma\beta}\right)^{1/(\beta-1)} \quad (3.17)$$

The above function of I_t shows that I_t is now an increasing function of the marginal revenue product of capital, q. Besides, uncertainty affects investment through q only, and its effect can be assessed by considering the effects of uncertainty on q.

3.4 Empirical Models

Abel (1983) claims that the growth rate of investment is linear function of the growth rate of q, equal to the growth rate of q multiplied by the elasticity of investment with respect to q_t, $1/(\beta - 1)$, given the marginal adjustment cost function is linear (or a quandratic adjustment cost function). In latter empirical studies (e.g. Abel and Eberly 2002; Eberly, 1997; or recently Baum, Caglayan, and Talavera (2010); see Table 3.A.1 for the list of empirical studies), investment ratio (i.e. investment scaled by capital stock) is regressed against q in a linear function. The very basic q based empirical is given at the following form:

$$(I/K)_{i,t} = \alpha_0 + \alpha_1 q_t + \varepsilon_t \quad (3.18)$$

where I is investment, K is capital stock, q is the ratio between firm market value and its replacement cost of capital. According to q theory, if the market is frictionless, q is a sufficient proxy for all firm's business opportunities. However, in reality, firm investments are influenced by other factors. Dixit and Pindyck (1994) argue that investment is partly or completely irreversible and there is uncertainty over the future rewards of the investment. Uncertainty for firms relates to the unknown value of variables which are determinants in their investment decisions; however, I assume that they know the probability distribution of these variables. A detailed discussion on these factors can be found in Blanchard, Rhee and Summers (1993), and Romer (2006), Ch. 8. Accordingly, in my empirical model, together with q, other factors generally found to be important for investment are also incorporated - uncertainty, cash flow, leverage, and sales. They have been incorporated to allow for the possibility of credit constraints, divergence between the market and fundamental value of capital, and the cost of uncertainty impacting on investment.

The empirical model to be estimated is therefore given by (3.19):

$$(I/K)_{i,t} = \alpha_0 + \alpha_1(I/K)_{i,t-1} + \sum_{j=0}^{k} \beta_j q_{i,t-j} + \sum_{j=0}^{k} \gamma_j Z_{i,t-j} + \sum_{j=0}^{k} \delta_j Var_{i,t-j} + firm_i + year_t + v_{i,t} \quad (3.19)$$

where I/K is the investment ratio, I is measured as the difference between sale and purchase of property, plant and equipment, and K is firm's capital stock at the beginning of the period t. Since I at firm level can be negative (or disinvestment) natural logs are not used in the model. Capital stock is measured in this study as book value of firm's total assets. Tobin's q is the ratio between total market value of the firm and its replacement costs, which is measured as market value of firm's equity plus book value of firm's debt (calculated as total assets minus common equity) scaled by book value of total assets. The inclusion of lagged q values is based on the notion that there are delays between the date when the decision is made to invest and the actual date when the investment occurs. Var is uncertainty, measured as the realized standard deviation of the monthly returns of the firm's stock prices within the firm year. Z is a vector of controlling variables. One of controlling variables is firm's cash flow, which is a proxy for the fundamental value of the firm. According to Blanchard, Rhee and Summers (1993), when the market and the fundamental value of the firm are not equal, one should include cash flow. Vector Z also includes firm sale ratio and the leverage ratio as they have been highlighted as important determinants of firm investment in existing literature. Sale ratio is measured as sales divided by lagged total book value of assets. Cash flow is measured as net profit after tax before abnormal items plus depreciation and amortization scaled by lagged total book value of assets. Leverage equals total debt divided by total assets and sales ratio is the firm revenue scaled by total assets. The details of the calculations are shown in Data Appendix of this chapter.

In the regression model, time dummies are included to account for possible business cycle effects as well as other macro-economic factors not mentioned in the model that influence all firms from year to year. Firm dummies in the fixed effects regression model are added to account for other unobservable factors which are not proxied by explanatory variables and are time invariant. The baseline model should also be extended with a firm size dummy that categorizes firms by their size. Financial literature claims that firm size is a proxy for financial constraints and information asymmetry (Fazzari, Hubbard and Petersen, 1988). The baseline model is extended with lags of explanatory variables as contemporary investment may be driven by past information and also to avoid endogeneity issues. The use of lagged uncertainty measures is motivated by the fact that actual investment at time *t* is affected by observed uncertainty in the environment in the past periods.

The model is run with and without the lagged dependent variable, the investment ratio. The static capital structure model (without the lagged investment ratio) will be estimated for comparison purposes using the pooled OLS, Fixed Effects (FE), and Random Effects (RE) estimators. In addition, to account for the momentum of investment, the lagged dependent variable is added to the right hand side to keep the other variables (including Tobin's *q*) from transforming the model into a dynamic one. This is done because a large percentage of firm projects may last for more than one year, so the investment in time *t* may be correlated with investment in previous years.

However, adding the lagged dependent variable in the OLS regression will lead to asymptotically biased estimates as there may be correlation with the error term; furthermore, the RE model and the FE model estimates may suffer from bias due to unobserved heterogeneity and possible endogeneity of the regressors. In order to solve this problem, Generalized Method of Moments (GMM) dynamic panel estimator can be used. According to Roodman (2009), GMM is an unbiased estimator with advantages in panels such as this one; that is, with small T and large N. In addition, GMM is profound in estimating dynamic capital structure models (with the lagged dependent variable) as suggested by Blundell and Bond (1998). GMM is useful as it corrects for unobserved heterogeneity and endogeneity with the aid of an instrumental variable matrix consisting of all available lags of dependent and exogenous variables.

Theoretically, when the capital stock is higher than its optimal level, the firms can disinvest by selling its fixed asset/capital (Abel and Eberly, 1999). In reality, firms' investment is irreversible, as selling plant and equipment is difficult, and if successful they may have to sell at a price well below the real value of the plant and equipment. Sale of existing property plants and equipment is not always a choice even in the case where the firm wants to disinvest. The data shows an asymmetry in investment, as most of investment is greater or equal to zero, while negative investment is minority (approximately 9%).

Taking into account the asymmetric nature of investment, a logit model is estimated to evaluate the effect of uncertainty on the firm's decision to investment. In the logit model, the dependent variable is a bivariate dummy which takes the value of 1 if investment in the period is positive and 0 otherwise. The model tests the determinants of a firm's decision to invest (rather than the amount of investment). According to the real option theory, when uncertainty increases, firms either wait or invest and thus, lose the value of the option. Investment projects will be implemented only their returns have exceeded a trigger value that reflects the cost of extinguishing the firm's call option. Uncertainty increase will raise the trigger value, which delay investment, or reduce the probability of positive investment. This theory is tested by regressing a panel logit model based on the following equation:

$$InvDum_{i,t} = \alpha_0 + \sum_{j=0}^{k} \beta_j q_{i,t-j} + \sum_{j=0}^{k} \lambda_j (Z_{i,t-j}) + \sum_{j=0}^{k} \gamma_j Var_{i,t-j} + firm_i + year_t + v_{i,t} \tag{3.20}$$

where $InvDum$ is the binary variable of investment; taking the value of 1 if investment is positive and 0 otherwise. The probability of positive investment at time t is allowed to depend on the outcome of investment in t − 1 as well as q, uncertainty and other variables. In addition to the above estimates, a pooled regression is estimated. Advantage of pooling is to increase the sample size, thereby obtaining more precise estimates and test statistics with greater power (Wooldridge, 2002).

3.5 Data

Annual accounting data of all Australian listed firms, available from 1987 to 2009 is obtained from the Aspect Fin Analysis. These companies are or were listed on the Australian Securities Exchange (ASX). Data on firms' daily stock prices is from the Share Price and Price Relatives (SPPR) dataset from 2nd Jan 1987 to 31st Dec 2009. The fiscal year for most firms is from July 1st to June 30th of the following year. My firm population includes all listed as well as delisted companies on the ASX so to avoid “survivor biases”. The firms for the sample were selected using a simple selection criterion. All Australian firms were included in the sample except for those firms in the financial, utility, and insurance and property sectors. Insurance, property and financial firms are excluded because of their relatively low physical capital investment, while utility firms are excluded due to their regulated nature. The following next couple of paragraphs discuss adjustments to the dataset. The end result of the adjustments is an unbalanced panel dataset of 1235 companies over the 1987-2009 period, with total 12175 firm years.

In order to control for outliers, the growth rate of each firm’s total assets is calculated, and the annual distribution of this growth rate above the 98th percentile is cut to remove firms exhibiting substantial changes in firm size. In order to exclude firms that show a clear evidence of financial distress, the observations that have the cash flow ratio (calculated as total profit after tax before abnormal items plus depreciation scaled by beginning-of-period capital) below -50 percent for two continuous years are excluded. This measure is utilised as an exclusion criteria because when the cash flow loss over two years accounts for more than 50 per cent of total assets, firms are in financial distress.

As this study focuses more on middle and large firms, those with capital lower than 1 million AUD (year 2009 prices) in any year of their life are excluded. The reason this study focuses more on middle and large firms is to avoid any financing frictions which might be present for smaller firms and to avoid the bias in the model, resulting from small capital stock which causes values of variables to become abnormally large, given the small denominators in the ratios. Later on, when the minimum capital threshold is changed to 2 and 3 million AUD, regression results are qualitatively similar.

The data is checked for large discontinuities in the book value of capital that cannot be explained by investment, capital expenditures or depreciation reported by the firm. If large discontinuities are present, then those years/ firms are removed. Following Bond and Meghir (1994), only companies that appear for at least 5 consecutive years in the data are kept in the sample. To account for mergers or large acquisitions, the delisted firm’s last year’s observations, with delist codes indicating merging and acquisitions are dropped. Furthermore, the 1st and the 99th percentile of all main variables (*q*, investment ratio, cash flow ratio, sales ratio and leverage ratio) is winsorized. This is done by setting the tail values equal to some specified percentile of the data; here they are the 1st and the 99th percentile. Following Barnett and Lewis (1994), this approach reduces the impact of extreme observations by assigning a cut-off value, thereby removing values past the cut-off point.

Data Appendix summarises the construction of most of the variables used in the model. However, the construction of some important variables is highlighted here. Investment, cash flow, and sales-to-capital ratios are all constructed using the corresponding Compustat definitions for the variables in the numerator. The denominator on the other hand uses the lagged end-of-period value of capital stock (that is, the current periods initial capital stock) to approximate the within-period capital available for production.

Uncertainty can come from many sources. Firms may be uncertain about two types of factors, firm specific factors, such as output prices, demand, input costs, capital costs, technology, firm structure and organisation, and future profitability; and factors related to the external environment, such as, the movements of exchange rates, inflation, interest rates or stock markets. Measuring uncertainty for specific firms is difficult because reasonably high quality data on the variables of interest (such as output prices, input costs, demands) is not available on a sufficiently disaggregated basis (Leahy and Whited, 1996). In the existing literature on the investment-uncertainty relationship, several methods have been used for measuring uncertainty. Firstly, one can use the unconditional variance of the historical data of the variables of interest as a proxy for uncertainty. The second method measures uncertainty as the volatility of the unpredictable part derived from a prediction model (Koetse, 2006). Another popular method is measuring uncertainty by a GARCH based model of volatility along the lines of Episcopos (1995).

In this chapter, uncertainty is primarily measured by the first method, using the within-year volatility of the firm's monthly stock price returns. This method is widely used by researchers, for example, see Caballero and Pindyck (1996), Leahy and Whited (1996), and Bloom *et al.* (2007). It is the standard deviation of stock price returns during the firm's current accounting period, calculating monthly to avoid the over volatility of daily stock price returns. Stock prices are forward-looking measures of profitability, containing both firm uncertainty and market uncertainty. Other measures of uncertainty are discussed in the robustness section, which give qualitatively similar results.

Descriptive Statistics

The descriptive statistics of firms in the sample are presented in Table 3.1. Notice that in virtually almost variables, the median is smaller than the mean, indicating positive skewness in the data. With Tobin's *q*, both mean and medium are virtually larger than one (the should-be long-term average value of *q* in steady state claimed by the *q* theory). This is probably because of credit constraints or uncertainty. These results are comparable to the result of Chang *et al.* (2008) who examine investment and cash flow of listed Australian firms.

Table 3.1: Descriptive statistics of main variables

Variable	**Mean**	**Medium**	**Min**	**Max**
Investment	0.094	0.039	-0.258	1.497
Sales	0.86	0.581	0	5.181
Cash flow	0.025	0.057	-2.60	0.624
Leverage	0.41	0.389	0.006	3.327
Tobin's *q*	1.67	1.221	0.282	20.024

The term multicollinearity is used to describe the situation when a high correlation is detected between two or more predictor variables. To check for multicollinearity, the correlation matrix is presented in Table 3.2.

Table 3.2: Correlation matrix

	Investment	Cash flow	Sales	Tobin's *q*	Leverage	Uncertainty
Investment	1.00					
Cash flow	-0.08*	1.00				
Sales	-0.06	0.29	1.00			
Tobin's *q*	0.15*	-0.10*	-0.04*	1.00		
Leverage	-0.07*	0.07*	0.27*	0.15*	1.00	
Uncertainty	-0.06*	-0.22*	-0.13*	-0.05*	0.04*	1.00

Note: * significance level of 5%.

The correlation matrix gives some insights into the possible relationships between the variables of interest. The values obtained are similar to previous research using Australian firms (for example, Chang *et al.* 2007; and Mills *et al.* 1995). We see however, that the correlation coefficients are not too large which could lower the possible bias of multicollinearity in the regressions. The average Tobin's *q* is 1.67, which is larger than one. Investment is positively correlated with Tobin's *q*, and negatively correlated with leverage, uncertainty and cash flow. The negative correlation coefficient between investment and cash flow is consistent with the findings in La Cava (2005), however, this is inconsistent with the intuition that corporate investment depends positively on internal cash flow, which in many cases implies the existence of financial constraints. Recently however, Cleary, Povel and Raith (2007) show that the relationship between investment and internal cash flow is U-shaped. Namely, the relationship is negative for extremely low levels of internal funds, which is in line with the firms in my sample as a large percentage of firms has a negative level of internal funding. This counter-intuitive correlation between cash flow and investment will be discussed in the forthcoming section.

3.6 Empirical Results

In this section the empirical model is estimated using different estimation methods in order to analyse the determinants of investment by controlling for various variables. First, the data is pooled to examine the possible effects of control variables and uncertainty on investment decisions. Pooled regressions combine both dimensions in one data set by neglecting time and cross-sectional structure, and heterogeneity across subjects of interest, while assuming orthagonality between regressors and the residual. According to Wooldridge (2002), pooling increase the sample size, thereby obtaining more precise estimates and test statistics with greater power. The year dummies are added to account for possible business cycle effects and unobservable variables that vary over time. Only the contemporaneous and the first lag of explanatory variables are presented as the longer lags are not significant in the regression. This shows that the investment decision in time *t* may be influenced only by the information in the current period, *t*, and in the preceding one, *t-1*. Results are presented in Columns 1 and 2, Table 3.3.

Table 3.3: Parameter estimates of pooled and logit regressions

	Pooled regression	**Pooled regression with year dummies**	**Logit (panel)**
Dependent variable	**(1) Investment ratio (I/K_t)**	**(2) Investment ratio (I/K_t)**	**(3) Investment indicator**
q_t	0.01	0.00	0.03
	(1.61)	(1.36)	(1.07)
q_{t-1}	0.02***	0.02***	0.14***
	(5.65)	(5.11)	(3.46)
$cash\ flow_t$	0.05**	0.05**	0.45***
	(2.18)	(2.19)	(5.25)
$cash\ flow_{t-1}$	-0.03	-0.03	0.13*
	(1.39)	(1.39)	(1.65)
$sales_t$	0.01**	0.01**	-0.03
	(2.41)	(2.42)	(0.11)
$sales_{t-1}$	-0.03***	-0.03***	1.25***
	(5.10)	(5.23)	(3.93)
$leverage_t$	0.07***	0.07***	0.25
	(3.56)	(3.72)	(1.19)
$leverage_{t-1}$	-0.12***	-0.12***	-0.39*
	(5.55)	(5.57)	(-1.76)
$uncertainty_t$	-0.01**	-0.01***	-0.25***
	(3.26)	(2.82)	(5.88)
$uncertainty_{t-1}$	-0.00	-0.00	-0.11***
	(0.07)	(0.24)	(2.90)
$constant$	0.10***	-0.01	n/a
	(17.87)	(0.79)	
R^2	0.07	0.08	n/a
N	10254	10254	6208

Note: * p<0.1;** p<0.05; *** p<0.01. t statistics are in parentheses (z statistics are shown in Column 3). q is Tobin's q, $sales$ is the ratio between total sale revenue and beginning-of-period capital, $cash\ flow$ is ratio between cash flow and beginning-of-period capital, $leverage$ is ratio between total debt and total asset, $uncertainty$ is measured as the volatility of firm's stock price returns. The pooled regression is estimated using OLS while standard errors are robust (Eicker-Huber-White) standard errors to account for heteroskedasticity and correlation of disturbances within groups. Year dummies coefficients are included in Column 2 but not shown. The panel logit estimation result in Column 3 presents the marginal impacts of changes in the explanatory variables on the probability of making investment.

The results of the pooled model confirm the expected relationship between the investment decision and its determinants. The results show that the coefficient of uncertainty is statistically significant and negative, implying that investment is inversely related to uncertainty. The coefficients of lagged Tobin's q and the leverage variables are of the correct sign and are significant. In the second column, a regression with time dummies is run to account for the fact that the sample of firms may have different distributions at different time periods (coefficients of the time dummies are not shown in Table 3.3). When the time dummies are included in the regression, the results are consistent with those of the regression without the time dummies.

To answer the question “what factors drive the firm’s decision to invest?”, a logit model regression of the investment indicator $InvDum_{i,t}$ (taking the value one if investment is positive and zero if investment is zero) as in Equation 3.20 is run, on the explanatory variables used in my baseline model. Hence, the regression tests the probability of investment being greater than zero given the explanatory variables. The role of q, uncertainty and other variables in the logit model is to predict the probability of investment/disinvestment, rather than the amount of investment/disinvestment. The logit regression results in Column 3 of Table 3.3 show that the investment decision is driven by the anticipated variables (including Tobin’s q, cash flow, sales and uncertainty). The first lag of Tobin’s q plays a positive and significant role on the investment decision. Lagged sales and cash flow both play a positive and significant role on the investment decision, while lagged leverage plays a negative role; all the results are as expected. Therefore, the more cash flow the firm has, the more likely it is to undertake an investment. Also, the higher debt is as a ratio of total assets, the less probability the firm carries out the investment project. Most importantly, the results suggest that uncertainty plays a negative role in the investment decision. In short, given the above results it is clear that the investment decision is driven by the information corresponding to the firm’s business situation in the previous year (that is, first lag of sales, first lag of leverage and profitability) and the known business opportunities proxied by q.

The results of the baseline regression – considering only the impact of a change in Tobin’s q, cash flow, sales, uncertainty and the interaction between sales and uncertainty on investment – are shown in Table 3.4. The estimator used in the first five columns of Table 3.4 is the Fixed Effects (FE) estimator, as the Haussmann test results suggest Fixed Effects specification is preferred to Random Effects specification. The FE model contains firm-specific effects that are time invariant and unobservable but arbitrarily correlated with other regressors; and, is likely to be more appropriate in this case as the sample consists of a broadly exhaustive population (as differences between individuals may be viewed as parametric shifts in the regression function). The results in Table 3.4 show that in the augmented model, q_{t-1} and sales are significant in terms of the investment rate.

Table 3.4: Results of the baseline model

Dependent variable: I/K_t	Fixed Effects	Fixed Effects	Fixed Effects		Fixed Effects	Fixed Effects	Difference GMM
			Large firms	Small firms			
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
I/K_{t-1}		0.13***	0.06**	0.09***	0.13***	0.13***	0.19***
		(6.14)	(2.17)	(3.26)	(6.08)	(6.13)	(6.79)
q_t	0.01*	0.01*	0.00	0.01***	0.01**	0.01**	0.01*
	(1.78)	(2.07)	(0.22)	(2.99)	(2.14)	(2.06)	(1.92)
q_{t-1}	0.02***	0.02***	0.03***	0.01***	0.02***	0.02***	0.01***
	(5.88)	(5.67)	(4.64)	(4.15)	(5.66)	(5.64)	(3.87)
$cashflow_t$	0.04*	0.03	0.05	0.00	0.03	0.03	0.04
	(1.78)	(1.29)	(1.04)	(0.13)	(1.24)	(1.48)	(0.70)
$cashflow_{t-1}$	-0.02	-0.02	-0.12***	0.01	-0.02	-0.02	-0.07**
	(-1.16)	(-1.05)	(-2.88)	(0.47)	(-1.12)	(-0.97)	(-2.24)
$sales_t$	0.03***	0.04***	0.02***	0.04***	0.03***	0.02***	0.04**
	(5.40)	(5.61)	(3.19)	(4.04)	(5.53)	(3.06)	(2.32)
$sales_{t-1}$	-0.01	-0.01**	0.00	-0.01**	-0.01**	-0.01**	-0.02**
	(-1.38)	(-2.40)	(0.10)	(-2.14)	(-2.41)	(-2.02)	(-1.98)
$leverage_t$	0.07***	0.06***	0.12***	0.02	0.06***	0.07***	-0.02
	(3.23)	(3.03)	(3.61)	(0.94)	(2.98)	(3.92)	(-0.25)
$leverage_{t-1}$	-0.10***	-0.10***	-0.17***	-0.05	-0.10***	-0.11***	-0.01
	(-4.20)	(-4.28)	(-5.20)	(-1.73)	(-4.23)	(-5.84)	(-0.16)
$uncertainty_t$	-0.01***	-0.01***	-0.01*	-0.01***	-0.01***	-0.02***	-0.02***
	(-4.21)	(-3.85)	(-1.75)	(-3.49)	(-4.67)	(-4.31)	(-3.55)
$uncertainty_{t-1}$	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01
	(-1.65)	(-1.02)	(-0.73)	(-0.90)	(-0.64)	(-1.00)	(-1.44)
$BIG * uncertainty_t$					0.01***		
					(3.09)		
$sales * uncertainty_t$						0.01*	
						(1.75)	
$constant$	-0.05	-0.05	0.01	-0.12***	-0.05	-0.04	
	(1.33)	(-1.48)	(0.69)	(-8.35)	(-1.39)	(-1.22)	
R^2	0.03	0.10	0.10	0.09	0.10	0.14	
N	10254	10254	5395	4859	10254	10254	8834
Hansen test (*p*-value)							0.71
AR(2)							0.98
Difference-in-Hansen tests of exogeneity of instrument subsets							0.98

Note: * p<0.1, ** p<0.05; *** p<0.01. t values are in parentheses. All models include time dummies to account for possible business cycle effects and unobservable variables that vary over time. The same notation as in Table 3.3 is used. I/K_t is investment ratio. BIG is a binary variable proxying for the size of firms. Standard errors are robust to arbitrary autocorrelation and heteroskedasticity. Estimator in Column 6 is one step difference GMM. The instruments used in Column 6 are the second to sixth lags of $q, cash\,flow, sales, leverage$, year dummies and all the lagged measures of $uncertainty$. Instrument validity is tested using a Sargan–Hansen test of the overidentifying restrictions. Second-order serial correlation in the first-differenced residuals is tested using a Lagrange multiplier test (Arellano and Bond, 1991). The panel data is unbalanced.

Columns 1 and 2 of Table 3.4 show the results of the static model which includes and excludes the lag of the dependent variable. It is plausible that the effects of investment are persistent and that one of the factors that affects investment today is investments in the previous periods; therefore, one lag of the dependent variable is added to account for this notion. The results from Column 2 are almost the same with those of Column 1, showing that the inclusion of the lag of dependent variable not change the estimation result. Tobin's *q*, sales, leverage and uncertainty are the main variables that affect investment, which is consistent with existing literature; cash flow is only significant at the 10 per cent level. After controlling for *q*, the proxy for business opportunity, uncertainty has negative and significant effect on investment. Given the sum of coefficients, it seems likely that the effect of uncertainty is as large as that of Tobin's *q*. This result is consistent with other studies using a similar *q* model for the US and UK (for example, Bond *et al.*, 2005; and Bulan, 2005).

Most of the estimated coefficients of Tobin's *q* are significant and the magnitude is on average 0.02, which suggests that Tobin's *q* has a moderate influence on investment. The magnitude of Tobin's *q* coefficient, 0.02, is consistent with previous studies on US firms. For instance, Leahy and Whited (1996) find that the coefficient of Tobin's *q* ranges from 0.022 before controlling for cash flow to 0.04 after controlling for cash flow. Many other studies also find evidence of a small coefficient of Tobin's *q*; Bond *et al.* (2005) find that the Tobin's *q* coefficient for UK firm investment is below 0.02; Mills *et al.* (1995) find a Tobin's *q* coefficient of 0.018 for 66 Australian firms; while, Baum *et al.* (2008) find that the coefficient for Tobin's *q* is also small in their investment regressions.

Columns 3 and 4 of Table 3.4 contain results for two different samples of firms that are based on firm size. Using capital data the firms are categorized into two groups - large and small. The coefficient of lagged uncertainty on small firms is larger in absolute terms. This is a plausible result because small firms are more sensitive towards changes in the business environment compared to large firms.

In Column 5, a regression with an interaction term between firm size and uncertainty is run, as it is believed that large firms suffer less asymmetric information problems and have fewer difficulties in accessing external capital markets compared to small firms (see, for example, Fazzari *et al.*, 1988). Firm size is defined by a 'big firm' dummy variable, BIG_{it}, that takes the value 1 when total assets are above the sample median within a certain year, and 0 otherwise. This dummy is interacted with the uncertainty variable to capture any different effects uncertainty may have on financially constrained firms; while naturally, the coefficient on the uncertainty term by itself captures the responsiveness of investment to uncertainty for unconstrained firms. The coefficient on the interactive term is found to be significant, which means that uncertainty plays a much larger role in the investment decisions of financially constrained firms compared to unconstrained firms.

Furthermore, Column 6 regression includes an interaction term between the uncertainty measure and the sale ratio that is significant and positive, indicating a stronger effect of sales on investment at higher levels of uncertainty.

Unlike previous studies on firm investment in Australia (La Cava, 2005; and Chang *et al.*, 2007) that find that cash flow positively and significantly affects investment, the results in this study show that cash flow is not very significant. The different results obtained could be a result of the selection criteria of firms in the sample. For example, Chang *et al.* (2007) eliminated all firms with a minimum stock of property, plant and equipment of less than $A5m, leaving them with 420 firms. Whereas La Cava's (2005) sample, consists of 300 firms and 1,700 observations over the 1990 to 2004 period. My sample on the other hand, contains 1235 companies over the 1987 to 2009 period, a total of 12175 observations.

Analogous to La Cava (2005), I find that many of the listed/delisted firms on the ASX have had negative cash flow over a large number of consecutive years without being delisted from the ASX. Numerous firms in industries such as materials and business services (which are the main industries in Australia) have had more than 60 per cent of their operating years exhibiting negative cash flow. While firms that show a clear evidence of financial distress are excluded, nevertheless there are still many firms that exhibit negative cash flow during their years of operation. As aforementioned, due to the irreversible nature of investment, firms rarely sell property (especially plants and equipment) when they want to disinvest. In general the evidence shows that the effects of cash flow on investment in Australia are relatively insignificant. This is thought to be due to the asymmetry in the distribution of cash flow around zero which causes us to find an insignificant effect of cash flow on investment.

By adding a lagged dependant variable we encounter endogeneity issues which lead us to use the difference GMM estimator when estimating the dynamic panel model. GMM has been widely used to deal with unobserved heterogeneity and endogeneity bias in estimation. The lags of the Tobin's *q*, cash flow, leverage, and sales, as well as lags of measures of uncertainty are employed as GMM instruments (Arellano and Bond, 1991). By using GMM which tests for endogeneity, we take into account the endogeneity between investment and uncertainty. In fact, firm level uncertainty is not purely exogenous. For example, the decision to undertake a risky investment project may introduce heightened uncertainty over the firm’s future returns. Latent factors may also affect both uncertainty and the attractiveness of investment, creating a non-causal correlation. Following prior literature, endogenous uncertainty has been handled by using ‘internal’ instruments: lagged values of the dependent and explanatory variables (see, for example, Leahy and Whited, 1996; Bulan, 2005; and Bloom, Bond, and Van Reenen, 2007).

The results of the dynamic model are presented in Column 7 of Table 3.4 and support the results of the *q* based model. Tobin’s *q,* sales, and uncertainty again are determinants of firm investment with the coefficients having the consistent signs and comparable magnitudes. The lag of the dependent variable plays a significant role in deciding investment, showing the persistence of investment. The consistency in the results amongst the different estimators confirms the consistent behaviour of Australian firms’ investment.

3.7 Different Measures of Uncertainty

In this section the investment model is tested with some alternative measures of uncertainty. According to the literature, various kinds of proxies have been used to measure uncertainty. At the firm level, uncertainty can be classified based on the sources where the uncertainty comes from, which is often divided into macroeconomic uncertainty, industry-wide uncertainty and idiosyncratic (or firm-specific) uncertainty. Uncertainty can be measured from the volatility of macroeconomic variables, such as aggregate demand, exchange rates, interest rates and inflation, just to name a few. To date, a large amount of studies utilise macroeconomic uncertainty because of the availability of macro data, while only a small amount utilise firm level uncertainty. It is difficult to distinguish between the industry and the firm idiosyncratic sources of uncertainty in empirical research, mainly due to data-related constraints; therefore, empirical studies that distinguish explicitly between these two sources of uncertainty are also scarce (Koetse, 2006).

The robustness of the role of uncertainty on Australian firm investment is tested with the following changes to the uncertainty measures. First, instead of using volatility of firm's monthly stock price returns, volatility of firm's daily stock price returns is used. Second, macro-economic uncertainty is measured using two sources. One measure is based on the volatility of the Westpac – Melbourne Economic Leading Index, while the other is volatility of All Ordinaries Stock Index on the Australian Stock Exchange. Third, firm specific uncertainty is measured via several proxies that have only been used recently by Baum *et al.* (2008).

A proxy for macro-economic uncertainty is volatility of All Ordinaries Stock Index on the Australian Stock Exchange. The use of the volatility of stock market index returns as a measurement of uncertainty has the advantage as in principle it captures all relevant sources of risk. However, according to Guiso and Parigi (1999) share prices may also respond to extraneous information, reflect irrational behaviour and the presence of noise traders, or be dominated by speculative bubbles and subsequent crashes rather than by changes in the firm's fundamentals or in its perceived uncertainty. This urges one to think about other proxies for uncertainty that have been used in literature.

Another proxy for macroeconomic uncertainty is constructed from the conditional standard deviation of the index of leading economic indicators (here is Westpac – Melbourne Economic Leading Index) as the index can be claimed as a measure of overall macroeconomic activity. The conditional variance of the index of leading indicators is estimated with a generalized ARCH (GARCH) model, where the mean equation is first-order autoregressive AR(1), allowing for ARMA errors. The twelve-month moving average of the conditional standard deviation is computed.

Several methods have been used for measuring uncertainty in existing literature on firm investment. Many studies use historical data on variables of interest to create an uncertainty proxy. Two methods that have been used in the past are that one can take the unconditional standard deviation of a series and use it as a proxy for uncertainty. Another method is to use a more complicated prediction model in order to take out the 'predictable' part of a time series, and then measure the uncertainty by the volatility of the unpredictable part (Koetse, 2006). In this study, the proxy for uncertainty is the volatility of the unpredicted part of the Capital Asset Pricing Model (CAPM) model, similar to Baum *et al.* (2008). I start from a conditional return model (such as CAPM), where the stock return is conditionally predicted based on the market stock return and beta that is specific for the company. The unpredicted part of the regression or the residuals is unobservable. The standard deviation of the residuals can thus be used as a proxy for uncertainty.

To allow for time variation in the regression coefficients and therefore indirectly, possible time variation in the factor loadings, rolling regressions on the CAPM equation are implemented to estimate firm specific excess returns. Daily returns are calculated as the first differences of the natural logarithms of the respective indices. To calculate daily excess returns, the daily 90-day dealer bill rate is subtracted and is available as a proxy for the risk-free rate. Beta is then calculated using CAPM to withdraw the residuals and uncertainty is therefore measured as the annual standard deviation of the residuals series.

CAPM theory implies to measure uncertainty by using the covariance between the firm stock returns and market returns. However, as a result of having no data on the risk of investment projects in individual firms, it is assumed that risk of an investment is equal to the risk of the firms that carry out the investment. According to CAPM, the required rate of return on an investment should be positively related to that investment's risk, which is measured by the covariance of its returns with the market as a whole. An increase in the covariance should increase the riskiness of investment, increasing the required rate of return and reducing the desired level of capital stock (Leahy and Whited, 1996). Using covariance between stock returns and market returns as proxy for uncertainty, Baum *et al.* (2008) find a significant effect of uncertainty on investment even in the presence of q, cash flow and the debt-to-capital ratio. They consider this covariance as the interaction between firm-specific and macroeconomic uncertainty. Therefore, there are two new measures of firm specific uncertainty based on the CAPM. First is firm specific uncertainty obtained from the residuals, and the second is the covariance between the firm stock returns and market returns.

The one step Difference GMM estimator again is used to run the regressions. All lags of the Tobin's *q*, cash flow, leverage, and sales are employed as GMM instruments. In the regressions with uncertainty measures, lags of those measures were also included as GMM instruments (Arellano and Bond, 1991). By using GMM which tests for endogeneity, we take into account the endogeneity between investment and uncertainty. In fact, firm level uncertainty is not purely exogenous. For example, the decision to undertake a risky investment project may introduce heightened uncertainty over the firm’s future returns. Latent factors may also affect both uncertainty and the attractiveness of investment, creating a non-causal correlation. Following prior literature, endogenous uncertainty has been handled by using ‘internal’ instruments: lagged values of the dependent and explanatory variables (see, for example, Leahy and Whited, 1996; Bulan, 2005; and Bloom, Bond, and Van Reenen, 2007).

The dynamic model is estimated by including a lag of the dependent variable extended with Tobin’s *q* (to account for business opportunities and possible uncertainty effects via *q*) and both firm-specific and macroeconomic uncertainty. Both contemporaneous and lagged proxies of macroeconomic uncertainty are used. The results on different proxies for uncertainty are shown in Table 3.5. Columns 1, 3, and 4 are models where firm-specific uncertainty is included. In these columns, uncertainty is measured respectively as the unconditional standard deviation of firm share price returns, the covariance between firm share price returns and market stock index returns, and the standard deviation of residuals obtained from CAPM based model regressions for firms’ share price returns on market portfolio returns. In Column 2 and 7, uncertainty is macro-economic uncertainty, proxied by volatility of AllOrds Stock Index returns and conditional standard deviation of the Westpac Economic index obtained by a GATCH model respectively. In Column 5, both macro-economic uncertainty and firm-specific uncertainty are included.

Table 3.5: Sensitivity analysis for different measures of uncertainty

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
I/K_{t-1}	0.09^{*}	0.10^{*}	0.08	0.10^{*}	0.09^{*}	0.10^{*}	0.07
	(2.01)	(2.17)	(1.86)	(2.25)	(2.03)	(2.13)	(1.29)
q_t	0.00	0.01	0.00	0.01	0.00	0.01	0.01
	(1.55)	(1.71)	(1.31)	(1.75)	(1.55)	(1.67)	(1.21)
q_{t-1}	0.02^{***}	0.02^{***}	0.02^{***}	0.02^{***}	0.02^{***}	0.02^{***}	0.02^{***}
	(5.75)	(5.88)	(5.92)	(5.83)	(5.73)	(5.81)	(5.17)
$cashflow_t$	-0.04	-0.05	-0.03	-0.04	-0.04	-0.05	-0.02
	(-1.37)	(-1.56)	(-1.04)	(-1.36)	(-1.38)	(-1.48)	(-0.56)
$cashflow_{t-1}$	-0.04	-0.04^{*}	-0.03	-0.04	-0.04	-0.04^{*}	-0.03
	(-1.88)	(-2.02)	(-1.58)	(-1.76)	(-1.91)	(-2.05)	(-1.31)
$sales_t$	0.03^{**}	0.03^{**}	0.02^{**}	0.03^{**}	0.03^{**}	0.03^{***}	0.03^{***}
	(2.92)	(3.20)	(2.75)	(2.97)	(2.91)	(3.41)	(3.29)
$sales_{t-1}$	-0.01^{*}	-0.01^{*}	-0.01^{**}	-0.01^{*}	-0.01^{*}	-0.01^{*}	-0.01^{**}
	(-2.36)	(-2.12)	(-2.93)	(-2.43)	(-2.41)	(-2.29)	(-2.67)
$leverage_t$	0.07^{*}	0.08^{*}	0.08^{**}	0.07^{*}	0.07^{*}	0.08^{**}	0.05
	(2.06)	(2.34)	(3.00)	(2.13)	(2.17)	(3.21)	(1.86)
$leverage_{t-1}$	-0.10^{***}	-0.10^{***}	-0.11^{***}	-0.10^{***}	-0.10^{***}	-0.10^{***}	-0.09^{***}
	(-4.23)	(-4.23)	(-5.33)	(-4.21)	(-4.18)	(-5.21)	(-3.44)
$sdstockre_t$	-0.05^{**}				-0.05^{**}	-0.06^{*}	
	(-2.79)				(-2.93)	(-2.28)	
$sdstockre_{t-1}$	-0.05				-0.06	-0.02	
	(-1.80)				(-1.94)	(-0.86)	
$sdallordsre_t$		-0.44			-0.69	-0.25	
		(-1.57)			(-1.30)	(-0.75)	
$sdallordsre_{t-1}$		-0.24			0.32	-0.02	
		(-1.25)			(0.38)	(-0.08)	
cov_t			-2.07^{*}			-0.92	
			(-2.17)			(-1.09)	
cov_{t-1}			-2.39^{*}			-2.27	
			(-2.20)			(-1.93)	
$sdresid_t$				-0.04^{*}			
				(-2.52)			
$sdresid_{t-1}$				-0.02			
				(-1.53)			
$avsdwestpac_t$							-46.44
							(-1.06)
$avsdwestpac_{t-1}$							-4.79
							(-0.09)
AR(2)	0.16	0.19	0.15	0.19	0.17	0.24	0.09
Hansen test *p* value	1.00	1.00	1.00	1.00	1.00	1.00	0.96

Note: t values are in parentheses, a full set of year dummies is included in all specifications. All estimates are generated by Arellano–Bond one-step difference GMM. The instrument set is described in the text. The same notation as in Table 3.4 is used. *p* is the Hansen–Sargan test p statistics of over-identifying restrictions, while AR(2) is the Arellano–Bond test of second-order autocorrelation in the errors. $sdstockre_t$ is year-within standard deviation of stock price returns proxying for firm uncertainty, $sdallordsre_t$ is standard deviation of the within-year AllOrds index returns which is proxy for market uncertainty, cov_t is the covariance between stock return and market return. $avsdwestpac_t$ is within-year standard deviation of GATCH prediction of WestPac Index measuring macro uncertainty. $sdresid_t$ is within-year standard deviation of residuals of CAPM model of firm stock return, which is the un-predicted part of stock return.

We see from Table 3.5 that regardless of the way firm-specific uncertainty is measured, it consistently has a negative effect on firm investment. We find no evidence that macroeconomic uncertainty measured by the volatility of the stock market index (via AllOrds Stock Index) and GATCH of the Westpac – Melbourne Economic Leading Index has a significant effect on firm investment, especially when the model includes firm level uncertainty. This may be because macroeconomic uncertainty affects firm investment via the volatility of firm shares, or because investment decisions are influenced mainly by firm idiosyncratic uncertainty. Firms could pay more attention to its specific condition to consider investment decisions. In addition, as time dummies are added to the models to proxy for the unobservable time variant variables, they could be highly correlated with business cycles, reducing the role of our proxy of macroeconomic volatility. When the time dummies are taken out, coefficients of the macroeconomic uncertainty variables become significant.

Our results are consistent with empirical findings in other countries. Baum, Caglaya and Talavera (2008) examine the uncertainty-investment relationship for US firms and find that firm specific and CAPM-based uncertainty has a significant and negative effect on investment. Bo (2002) provides evidence that firms' investment is more sensitive to idiosyncratic uncertainty rather than aggregate uncertainty.

3.8 Conclusion

This chapter tests the implication of the Tobin's *q* model of investment incorporated with uncertainty, using annual data of listed and delisted non-financial firms on the Australian Stock Exchange from 1987 to 2009. This is the first study on the effects of uncertainty on firm investment in Australia using various measures of uncertainty. The chapter contributes to existing literature by analysing factors that influence Australian firms' investment.

In the chapter, there is strong evidence that Tobin's *q*, cash flow, sales and leverage are the driving factors of investment as claimed by existing literature and as hypothesised in the empirical model proposed in Section 3.4. The implications of the results in this chapter are that financially constrained firms are more sensitive to uncertainty, while large firms are more likely influenced by business opportunities (proxied by *q*). The contemporaneous and the first lag of the variables of interest are only significant, deeper lags are not, implying that firms make investment decision based on current and the most recent information.

One of the key implications of this study is that uncertainty has strong negative effects on firm investment. The magnitude of the uncertainty effect is relatively strong compared to other factors of interest; although, the strength does depend on the measures of uncertainty utilised. Also, the results show that the impact of uncertainty is dictated by its type. It appears that when both firm specific and market uncertainty are incorporated into the regression model, the firm specific uncertainty is more important for investment decisions compared to macroeconomic uncertainty; that is, macro uncertainty does not seem very relevant for firm investment. This could be due to the weak proxies used for macro uncertainty, or because the time dummies in the model play an essential role. Furthermore, there is evidence of a negative association between investment and firm idiosyncratic uncertainty. This implies that when the firm becomes more uncertain and as the volatility of stock price returns increases, companies take more caution and invest less. We also see a decline in investment when companies face lower revenues and a higher risk of borrowing.

3A.1. Data Appendix

Investment = Purchase of Property Plants and Equipment (PPEs) – Sales of PPEs.
Cash flow = profit after tax before abnormal + depreciation and amortization
Sales = total revenue
Capital = total book assets
Investment ratio = investment / capital at the beginning of the year
Cash flow ratio = cash flow / capital at the beginning of the year
Sale ratio = Sales / capital at the beginning of the year
Leverage = total debt / total book value of equity
Tobin's *q* = (total market value of equity – book value of equity +book value of total asset)/total asset
Total market value of equity= share price at the year-end times total outstanding number of shares.

3A.2. Appendix 1

Table 3.A.1: List of firm level studies on uncertainty and investment

Name	**Model/Sample**	**Uncertainty measures**	**Conclusion**
Baum *et al.* (2010)	*q* model extended with interaction terms between uncertainty and firm's cash flow US manufacturing firm, 1984-2003	Market uncertainty and firm's CAPM based uncertainty measure	Market uncertainty through cash flow on investment is negative, whereas the effect of firm-specific uncertainty is positive
Baum *et al.* (2008)	Investment rate =f(lagged investment rate, *q*, debt, cash flow, sales growth, intrinsic uncertainty, extrinsic + CAPM based risk measure) US firms, 1984 - 2003	Firm-specific uncertainty based on stock return volatility and a CAPM-based uncertainty	Firm-specific and a CAPM-based uncertainty have a significant and negative effect on investment, whereas, the market-based uncertainty has a positive association with investment.
Fuss & Vermeulen (2008)	Investment rate=f(lagged investment rate, output change, uncertainty) Belgian firms, 1987-2000	Demand and price uncertainty measures based on a survey of firms' expectations on future demand and price changes	Demand uncertainty has a negative effect on investment plans and realized investment. No effect of price uncertainty
Bloom *et al.* (2007)	Investment ratio =f(output growth, squared output growth, error correction terms, uncertainty) U.K. manufacturing companies, 1972–1991	Variance of stock returns	Uncertainty depresses investment
Bond *et al.* (2005)	*Q* model with uncertainty Listed non-financial UK firms, 1987-2000	volatility of firm share price; volatility of the average or 'consensus' forecasts of firm future earnings; dispersion across individual analysts' forecasts of future earnings; and variance of the forecast errors observed ex post for the consensus earnings forecasts	Higher uncertainty reduces investment in the short term
Bulan (2005)	Investment ratio=f(*q*, cash flow, Marginal profitability of capital, market, industry and firm measures of	Standard deviation from unpredicted component in a stock return equations; realized volatility of	Macroeconomic uncertainty reduces investment after controlling for Tobin's *q*, MPK and cash flow.

	uncertainty) US firms	firm equity returns	Firm-specific uncertainty depresses firm investment
Bond and Cummins (2004)	Investment ratio=f(*q*, uncertainty, real sales growth, interaction between real sales growth and uncertainty) U.S. firms, 1982-1999	Three measures of uncertainty	For each individual uncertainty, a significantly negative long-run effect of higher uncertainty on capital accumulation, robust to the inclusion of the *q* variables
Driver *et al.* (2005)	ECM model with profitability, for the two major asset types of physical capital in the UK	Dispersion of subjective forecasts for GDP; conditional volatility in output growth	The effect of uncertainty is to depress aggregate investment
Henley *et al.* (2003)	Investment ratio=f(lagged investment ratio, sales, debt, uncertainty of firm and industry) UK listed industrial companies, 1972-1995	Industry-wide uncertainty: a moving standard deviation of the sector producer price index; Firm uncertainty: 24-month moving average of the squared forecast residual based on CAPM model	Changes in industry-wide and in firm-specific uncertainty influence investment in opposite directions
Von Kalckreuth (2003)	Investment ratio=f(sales growth, cash flow, uncertainty) German firms, 1987-1997	Variance of the errors of sales forecasting equation and operating cost	Uncertainty have a systematic negative impact on investment
Bo (2002)	Dutch listed companies Investment ratio=f(*q*, uncertainty)	Idiosyncratic uncertainty of firms from forecast errors of sales derived from a state space model	Uncertainty depresses firm investment, idiosyncratic uncertainty is more important
Hatakeda (2002)	Investment ratio=f(proxy variable of marginal *q*, the liquidity financial asset ratio, land-to-capital ratio, uncertainty) Japanese firms, 1983 to 1993	Volatility of marginal *q* using two ways: realized standard deviation of a variable and standard deviation of the residuals from a statistical model	The relationship is negative and large in absolute value for medium-to-small firms and high-leverage firms that are likely to be subject to a liquidity constraint
Peeters (2001)	neo-classical model, investment = f(value added to capital ratio, debt, uncertainty) Belgian and Spanish firms, 1983-1993	Standard deviation of unpredicted part of forecasting models	Output price uncertainty depresses investment and investment behaviour seems strongest for the group of large and the group of high-leveraged firms in Spain

Ogawa and Suzuki (2000)	Investment=f(profit, cost of capital, land stock, uncertainty) Japan manufacturing firms,1970-1993	Conditional standard deviation of firm's sales growth rate	Aggregate and industry-wide uncertainty has negative effect on investment, material industries are more sensitive to the negative effect of uncertainty than machinery industries
Guiso and Parigi (1999)	Investment ratio=f(sales, lagged investment ratio, other control variables) Italian firm, 1993	Subjective variance of future demand forecasted from the three-year annual average demand growth rate, scaled by the stock of capital	Demand uncertainty depresses firm investment
Minton and Schrand (1999)	Investment = f(cash flow, capital costs) US firms, 1989-1995	Cash flow volatility	Higher cash flow volatility is associated with lower average levels of investment in capital expenditures, R&D, and advertising
Pattillo (1998)	Investment=f(profitability, value added, characteristics of firms) Ghanaian firms, 1994–95	Variance of subjective probability distribution over future demand	Uncertainty raises the trigger value at which firms invest
Leahy and Whited (1996)	Investment ratio=f(uncertainty, *q*, output, cash flow) US firms during 1981-1987	Forecast of the variance of the daily stock return for a year adjusted by the market debt to equity ratio.	A negative relationship between uncertainty and investment, but through Tobin's *q*
Ghosal and Loungani (1996)	US industries data, Industry level Investment ratio=f(uncertainty, sales, capacity utilization rate)	Price uncertainty: residual from the forecasting equation	Differences across industries in the investment-uncertainty relationship based on the extent of product market competition,
Driver, Yip and Dakhil (1996)	Capital growth=f(lagged capital growth, output growth, capital-labour factor cost, capital-output ratio, uncertainty) International firms from PIMS data	Market share turbulence	In a number of industries, uncertainty causes a depressing effect on capital investment

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Chapter 4

A Behavioural Model for House Price Dynamics in Australia

Abstract

This chapter analyses the dynamics of the Australian housing market during the last three decades using a housing behavioural economic model based on nominal variables and the behaviour of house buyers. I find that short-run nominal house prices are driven by nominal variables, including buyers' inter-temporal disposable incomes and interest rates. There exists a long-run co-integrated relationship at both the state and national levels between house prices and house acquisition costs. The empirical evidence shows that my nominal behavioural model is equivalent or even better than other conventional models in explaining house price dynamics in Australia.

4.1 Introduction

The housing sector plays an important role in the economic development of Australia, as it accounts for a very large proportion of Australian household wealth, while housing expenditures account for a large proportion of GDP and household expenditures. Fluctuations of house prices lead to consequences for other economic variables. Houses are the households' main assets, while mortgage debt is the main liability. Changes in house prices have profound implications on the rest of the economy, as large house price movements affect households' net wealth and their capacity to borrow and spend. Understanding the movement of house prices is therefore of major importance for economic policy makers.

In the house user-cost based conventional models, house prices are predominantly driven by fundamental variables such as income, demographics, the house user-cost of capital and the inelastic house supply (see Girouard, Kennedy, Paul van den Noord and Andre, 2006 for a detailed survey). However, the sharp increase in house prices in Australia over the last three decades cannot be explained sufficiently by these fundamentals. In fact, the remarkable survival of the Australian house market out of the Global Economic Crisis compels one to question what actually determines the dynamics of this market. To date, empirical studies show that the roles of factors determining house price movements in Australia are unclear.

Conventional housing theories are based on the assumptions of a frictionless competitive market in which house buyers have perfect foresight, transaction costs are zero, and houses are liquid assets. In these models, real variables are the only effective variables, while nominal variables are not relevant. However, there is great evidence that these assumptions are not realistic. In fact, houses are heterogeneous and illiquid assets and the majority of house buyers buy houses with mortgages that are subject to financial constraints. In addition, house buyers are influenced greatly by money illusion, while house purchasing activities depend on the mortgage payment affordability of house buyers. In contrast to the general theory, house buyers are very short-sighted and lack the information to engage in housing transactions. These facts motivate us to look for a new empirical model which is more applicable to actual market conditions.

In Australia, few empirical studies give insights into the behaviour of Australian house price dynamics. Amongst these scarce existing studies (Bourassa and Hendershott (1995); Bodman and Crosby (2004); Bewley, Dvornak, and Livera (2004); Abelson, Joyeux, Milunovich and Chung (2005); Berger-Thomson and Ellis (2004); and Otto (2007)), there is little confirmation of the key drivers of house price changes. Findings of these studies are subject to specific caveats or inconclusive findings when applied to Australian data. For instance, Bodman and Crosby (2004) find that the impact of economic fundamental variables and interest rates is not significant on house prices; while, Abelson, Joyeux, Milunovich, and Chung (2005) confirm the significant impact of interest rates on house prices. Berger-Thomson and Ellis (2004) find that interest rates have no long-term effect on house prices, a stance that differs from that of Bourassa and Hendershott (1995) and Berger-Thomson and Ellis (2004) who find a negative effect of interest rates on house price. Moreover, empirical research linking the long- and short-term determinants of Australian house prices is limited. It appears that insufficient data seems to prevent researchers from conducting co-integration analyses of house prices and their long-term determinants (such as, construction costs and land prices).

To fill this gap in the current literature, the main contribution of this chapter is the application of a new empirical model in explaining the dynamics of Australian house prices, a model that incorporates nominal variables which are not conventional in previous studies. The empirical model in this study is based on a theoretical model proposed by Madsen (2012). In his model, nominal house prices are driven by nominal variables through a mechanism based on the affordability test imposed by banks that provide loans to house buyers. In the short run, house prices will fluctuate so that the proportion of income to serve house loans is given by a ratio promulgated by banks. However, in the long run, house prices are determined by their replacement costs including construction costs and land prices as regulated by the Tobin's q principle. This research is a first attempt to analyse the roles of nominal variables on house prices and to use land prices, proxied by agricultural land prices, in the long-term co-integration relationship of house prices and their acquisition costs in Australia.

Consistent with the notion that house prices can fluctuate significantly at high frequency, this chapter uses quarterly data on house prices at both the state and national levels for eight Australian capital cities from at least 1980 Q1 to 2012 Q4. At the national level, data is available from 1970 Q1 therefore this chapter uses a much larger time span than previous studies on the Australian housing market.

I find evidence of a long-term relationship between house prices, land prices and construction costs using Australian state-level data, which is in according to Tobin's q theory. There is strong evidence supporting my behavioural model to explain price movements. Amongst other conventional models, only the user-cost of capital model explains satisfactorily the house price movement in Australia. There is evidence that an increase in house prices is due to both the short effects of demand variables (for example, income, mortgage rate and financial commitment) and long-run effects of supply variables (such as, construction costs and land prices). Results also show that a significant co-integration relationship exists between house prices, construction costs and land costs. If house prices in the short-run deviate from their long-term values, the error correction mechanism ensures that they return.

The remainder of the chapter is structured as follows: The next section contains a literature review of existing research on house prices in Australia. Section 3 proposes a theoretical foundation for the empirical research. Section 4 describes the data sources and how the variables are constructed. The empirical results of the baseline model are discussed in Section 5. Section 6 offers a comparison of my model's explanatory power with existing models. The last section is the conclusion.

4.2 Review of Relevant Empirical Literature on Housing Prices

The large literature on house prices can be divided into a number of major frameworks. The most common approach is that house prices should be measured based on an asset pricing framework, in which one assumes that houses prices are regulated by their fundamental values, calculated as the value of the discounted future net service streams received by owning the house. Within the present value framework, the house user-cost models (see Kearl, 1979; Dougherty and Order, 1982; and Poterba, 1984) emerge as the prominent housing price models. Poterba (1984) argues that the user-cost of housing determines house prices, and can be calculated as:

$$UC = (i_t + t_t^p)(1 - \tau_t) + \delta - \pi \,, \tag{4.1}$$

where interest rate forgone is i_t, property tax rate t_t^p, income tax rate τ_t, the depreciation rate of the house δ, and the appreciation rate of house value π. Assuming that households can easily switch between owning and renting a house, the arbitrage condition ensures that the expected cost of owning a house must be equal to its renting cost R or, $P[(i_t + t_t^p)(1 - \tau_t) + \delta - \pi] = R$. Therefore, the house price to rent ratio equilibrium condition should be

$$P/R = 1/[(i_t + t_t^p)(1 - \tau_t) + \delta - \pi] \tag{4.2}$$

The model presented by Poterba (1984) shows that house prices are influenced by tax rates, interest rates, house depreciation, and rentals. Likewise, house prices are correlated with the expectation of future house prices.

The analogy of the house market to the stock market seems to be straightforward. The rent-price ratio in the housing market is analogous to the dividend-price ratio in the stock market (Leamer, 2002). Asset pricing theory asserts that the current price is an adequate forecast of future dividends, as is claimed in Campbell and Shiller (1988). Under the assumption that the expected discount factor and expected cash flow are growing at a constant rate to infinity, price should be equal to the present cash flow divided by the real user-cost of capital:

$$P = R/\,[(i_t^r(1-\tau_t) - g_{t+1}^e] \qquad (4.3)$$

where R is the real cash flow, which is usually proxied by real rental, i_t^r is the real interest rate, the income tax rate is given by τ_t, and g_{t+1}^e is the real capital gain or the assumed constant growth rate of real house prices. A detailed discussion of the use of rent as a proxy for housing service revenue can be found in Smith and Smith (2006). According to Campbell and Shiller (2001), when the ratio of price over dividends is high, future price growth for stock is less likely. The analogous statement is reasonably expected to be true for the housing market (Gallin, 2008). Thus, house price is positively related to the rental value of the house and inversely related to the real user-cost minus the growth rate in rental values.

House price models based on the asset pricing framework, such as the user-cost model, are based on some assumptions, including perfect markets and perfect house buyers' foresight. However, there are reasons why the real user-cost of capital may not be a relevant determinant of house prices, even when some potential house buyers have perfect foresight. First, credit constraints may prevent rational house buyers from exploiting profit opportunities. Second, the market is not liquid, so the house owner cannot switch between owning and renting a house very easily. It can be understandable that the investigations of Poterba's model on renting data for the price rent ratio provide mixed results.

Another branch of the house-price models is based on Tobin's q theory augmented with replacement cost. Accordingly, investors optimize the total profit objective function, in which investment and replacement costs play an important role.

In a recent paper, Madsen (2009) uses the Tobin's q principle and extends the model by Poterba (1984) by allowing for the optimizing behaviour among consumers and investors and the influence of taxes on the effective acquisition costs of houses. He finds that in the long run, house prices will reach a steady state level, where both housing stock and q are at a steady equilibrium. Namely, Madsen (2009) shows that, in the long run, there is a level of q at which the house stock is stable, and if there are any shocks, the q and housing stock will reverse back to a new equilibrium level. Accordingly, house prices will be determined by their replacement costs in the long run.

To explain the cyclical pattern of housing prices, theoretical papers, like Dougherty and Order (1982) and Meen (1990) use inter-temporal consumer utility maximization models, where the optimal allocation of housing services over the life cycle is determined by the real user-cost of housing and the marginal rate of substitution between housing services and the consumption of non-durables. Assuming a household needs to make decisions in purchasing houses or non-durable goods, the utility maximization problem leads to a relationship between house prices and cost of capital which is similar to the user-cost-based models.

Another group of theories, such as of Shiller (2006) and Piazzesi and Schneider (2009) focus on the role of expectations in determining house-price dynamics. Shiller (2006) states that, herd behaviour, the irrational expectation of a non-stop increase of house price and buyer competition drive house prices up. The bubbles and crashes in house markets that cannot be explained by fundamental value models pave the way for the behavioural explanations of house price dynamics. Herd spirit plays a role in housing bubbles, even when interest rates are high, as house prices keep increasing dramatically.

The foresight of house buyers may also be questionable. According to Case and Shiller (2003), majority of real estate market participants are naïve amateurs with limited information and little or no experience in assessing the fundamental value of the houses they are buying and selling. It is unlikely that, participants value houses using the approach of present value of the expected cash flow. Smith and Smith (2006) say that the prices of houses are determined by the sale prices of similar houses in the neighbourhood, and that is one cause for house price bubbles. House prices are in part driven by non-fundamental speculative phenomena such as fads or bubbles (Stein, 1995).

There exists a need to incorporate the behavioural approach into the asset price rational expectation models. However, how does one incorporate behavioural factors into a conventional model such as Tobin's *q* or the user-cost based one which are dominated by rational expectations? Recently, a significant effort was undertaken by Madsen (2012) to address this question. Madsen (2012) develops a behavioural model in which house prices are determined by behavioural factors, such as the nominal mortgage interest rate, the principal repayment, the down payment, the after-tax disposable income of house buyers and house owners and financial innovations. In the long run, he finds that the principle of Tobin's *q* holds, as house prices are determined by the replacement cost of houses, under the assumption that house buyers and developers are motivated to build new homes if house prices exceed their replacement costs.

Australian house price empirical literature

Based on theoretical models, many studies develop empirical models to test the former or just to examine factors that may explain house price dynamics (see Leung, 2004, for a survey). In the literature of house price empirical models, there is often an interaction between the supply and demand models that determine house prices. On the demand side, given the standard demand function, the quantity of houses demanded depends on the price of housing services and demand shifters. The price of houses is a function of the price of housing services equivalent to the user-cost under a no arbitrage opportunity condition, disposable income, interest rate, tax, and a vector of demographic factors such as migration and household characteristics, and available housing stock. House prices should be negatively correlated to user-costs, and since user-cost is measured as in Equation 4.1 (abstracted from Poterba, 1984), house prices are therefore influenced by the interest rate, tax, depreciation, expected house price increases, and inflation.

On the supply side, the supply of housing is a function of the housing stock, construction costs, and residential/developed land costs. The house production function can be in the form of a Cobb-Douglas function of capital, labour, materials and technology. Another model, Tobin's *q* is also used to explain the interaction between housing prices and housing stock. Accordingly, housing investment is a function of marginal *q*, which is the ratio between the market price and the replacement costs of an additional unit of housing to be built.

The growth rate of house prices in industrial countries is positively affected by real income growth and credit availability, and negatively affected by interest rates (Terrones and Otrok, 2004). Housing prices also depend on the structure of mortgage markets and other structural factors, such as the adjustability of mortgage rates in home loan contracts and innovations in mortgage markets (Schnure, 2005). Evidence suggests that the process of securitization of the U.S. mortgage market has contributed to the country's house price fluctuations (Barth, 2009).

Given the growing importance of the housing market in Australia during the last few decades, the number of studies on house prices in Australia is surprisingly scarce. Of those that do exist, conclusions are contradictive or inconclusive, while the common theme is studying the determinants of house prices at either the state or national levels, or both. The forthcoming discussion reviews these studies, outlining their methods, results and weaknesses.

Bourassa and Hendershott (1995) analyse the changes in real house prices in Australia over the period of 1979 to 1993. They use an error adjusted term-based model, allowing for the possibility of speculative bubbles, in which the error correction terms come from the difference between actual and equilibrium house prices, forecasted using a basic recursive formula. Data for the six cities is pooled and the resulting model is estimated by Ordinary Least Squares (OLS) without any attempt to exploit the panel nature of the data. Their findings indicate that the local real income, employment growth, population growth due to net immigration, real after-tax interest rates, and construction costs are significant explanatory variables for real house price movements.

Meanwhile, Bodman and Crosby (2004) use quarterly REIA data on real house prices in five Australian capital cities from 1980 to 2003 and examine a model similar to that of Bourassa and Hendershott (1995) on house price movements. Their study finds weak evidence of the impact of economic fundamental variables as well as price bubbles. Namely, they find that interest rates have no significant effect on house prices. Bewley, Dvornak, and Livera (2004) also seek to model the quarterly growth rate of real house prices in the state and territory capital cities using a non-structural VAR model to examine the power of lags of house prices in one city, in forecasting changes in other Australian cities. They find evidence of a positive spill-over effect from the Sydney housing market onto house prices in other Australian capital cities.

Abelson, Joyeux, Milunovich, and Chung (2005) explain changes in real house prices at the economy-wide level in Australia for the period of 1970 Q1 to 2003Q1, using an asymmetric error correction model for aggregate quarterly data. They find that the determinants of long-run real house prices are real disposable income, unemployment, real interest rates, equity prices, CPI, and the supply of housing. However, their research has shortcomings as their empirical model lacks a concrete theoretical framework, while their long-run model includes a list of influential variables advocated by previous literature.

Berger-Thomson and Ellis (2004) model house price also using an error correction model and find that interest rates have no long-term effect on house prices, a stance that differs from that of Bourassa and Hendershott (1995) and Berger-Thomson and Ellis (2004), who find a negative effect of interest rates on house price. Otto (2007) examines the behaviour of house prices of Australian cities using an ADL model for the 1986 to 2005 period. The explanatory variables he includes are lags of house price growth, mortgage rate, inflation rate, unemployment, population, introduction of GST in September 2000, and the Sydney effect. He finds evidence that fundamental economic variables aid in explaining individual capital city house price movements, but the size of the effects is not equal across all cities. Particularly, he finds that mortgage rates are very important, as house prices have become increasingly sensitive to the level of mortgage rates.

The aforementioned studies highlight factors that influence house price dynamics, however, they fail to develop a reliable model for explaining the movement of house prices in Australia. According to Meen (2001) one may encounter difficulties in developing such a housing price model. First, the theoretical foundations in modelling are weak which leads to misspecification of the relationship amongst the variables. Second, there is a lack of emphasis on the supply side as current literature ignores supply-side variables such as construction costs and land costs. However, this could be due to the availability of supply side data. Third, the use of aggregated data ignores state specific characteristics which may be an influencing factor. Existing theoretical models are not satisfactory to explain the movement of Australian house prices, and therefore there is a need for models that are more applicable to the Australian housing market.

Existing research suggests that people often make financial decisions in nominal terms. Money illusion—the tendency to think in terms of nominal rather than real monetary values—is common in a wide variety of contexts (Shafir, Diamond, and Tversky, 1997). In the housing market, house buyers are influenced by money illusion as well. They are willing and able to take larger loans during periods of low inflation and low nominal interest rates than in periods of high inflation and high nominal interest rates, because nominal mortgage expenses per dollar borrowed are lower. However, there is no research on money illusion in the housing market in Australia. Remarkably, Ellis (2005) provides evidence that disinflation creates motivation for house prices to increase, which has been profound in the Australian housing boom during recent decades. Hence, there is a clear need to study the impact of money illusion through nominal rather than real variables on house prices.

4.3 Theoretical and Empirical Models

The theoretical model in this chapter is a simplification of the behavioural model of house prices by Madsen (2012), called the repayment model. On the house demand side, the proportion of house mortgage costs over income of a representative house buyer should be within a given range set by bank regulation and willingness to lend. Banks impose a repayment ratio test when lending to individual households up to a certain portion of their current nominal income. Here the representative house buyer makes 'short sighted' buying decisions based on the current conditions rather than long-term conditions. They give more weight to the most recent flows of payments and they are influenced by money illusion—the tendency to think in terms of nominal rather than real monetary values. Without loss of generality, it is assumed that all households are house buyers, as majority of them need housing services, and they borrow to buy houses.

For the representative house buyer, the fraction of his current and expected disposable income required to service the mortgage debt (to pay interest rate, property tax, and principal repayment) is given by the following repayment ratio:

$$\Psi_{it} = \frac{[(i_{it}+t_{it}^{p})(1-\tau_{it})+\phi_{it}].M_{it}.P_t^h}{[\bar{Y}_{it}^{\alpha}[E(\bar{Y}_{i,t+1})]^{1-\alpha}]} \quad (4.4)$$

where Ψ_{it} is the proportion of the house buyer i's total disposable income (current and expected $\bar{Y}_{it}^{\alpha}[E(\bar{Y}_{i,t+1})]^{1-\alpha}$]) at time t used to service the mortgage debt, $\bar{Y}_{it}$ is current nominal disposable income (including government transfers) of the house buyer, M_{it} is number of house that the household would buy to use, P_t^h is a representative house price that the buyer buys, α is the constant relative weighting of contemporaneous and expected income in the lending provision, $0 \leq \alpha \leq 1$. The larger α, the more weight the banks give to the most recent flows of income of the house buyers when considering house-buyer's loan application. In the numerator, t^p is the property tax rate, i is the nominal lending rate, τ is the tax rate at which interest rates and property taxes can be deducted, ϕ_{it} is the ratio of the principal repayment as a percentage of the housing loan. Ψ_{it} is decided by the banks, mostly ranging from 25-30% of buyers' income and seldom higher than 30% to minimize the default risk of the house loans. Ψ_{it} can be a function of the willingness of banks to lend to house buyers, level of uncertainty in the economy, innovation and competition of financial markets and the degree of regulation of the credit system.

If houses are homogeneous, for the average house buyer, there is no longer the subscript i; thus,

$$\Psi_{t} = \frac{[(i_{t}+t_{t}^{p})(1-\tau_{t})+\phi_{t}]M_{t}.P_t^h}{[Y_{t}^{\alpha}[E(Y_{t+1})]^{1-\alpha}]/N_t} \quad (4.5)$$

while N is the number of home buyers and Y is the sum of the disposable income of all house buyers.

We then can calculate house price as:

$$P_t^h = \Psi_t.\frac{[Y_{t}^{\alpha}[E(Y_{t+1})]^{1-\alpha}]}{[(i_{t}+t_{t}^{p})(1-\tau_{t})+\phi_{t}]M_{t}.N_t} = \Psi_t.\frac{[Y_{t}^{\alpha}[E(Y_{t+1})]^{1-\alpha}]}{[(i_{it}+t_{t}^{p})(1-\tau_{t})+\phi_{t}]H_t} \quad (4.6)$$

where H is the housing stock, which is equal to the number of house buyers times the number of representative houses that each household buys.

Taking the log and the first difference of both sides of Equation 4.6 yields:

$$\Delta \ln(P_t^h) = \Delta \ln(\Psi_t) + \alpha \Delta \ln Y_t + (1-\alpha)\Delta \ln E[Y_{t+1}] - \Delta \ln[(i_t + t_t^p)(1-\tau_t) + \phi_t] - \Delta \ln H_t \quad (4.7)$$

where Δ is the first-period difference.

The above model has the following implications: nominal house prices depend on the affordability ratio, total disposable income, expected disposable income, financial and monetary innovations (via interest rate, mortgage rate), tax rates and investment. The model also takes into account the possible effect of inelasticity of house supply via the house stock term H_t. This is in line with the hypothesis that limited house supply will affect house price dynamics (Glaeser, Joseph and Raven, 2005).

The last term $\Delta \ln \mathrm{H_t}$ in Equation 4.7 can be considered as an error correction term in the sense that building investment closes the gap between the house price and its replacement cost. If $\Delta\, ln\, H_t$ is positive, it means investment is positive, and an increase in housing stock could reduce house prices. It is only until $\Delta\, ln\, H_t = 0$ when housing demand and supply reach equilibrium and the house price equals its replacement cost, reaching its long-term level. It is also assumed that the growth of house price is determined by the demand side via demand factors, income (Y), the affordability of the household to pay the house mortgage (Ψ_t), and the cost of borrowing via term $[(i_t + t_t^p)(1-\tau_t) + \phi_t]$. The house price is also determined by the supply side via the change of housing stock (H_t), as the stock increase will reduce the house price and the cost of investment via interest rate i_t and the tax τ_t.

Replacing the last term of Equation 4.7, we have:

$$\Delta \ln\left(P_t^h\right) = \Delta \ln(\Psi_t) + \alpha \Delta \ln Y_t + (1-\alpha)\Delta \ln E[Y_{t+1}] - \Delta \ln\left[(i_t + t_t^p)(1-\tau_t) + \phi_t\right] - ECT_{t-1} \quad (4.8)$$

where ECT_{t-1} is error correction term and equals $\Delta\, ln\, H_t$.

If adding subscript *i* to account for eight different states in Australia, assuming $t_t^p = \phi_t = 0$ as they basically do not change with time, and allowing for lags and persistence of house prices, the empirical model to be tested is as follows:

$$\Delta \ln\left(P_{it}^{h}\right) = \alpha_0 + \alpha_1 \Delta \ln(\Psi_t) + \sum_{j=1}^{k} \beta_j \Delta \ln P_{i,t-j}^{h} + \alpha_3 \Delta \ln Y_{i,t+1}^{e} + \alpha_4 ECT_{i,t-1} + \sum_{j=0}^{k} \vartheta_j \Delta \ln Y_{i,t-j} + \sum_{j=1}^{k} \omega_j \Delta \ln i_{i,t-j}^{m} + \varepsilon_{it} \quad (4.9)$$

where P_{it}^{h} *i*s the nominal house price of state *i* in time *t*, proxied by house price indices of corresponding states in the empirical part. Ψ_{t} is the affordability ratio, the ratio between the cost to service the mortgage debt and the disposable income, $Y_{i,t}$ is total nominal disposable income of house buyers, $Y_{i,t}^{e}$ is the total expected nominal disposable income of house buyers, $i_{i,t}^{m}$ is the mortgage rate imposed by banks, ECT_{t-1} is the error correction term obtained by regressing the long-run equation between the level of house prices and their long-run determinants (given by the theory), and ε is a stochastic error term. For the Australian case, the tax rate used for the owner-occupiers for the purpose of tax deductions is zero, as interest is not tax deductable. We estimate the model without the tax shield term $\left(1 - \varphi_i \tau_{i,t-j}\right)$ as this tax shield in fact basically does not change with time.

The theory proposed by Madsen (2009) states that, in the long term, Tobin's q theory holds in the housing market. If house price is higher than its replacement cost (construction cost and land costs), investors are motivated to invest in a new house to earn profit. This increase in supply will push house prices down until the q ratio is equal to one. Obviously, the replacement costs go in line with a change in construction cost and land cost. Therefore, the house price according to this theory should return to its long-term value determined by construction and land costs. In other words, in the long-run, it is expected that house prices will be co-integrated with residential land price and construction costs.

Therefore, ECT_{it} in the above equations come from the deviation of house prices from their should-be values given the long-term relationship between house prices, construction costs and residential land costs, which should be:

$$\ln\left(P_{it}^{h}\right) = \beta_{i0} + \beta_{i1} \ln(cc_{it}) + \beta_{i2} \ln lc_{it} + ECT_{it} \quad (4.10)$$

where cc_{it} is house construction costs and lc_{it} is the residential land cost for one house. The conjecture of house prices converging to their building costs in the long run has been proposed in the literature; namely, it is in line with Tobin's q theory in the housing market.

Briefly, according to the model, in the short–run, house prices fluctuate to the level at which the nominal mortgage expenditure is a fixed percentage of the disposable income of house buyers based on the lending rules of banks, as house buying is sponsored largely by loans from banks. The model reveals that house prices are determined by the nominal mortgage interest rate and financial innovations, the principal repayment, the after-tax disposable income of house buyers, and the net flow of potential house owners into the housing market. In the long run, it is assumed that house prices are dictated by the replacement costs of houses under the principle that house buyers and developers keep building new homes as long as house prices exceed their replacement costs. In other words, the model incorporates demand factors (such as disposable income, mortgage interest rate which drives the cost of borrowing, and population) and supply factors (replacement costs) in the short run, while in the long run it incorporates replacement costs.

The model also incorporates principles consistent with the income expectation theory (Kahn, 2008) according to which house prices go up today because of a positive change in expectations about future income growth. Accordingly, the expectation of higher sustained income growth in the future $Y_{i,t+1}^{e}$ is a driving force for today's house prices.

In the house price literature, there are numerous studies using error correction models with demand side variables. For example, Abelson *et al.* (2005) conduct a co-integration test between real house price and stock index, disposable income, exchange rate, CPI, unemployment rate, and housing stock per capita in the Australian market. However, studies rarely model house prices and supply side variables (both construction costs and land costs) using an error correction framework. Only recently, Madsen (2012) uses a co-integration model between house prices and construction costs in an analysis of annual panel data, including Australia. Also, Carrington and Madsen (2011) use a co-integration model between house prices and rental costs in the case of the US housing market. One of the prominent implications from these two studies is the need to take money illusion into account and to model house price movements using nominal variables, an approach not seen in previous studies. Given the implications of money illusion, the focus of this study is on the role of nominal variables.

In the Australian context, there are two sets of data. The baseline house price model will be tested using panel data on eight Australian states and territories. First, a time series regression will be conducted for each individual state, followed by a panel data estimation to gain further efficiency. The regression using panel data has the advantage of incorporating idiosyncratic regional characteristics, which are cancelled out in the aggregated data. However, there are certain variables for which data are not available at the state level, such as money supply for each state. Therefore, a regression using the nationwide data set is also run.

4.4 Data

In terms of data for house prices for each of the eight capital cities, the most extensive data set available, the quarterly median prices (HPI) for established houses are provided by the Real Estate Institute of Australia (REIA) and are available for the period 1980 Q1-2012 Q4. Another state-level data set of house prices is from the Australian Bureau of Statistics (ABS) but covers a shorter period of time, 1986 Q2 to 2012 Q4. Costello, Fraser, and Groenewold (2011) contain a discussion on why the REIA data set is appropriate. Therefore, in this study the former dataset is used for state-level estimates. If the house price data from ABS is used, the regression results are qualitatively similar. It is reasonable because the correlation between the REIA and ABS house price time series for the states and territories is very high; the correlation coefficients are over 0.99 in all states.

House price data at the national level are from two sources. The house price data from 1986 Q2 onward are from the ABS, while the data before 1986 Q2, back to 1970 Q1 is obtained and spliced from Abelson and Chung (2004). The state-level rental data is defined as the rent cost index of tenants' rent from the state-level Consumer Price Index (CPI), collected from Datastream and dated back to 1972 Q2.

In testing robustness of different models, the user-cost of housing capital has been used as an explanatory variable. The estimate of the user-cost of housing capital is based on Poterba's (1984) traditional model of user-cost, a formula consisting of the standard home loan variable rate, the property tax rate, the marginal income tax rate (at twice the median income tax rate) and expected inflation (from a forecast model). As home loan interest payments are not tax deductable from income of home owner-occupiers in Australia, home loans are often paid back as soon as possible. The actual loan term therefore is often much shorter than the official long-term loan of 25 years provided by commercial banks.

Also, majority of home loans use standard variable home loan rates rather than long-term 25-year mortgage rates. According to ABS cat. 5609 (Table 09a), on average the fixed-term loans account for only 11 percent of the total dwelling loans during the period from 1991 to 2012. Therefore, throughout the chapter the variable standard home loan interest rate consistently used is as the mortgage rate in the empirical model. Stamp duties and property taxes are not included in the model, because the data for these taxes are not available over the time period of interest. Income taxes are excluded from the model, as house owners do not receive mortgage deductibility. The construction cost indices for eight capital cities are from ABS cat. 6427. The indices reflect inflation of the material and labour costs for constructing new houses. As there is no construction cost data for North Territory and ACT, North Territory data are proxyed by Queensland data and ACT data by Sydney data.

At the state level, seasonally adjusted nominal state final demand is used as the proxy for state nominal disposable income. The data comes from the ABS and are available from 1983 Q3. The national level data for GDP are also from the ABS, dating back to 1959 Q1. The REIA Home Loan Affordability Indicator is used as proxy for the ratio Ψ_t. The indicator is a ratio of median family income to average new loan repayments. An increase in the REIA indicator represents improved affordability. The data regarding this affordability index dates back to 1980 Q1.

As Australian residential land price data do not exist, agricultural land prices are used to proxy for residential land prices. The data of annual agricultural land prices dates back to 1978 and was kindly provided by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). The annual data are then interpolated into quarterly. The reason for employing agricultural land prices as a proxy is, according to Madsen (2009), residential land prices are proportional to agricultural land prices. An increase in the price of agricultural land will push up the prices of developed land at the outskirts of a city, which in turn makes houses closer to the city centre relatively more affordable and leads to an excess demand for these houses. Thus, a ripple effect will push house prices in the whole city up following the initial increase in the price of agricultural land.

In addition, residential land prices are determined by agricultural land values, land development costs, and the ease of accessibility to central urban areas. Although agricultural land prices cost only a fraction of the price of developed land, Madsen (2009) finds that the prices of agricultural land and developed land move proportionally. Wheaton (1974) claims that land at the outskirts of the city is developed for housing until the rental price of urban land equals the rental price of agricultural land. It is reasonable to assume that agricultural land around large Australian cities can easily be converted into urban developed land, thus, permitting the use of agricultural land prices as a proxy for residential land prices.

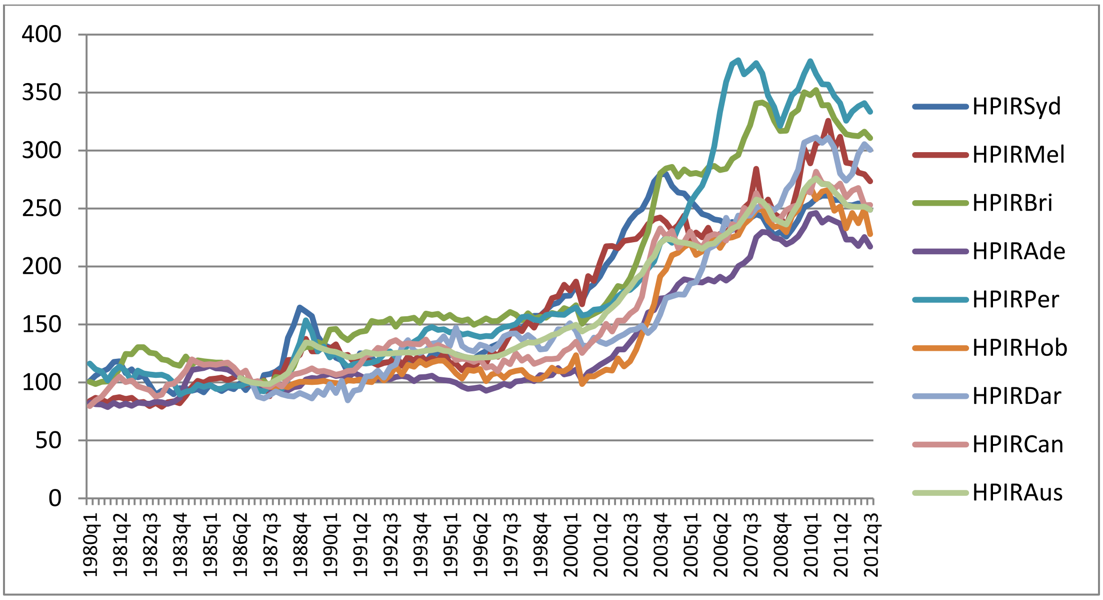
One of the right hand side variables in the baseline model is the expected income change rate. To proxy for this variable, quarterly data of the national GDP real growth forecasts from The Australian Treasury and Reserve Bank of Australia (RBA) starting from 1990 Q2 are used. Following the publication of the quarterly National Accounts by the ABS, the Treasury normally prepares forecasts for each quarter, for internal purposes. The official GDP growth forecasts are usually published twice a year—for the federal budget and with the mid-year review—and normally cover only the financial year under consideration. As the information on forecasts is published, it could be assumed that this information is widely known by house buyers and used in their buying and investment decisions.

The detailed definitions and summary statistics for the explanatory variables used in this study are contained in the Data Appendix. Table 4.A.1 in the Table Appendix reports the results of the augmented Dickey-Fuller (ADF) unit root tests for the main variables used in the study. These unit root tests indicate that it is reasonable to treat the data series of house price indices, land costs, and construction costs as an I(1) series, while their first difference are a stationary I(0) series.

Some relevant characteristics of housing market in Australia

Some characteristics of Australian housing market support the assumptions of the aforementioned model. The Australian housing market has been remarked as having a high rate of ownership, owner-occupiers account for a dominant percentage in total households, nearly 70 per cent in 2010. Majority of new homebuyers take out a mortgage, as only around one-quarter of dwelling transactions do not involve a mortgage (Bloxham, McGregor and Rankin, 2010). Imputed rental income and capital gains on the sale of owner-occupied property are tax exempt. However, interest payments on owner-occupied mortgage debt are not tax-deductible, thus creating an incentive for households to pay off their mortgage debt quickly. The house investors attract a tax deduction on their income from the house investment. The tax regime in Australia is considered to be generous towards individual landlords, encouraging small-investor participation in the housing market in Australia (Ellis, 2006).

Figure 4.1: Real house price fluctuations for Australian cities (1980Q1-2012Q3)



Source: REIA, 2012 (base year 1986 =100).

There has been a significant increase in house prices over the last three decades. According to Figure 4.1, house prices of all capital cities in Australia increased more than three times in real terms during this period, although some slight decrease was observed after the Global Financial Crisis in 2007.

The pair correlation test shows that the growth rates of house prices are positively correlated across all eight cities. However, there are differences in the growth of house prices across cities. Sydney and Brisbane experienced the highest average growth rates (about 1.2 per cent per quarter), while Hobart experienced the lowest (around 0.3 per cent). Over time, such differences will lead to a large divergence in the level of house prices across cities. A number of authors have argued that the price of housing in Australia—particularly in urban areas such as Sydney—is artificially high, in part due to government policies that restrict the availability of new land for housing (Caplin, Joye, Butt, Glaeser and Kuczynski, 2003, and Moran, 2007).

The house price increase in Australia during the period of 1980-2007 has often been attributed to demand variables, including rising real income per household, low unemployment rate, increasing proportions of the population in the 20-35 age group, lower nominal interest rates, and capital market innovations (real mortgage interest rate), in conjunction with supply variables, including an inelastic supply of houses in the short run and limited housing stock (Abelson *et al.*, 2005; and Yates, 2011). Moreover, there appears to be a high degree of persistence in the growth rates, which should be taken into consideration when regressing empirical models. This motivates one to add lags of the dependent variable of house price growth rates as well as explanatory variables to the right hand side the model.

4.5 Empirical Results

Given the availability of data, three regressions of the baseline model are run with two different data sets: (i) an error correction model regression using state level data, that is, regression for each state; (ii) a panel regression using data of all states; and (iii) a regression using the national level data and with the inclusion of some variables whose data are only available at the national level.

4.5.1 Individual state regression

Using the ECM on the individual states, the empirical model is tested using the two-step procedure of Engle and Granger (1987). A co-integration equation is first estimated to examine whether house prices in the long run are driven by their effective acquisition costs and whether demand plays a role in determining house prices in the long run. An error-correction model is subsequently estimated to account for the influence of demand shifts while allowing house prices to adjust to their effective acquisition costs in the long run. In terms of consistency of the estimates, Cameron and Trivedi (2009) state that the individual regressions provide consistent estimates of the coefficients.

The dependent variable is the quarterly growth in nominal house prices for eight particular states and territories, while the explanatory variables are buyers' disposable income (proxied by final state income), mortgage rate, construction costs, land costs (proxied by the agricultural land cost index), and the error correction terms extracted from the long-run co-integration relationship between house prices, land costs and construction costs. Other controlling variables claimed to be important by theoretical and empirical studies include rents, population growth and credit availability.

Firstly, following Stock and Watson (1993), I run the dynamic OLS regression of nominal house prices on construction costs and land prices, which is as follows:

$$\ln\left(P_t^h\right) = \beta_0 + \beta_1 \ln(cc_t) + \beta_2 \ln lc_t + \sum_{s=-n}^{m}[\beta_s^{'}\Delta \ln cc_{t+s} + \tau_s^{'}\Delta \ln lc_{t+s}] + ECT_t \quad (4.11)$$

where house prices are influenced in the long run by construction costs and land prices. Equation (4.11) is the same with Equation (4.10), except the subscript i is hidden for simplicity. The equation shows that house prices in the long-run gravitate towards replacement costs.

Secondly, the following equation that is based on the error correction framework will be regressed:

$$\Delta \ln\left(P_t^h\right) = \alpha_0 + \alpha_1 \Delta \ln(\mathrm{lc}_t) + \alpha_2 \Delta \ln(\mathrm{cc}_t) + \alpha_3 \Delta \ln(\mathrm{Y}_t) + \alpha_4 \Delta \ln pop_t + \alpha_5 \Delta \ln rent_t +$$

$$\alpha_6 \Delta \ln \Psi_t + \alpha_7 \Delta \ln i_t + \alpha_8 ECT_{t-1} + \varepsilon_t \quad (4.12)$$

where Δ is the first-period difference, lc is the land cost index, cc is the construction cost index, i_t is the mortgage rate which is the standard variable rate of the home loan, pop_t is total population, $rent_t$ is rental, Y_t is nominal disposable income, Ψ_t is affordability ratio given by banks, which will be proxied by house affordability index in the empirical section, ECT_{t-1} is an error correction term. If the equation is regressed using state level panel data, then subscript i is added to variables to denote individual states. The above equation is nested in Equation 4.9. I allow for deeper lags of the regressors to take into account the time it takes for information to be processed, the time it takes for the transaction to be completed and the time it takes for the house to be built. The restricted models are regressed, using the general-to-specific method to eliminate insignificant variables.

The results of the individual regressions are shown in Table 4.1 (for the restricted model), and the results of the states are divided into separate columns. The upper panel is the DOLS regression of Equation 4.11, examining the long-term relationship among house prices, land prices, and construction costs. The lower panel of Table 4.1 shows the regression results of Equation 4.12. The non-restricted regression results are in Table 4.A.2 in the Table Appendix.

A number of interesting findings emerge from Table 4.1. First, the Dynamic OLS regressions show that in all of the eight cities three variables of interest are co-integrated, that is, a long-term relationship exists amongst them. Augmented Dickey-Fuller unit root test statistics on the residuals from cointegration regression are significant at 5% level. Accordingly, house prices are co-integrated with construction costs and land prices (proxied by agricultural land prices) as predicted by the Tobin's q model in terms of the long-run dynamics. The coefficients of the lags of the growth rates of house prices are positive and significant, implying that there is persistence in the growth of house prices in most Australian capital cities (except Darwin and Hobart). It is also evident that the mortgage rates consistently influence the growth rate of house prices in the Australian capital cities. Results suggest that Sydney is most sensitive to mortgage rates; an explanation for this may be that the higher level of house prices in Sydney is financed considerably by higher mortgages.

Income (proxied by Final state demand) growth has a small effect on cities' house prices changes, except for Brisbane, Perth. This result, although counter-intuitive, is very similar to that of Otto (2007), who used an ADL model to examine the dynamics of state house prices. He also finds that the growth in income is not a significant driver of house prices at the state level. Population growth is has a significant effect on smaller cities like Brisbane, Adelaide, Perth, and Hobart, while they it is not significant in Melbourne, and the effect appears to be only temporary in Sydney.

Table 4.1: Individual restricted regressions on house price dynamics of Australian capital cities

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra
Step 1: Cointegration relationship								
Dependent variable $\ln P_{i,t}^h$								
$\ln cc_{it}$	1.97***	1.26***	1.51***	0.80***	1.10***	1.63***	1.56***	0.91***
	(5.80)	(10.57)	(3.05)	(8.51)	(5.38)	(2.81)	(6.67)	(6.74)
$\ln lc_{it}$	0.30**	0.61***	0.66***	0.73***	0.77***	0.59**	0.51***	0.63***
	(2.12)	(10.21)	(3.05)	(12.59)	(7.13)	(2.12)	(5.79)	(7.91)
Constant	-4.68***	-3.47***	-5.10***	-2.45***	-3.88***	-5.39***	-4.23***	-2.08***
	(-5.27)	(-10.09)	(-4.74)	(-14.8)	(-8.72)	(-5.18)	(-6.89)	(-6.84)
DF stat	-4.35***	-2.25**	-2.98***	-2.25**	-2.6***	-4.11***	-3.89***	-2.32**
Step 2: Short-term dynamics								
Dependent variable $\Delta \ln P_{i,t}^h$								
Constant	-0.01	0.01	-0.03	-0.01	0.01	0.00	0.01	0.01
	(-0.79)	(0.41)	(-2.47)	(-0.64)	(0.69)	(0.55)	(1.52)	(3.73)
$\Delta \ln P_{i,t-1}^h$		-0.27			0.32			
		(-2.47)			(2.50)			
$\Delta \ln P_{i,t-2}^h$	0.28	0.21	0.21					0.40
	(2.41)	(3.32)	(2.27)					(4.91)
$\Delta \ln P_{i,t-3}^h$				0.23			-0.32	
				(2.48)			(-2.77)	
$\Delta \ln cc_{i,t-2}$			0.89		1.15			
			(1.92)		(1.87)			
$\Delta \ln cc_{i,t-4}$		0.80			-1.16			
		(2.57)			(-2.29)			
$\Delta \ln lc_{i,t-1}$		0.29	0.54	0.26				
		(2.47)	(5.04)	(2.94)				
$\Delta \ln lc_{i,t-2}$	-0.39		-0.56					
	(-2.52)		(-3.47)					
$\Delta \ln lc_{i,t-3}$	0.51		0.4					
	(3.56)		(3.49)					
$\Delta \ln lc_{i,t-4}$							0.22	-0.18
							(1.84)	(-2.55)
$\Delta \ln Y_{i,t-3}$			-0.22		0.26			
			(-2.28)		(1.80)			
$\Delta \ln Y_{i,t-4}$							-0.30	
							(-2.27)	
$\Delta \ln[i_{i,t-1}^m]$	-0.21	-0.29	-0.37					-0.11
	(-1.97)	(-3.25)	(-4.09)					(-2.46)
$\Delta \ln[i_{i,t-2}^m]$								
$\Delta \ln[i_{i,t-3}^m]$	-0.37			-0.16	-0.14		-0.27	
	(-2.28)			(-3.77)	(-1.98)		(-3.50)	
$\Delta \ln[i_{i,t-4}^m]$			-0.14					
			(-1.75)					
$\Delta \ln pop_{i,t-2}$			-7.36	-11.36			3.24	
			(-2.11)	(-3.08)			(2.49)	
$\Delta \ln pop_{i,t-3}$		15.74		10.04				
		(3.49)		(2.70)				
$\Delta \ln pop_{i,t-4}$		-10.78	13.03					
		(-2.53)	(3.72)					
$\Delta \ln rent_{i,t-1}$	1.28			1.01				
	(1.82)			(2.37)				
$\Delta \ln rent_{i,t-2}$			1.76		-0.49			
			(3.68)		(-2.46)			
$\Delta \ln rent_{i,t-3}$	2.06							
	(2.48)							

$\Delta \ln rent_{i,t-4}$	-2.09		-1.35					
	(-3.62)		(-2.76)					
$\Delta \ln afford_{i,t-1}$			-0.15					
			(-2.48)					
$\Delta \ln afford_{i,t-4}$			-0.15					
			(-2.37)					
$ECT_{i,t-1}$	-0.26	-0.08	-0.22	-0.08	-0.10	-0.26	-0.18	-0.09
	(-2.43)	(-2.03)	(-4.55)	(-4.27)	(-2.19)	(-2.81)	(-3.82)	(-4.61)
R-squared	0.45	0.41	0.48	0.35	0.25	0.08	0.35	0.22
DW	1.71	2.04	1.97	1.99	2.01	2.00	2.16	2.13

Note: t statistics are in parentheses. The table shows only significant coefficients which are left in the models after general-to-specific procedures being done. Coefficient standard errors based on the Newey-West autocorrelation and heteroskedasticity consistent covariance matrix. The unrestricted models can be found in Appendix Table 4.A.2. Co-integration regressions are done using Dynamic OLS with AIC criteria to select numbers of lags and leads. $ECT_{i,t-1}$ is from the co-integration regression in the upper part of the table. Δ is one quarter difference. P_{it}^{h} is nominal house prices, cc_{it} is house construction costs, and lc_{it} is residential land cost, $Y_{i,t}$ is nominal final state demand, $i_{i,t}^{m}$ is the mortgage rate imposed by the banks, $pop_{i,t}$ is total population, $rent_{i,t}$ is rental and afford_t is affordability index. DF stat is Augmented Dickey-Fuller test statistics for co-integration test.

In addition, as predicted, the error correction terms are negative and statistically significant for all of the Australian states. The residuals from the co-integrating regression capture deviations of house prices and house acquisition costs from the equilibrium. Within the ECM framework, this means that the co-integration of house prices with land prices and construction prices drives house prices in the long run, and any deviation from long-run equilibrium will be corrected through the error terms. The coefficients of these correction terms vary from 0.1 to 0.3 in the different states, demonstrating relatively small variations across states. This implies that when shocks occur and prices deviate from their long-term trends, it takes 3.3 to 10 quarters in terms of time for the values to return to the steady state.

For robustness purpose, instead of running eight equations separately like in Table 4.1, I run a seemingly unrelated regression (SUR) to take advantage of the length of my panel dataset, small N (only eight) and large T, and also to take advantage of the possible correlation between error terms of the individual equations in order to gain more estimation efficiency (Zellner, 1962). Accordingly, I run the SUR model consisting of eight equations, one equation for each of the eight states. These eight equations are run simultaneously with their error terms assumed to be correlated across the equations using the Feasible Generalized Least Squares (FGLS) method. Although regressors in the equations have the same names, they actually are different variables since they are different time series of different states. This is a reasonable assumption, as macroeconomic events or shocks may affect all states during the periods in which they occur. A shortcoming of the SUR estimator is that we cannot apply general-to-specific procedure in order to obtain restricted form equations. The results of the SUR regression are in Table 4.A.3 in the Table Appendix. Comparing the SUR regression with the separate OLS state-level unrestricted regressions in Table 4.A.2, the SUR results are relatively similar and consistent with the findings of the OLS regressions, implying that the SUR estimator does not lead to more efficient estimates. It suggests the error terms are in fact independent between the equations, or implicitly house prices of different states react differently towards the common socks.

4.5.2 Panel data regression

In addition to running individual regressions on each of the eight capital cities, I run a regression on a panel dataset. The advantage of using panel data is to gain more efficiency and predictive power by reducing the effects of omitted variables and collinearity among the explanatory variables, and by uncovering dynamic relationships (Hsiao, 2007). For the purpose of robustness, I use different panel data estimators.

In order to account for unobservable and therefore omitted variables, a fixed-effect model could be used. The fixed effects model is a choice when the unobservable variables are correlated with the variables included in the model, and if the sample covers the entire population, as it does in this study (all eight states of Australia). However, the fixed-effects models have a major disadvantage as the variables that are common across the states are excluded from the regression, and therefore are not examined. In our empirical model, variables such as land prices and interest rates are common across states; and therefore, including these variables in a fixed-effect model is not feasible. In such a case, a random effects model is preferable and can be applicable by adding time dummies and other variables in the regression. In fact, after estimating both fixed- and random-effect models, the Hausman test suggests that they are equivalent. Therefore, the random effects estimator is utilised, and the parameters of the estimator are estimated using the

Feasible Generalized Least Squares (FGLS) method with the inclusion of state dummies. The results of the random effects estimator are shown in Column 1 Table 4.2.

In addition, other estimators are also employed since the dataset is characterised by a large T and small N, and individual specific effect models like random or fixed effects are more applicable to a panel characterised by small T and large N, and also because this type of data exhibits autocorrelation of the errors. Luckily, with a data panel having a large T and small N, we can take advantage of this and analyse the time series characteristic of the data. The ECM model can then be estimated separately for each state, and the results of the separate regressions are consistent (Cameron and Trivedi, 2009). However, to increase the estimation efficiency given the time series characteristics of the dataset, I use the estimation method of General Least Squares (GLS) with time and state dummies. This estimator permits both heteroskedasticity across panels and autocorrelation over time for a given panel. The dummies account for specific unobservable effects from business cycles (time-variant factors), seasonal effects, and states' specific effects (time-invariant factors).

The results are summarized in Table 4.2, in Columns 1 through to 5 with different model specifications. The results of the base line model using random effects are shown in Column 1 and 2. The growth of population is added in Column 3, while Column 4 is an extension of the baseline model with the affordability index. For Columns 1-4, error correction terms come from the regression of the log of house prices on the log of construction costs and land prices. Column 5 shows the results of the alternative income-based model, where error correction terms are calculated from the co-integration regression between house prices and rentals.

According to the baseline model results in Column 2, driving forces of house prices in Australian states include land costs, income, and mortgage interest rates. Most of the coefficients have the expected signs. A rise in income causes an increase in house prices, which is consistent with the theoretical model. While, an increase in the mortgage interest rate will lead to a decrease of house prices, as the cost of servicing the loan increases, causing house buyers to be less willing to purchase houses.

Table 4.2: Panel data regression on house price growth data 1980Q1-2012Q3

Dependent variable $\Delta \ln P_{i,t}^{h}$	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
$\Delta \ln P_{i,t-1}^{h}$	**-0.09**	**-0.12***	**-0.15*****	**-0.15*****	**-0.15*****
	(-1.48)	**(-1.91)**	**(-4.57)**	**(-4.38)**	**(-4.43)**
$\Delta \ln P_{i,t-2}^{h}$	**0.20*****	**0.19*****	**0.12*****	**0.12*****	**0.10*****
	(7.68)	**(4.89)**	**(3.55)**	**(3.40)**	**(2.86)**
$\Delta \ln P_{i,t-3}^{h}$	0.04	0.04	0.043	0.04	0.01
	(0.86)	(0.74)	(1.29)	(1.00)	(0.33)
$\Delta \ln P_{i,t-4}^{h}$	**0.15*****	**0.16*****	**0.14*****	**0.13*****	**0.11*****
	(2.89)	**(3.23)**	**(4.23)**	**(3.79)**	**(3.38)**
$\Delta \ln cc_{i,t-1}$	-0.06	0.04	0.10	0.13	
	(-0.35)	(0.23)	(0.49)	(0.61)	
$\Delta \ln cc_{i,t-2}$	0.46	0.20	0.21	0.17	
	(1.58)	(0.73)	(1.00)	(0.82)	
$\Delta \ln cc_{i,t-3}$	-0.21	-0.33	-0.21	-0.29	
	(-0.86)	(-1.41)	(-1.01)	(-1.38)	
$\Delta \ln cc_{i,t-4}$	0.06	-0.12	-0.11	-0.13	
	(0.28)	(-0.51)	(-0.53)	(-0.64)	
$\Delta \ln lc_{i,t-1}$	**0.56***	**3.55***	0.21	0.44	
	(1.68)	**(1.65)**	(0.30)	(0.63)	
$\Delta \ln lc_{i,t-2}$	0.33	**-46.30****	0.30	0.28	
	(1.26)	**(-2.08)**	(0.91)	(0.86)	
$\Delta \ln lc_{i,t-3}$	-0.31	**-10.10***	-0.71	-0.86	
	(-1.08)	**(-1.94)**	(-0.97)	(-1.16)	
$\Delta \ln lc_{i,t-4}$	0.48	**62.50****	0.67	0.67	
	(1.54)	**(2.07)**	(1.49)	(1.48)	
$\Delta \ln i_{i,t}^{m}$			0.90	**0.97***	**-25.30****
			(1.58)	**(1.69)**	**(-2.00)**
$\Delta \ln i_{i,t-1}^{m}$		**-40.30****	-0.12	-0.24	**1.11***
		(-2.04)	(-0.23)	(-0.44)	**(1.92)**
$\Delta \ln i_{i,t-2}^{m}$		**39.20****	-0.30	-0.38	**18.30***
		(2.07)	(-1.05)	(-1.33)	**(1.93)**
$\Delta \ln i_{i,t-3}^{m}$		**19.70****	0.05	0.02	**3.88***
		(2.00)	(0.11)	(0.04)	**(1.85)**
$\Delta \ln i_{i,t-4}^{m}$		**-36.70****	0.05	0.05	**-16.60***
		(-2.06)	(0.49)	(0.46)	**(-1.93)**
$\Delta \ln Y_{i,t}$			0.04		0.08
			(0.69)		(1.37)
$\Delta \ln Y_{i,t-1}$		-0.03	-0.03	0.01	0.02
		(-0.49)	(-0.42)	(0.16)	(0.39)
$\Delta \ln Y_{i,t-2}$		**0.13*****	0.09	**0.14****	**0.12****
		(3.11)	(1.48)	**(2.42)**	**(2.12)**
$\Delta \ln Y_{i,t-3}$		**0.21*****	**0.16*****	**0.21*****	**0.17*****
		(6.70)	**(2.73)**	**(3.67)**	**(2.89)**
$\Delta \ln Y_{i,t-4}$		0.09	0.08	**0.11****	0.08
		(1.07)	(1.50)	**(1.98)**	(1.36)
$\Delta \ln pop_{i,t}$			-0.08		
			(-0.08)		
$\Delta \ln pop_{i,t-1}$			**2.43****		
			(2.10)		

$\Delta \ln pop_{i,t-2}$			**1.95***		
			(1.71)		
$\Delta \ln pop_{i,t-3}$			0.95		
			(0.82)		
$\Delta \ln pop_{i,t-4}$			0.56		
			(0.49)		
$\Delta \ln afford_{i,t-1}$				**-0.07****	
				(-2.13)	
$\Delta \ln afford_{i,t-2}$				**-0.07****	
				(-2.08)	
$\Delta \ln afford_{i,t-3}$				**-0.09*****	
				(-2.67)	
$\Delta \ln afford_{i,t-4}$				**-0.07****	
				(-2.35)	
$\Delta \ln rent_{i,t}$					**0.31***
					(1.77)
$\Delta \ln rent_{i,t-1}$					**0.66*****
					(3.95)
$\Delta \ln rent_{i,t-2}$					-0.02
					(-0.11)
$\Delta \ln rent_{i,t-3}$					0.22
					(1.33)
$\Delta \ln rent_{i,t-4}$					0.09
					(0.50)
$ECT_{i,t-1}$	**-0.07*****	**-0.08*****	**-0.09*****	**-0.08*****	**-0.09*****
	(-10.3)	**(-10.6)**	**(-7.87)**	**(-7.01)**	**(-7.06)**

Note: * p<0.1; ** p<0.05; *** p<0.01. t values are in parentheses. The same notation as in Table 4.1 is used. State dummies and time dummies were included but are not shown. Constants are included but not shown. For Columns 1-4, ECTs come from the regression of the log of house prices on the log of construction costs and land prices. Column 5 ECT is from the regression of the log of house prices on the log of rents. Column 1 model is estimated using a random effects estimator. Column 2-5 regressions are carried out by panel-feasible GLS estimator with heteroskedasticity but uncorrelated error structure (as my panel is unbalanced) and panel-specific AR1 autocorrelation structure.

The error correction terms are significant at the one percent level and have the negative expected signs. This means that, in the short run, house prices may deviate from their long-term prices determined by land prices and construction prices, but in the long run, house prices will adjust and return to their long-term trend. However, the magnitude of the deviation suggests that they stray from their long-run equilibrium over a three-year period—about 11 per cent of the deviation is, on average, eliminated every quarter.

The variable that has the most consistent effect on the growth rate of house prices is the nominal mortgage rate. The estimated coefficient of the nominal interest rate is negative and statistically significant at one percent level. In the short run, land prices and construction cost growth rates do not affect significantly the house price movements, as the majority of coefficients are not significantly different from zero. This confirms the model implications, construction and land costs are only important in the long-run supply model. Also, the income variable has a significant and positive effect on house price movements. In general, the results are consistent with the predictions of my behavioural model: mortgage, disposable income and the long-term relationship between house prices and their acquisition costs have important effects on house price movements.

In Column 4, the affordability indices are significant and of the expected signs. Housing affordability is only an important determinant of house prices in the short run. When affordability indices increase, home loans are more affordable, the house prices decrease. However, since the denominator in the affordability index formula is home mortgage which is proportional to house prices, it is endogenously determined with house prices. As a result of this endogeneity, this significance of the relationship is not boasted.

As in Column 5, when the user-cost based specification to model house price movements is used, some remarkable results are obtained. Disposable income, rent, and the mortgage rate are significant, while the error correction terms (residuals from the co-integration regression of house prices on rental costs) stay significant and negative. The results are consistent with previous research using Australian data with user-cost models (e.g. Otto, 2007). It is also consistent with the previous results of individual regressions of the capital cities' time series. Next, the national level data is used to test the empirical model and to see how results compare to those obtained thus far.

4.5.3 National level data regression

Given the lack of available data on vital explanatory variables at the state level, this prompts us to conduct investigations using national level data, where the data of the important variables are available. The estimations based on state level data raise questions in regards to comparability with the national level data. The empirical models are re-tested with Australian aggregate data and extended with more explanatory variables, as the data are available at the national level. Importantly, my house price data sample at the national level can now be dated back to 1970Q1, which is significantly longer compared to the above panel data regressions (starting from 1980Q1), giving more creditability in terms of time series and co-integration analysis.

Similarly to the panel data regression, my baseline model is used to test the co-integration, short- and long-term effects of interested variables. First, after testing the integration order of house prices, construction costs, and land prices at the national level, I conclude that they are integrated of order 1 (or I(1)). Then the regression of the error correction equation using DOLS estimator with Akaike information criteria for lead and lags selection yields the following:

$$\ln\left(P_t^h\right) = \underset{(-5.66)^{***}}{-4.45} + \underset{(2.82)^{***}}{0.896}\ln cc_t + \underset{(6.82)^{***}}{0.84}\ln lc_t$$

DF=-4.44 $\boldsymbol{R^2}$**=0.98**

where DF is a Dickey-Fuller test statistic for co-integration. The null hypothesis of no co-integration can be rejected at the 5 per cent significance level. Both coefficients of land prices and construction costs are statistically significant, positive and close to unity. For example, the construction cost elasticity according to the regression is 0.9, which is almost equal to one. The lagged residuals of the above regression will be used as error correction terms for the following models.

The results of the regressions using national level data of Australian house prices are presented in Table 4.3. All main regressions are run using OLS, with the standard errors being based on the Newey-West heteroskedasticity and autocorrelation consistent covariance matrix.

Table 4.3: Regressions on Australia wide house price growth

Dependent variable $\Delta \ln P_t^h$	**(1)**	**(2)**	**(3)**	**(4)**
Constant	-0.00	-0.01	-0.05**	**-0.01****
	(-0.90)	(-0.29)	(-2.45)	**(-2.11)**
$\Delta \ln P_{t-1}^h$	**0.71*****	**0.73*****	**0.55*****	**0.56*****
	(7.05)	**(6.60)**	**(4.02)**	**(5.64)**
$\Delta \ln P_{t-2}^h$	0.21	0.16	0.17	**0.29****
	(1.64)	(1.19)	(1.04)	**(2.37)**
$\Delta \ln P_{t-3}^h$	**-0.26****	-0.21	-0.09	
	(-1.85)	(-1.25)	(-0.64)	
$\Delta \ln P_{t-4}^h$	0.12	0.09	**0.20***	
	(1.06)	(0.69)	**(1.93)**	
$\Delta \ln lc_{t-1}$	0.02	0.01	0.05	
	(0.23)	(0.12)	(0.50)	
$\Delta \ln lc_{t-2}$	-0.09	-0.07	-0.13	
	(-0.79)	(-0.63)	(-1.31)	

$\Delta \ln lc_{t-3}$	0.07	0.05	0.13	
	(0.87)	(0.59)	(1.27)	
$\Delta \ln lc_{t-4}$	-0.06	-0.04	-0.06	
	(-0.92)	(-0.50)	(-0.75)	
$\Delta \ln cc_{t-1}$	-0.19	-0.13	-0.37	
	(-0.68)	(-0.47)	(-1.03)	
$\Delta \ln cc_{t-2}$	0.16	0.12	0.21	
	(0.66)	(0.47)	(0.58)	
$\Delta \ln cc_{t-3}$	0.12	0.15	-0.12	
	(0.53)	(0.7)	(-0.33)	
$\Delta \ln cc_{t-4}$	-0.23	-0.24	-0.08	
	(-1.48)	(-1.44)	(-0.18)	
$\Delta \ln i^m_{t-1}$	**-0.38****	**-0.38****	**-0.61*****	**-0.40*****
	(-2.37)	**(-2.30)**	**(-3.03)**	**(-3.01)**
$\Delta \ln i^m_{t-2}$	0.19	0.19	0.31	**0.44*****
	(0.77)	(0.7)	(1.16)	**(2.69)**
$\Delta \ln i^m_{t-3}$	0.29	0.27	0.43	
	(1.44)	(1.22)	(1.69)	
$\Delta \ln i^m_{t-4}$	**-0.24****	**-0.24***	**-0.41****	**-0.16****
	(-2.01)	**(-1.86)**	**(-2.53)**	**(-2.31)**
$\Delta \ln Y_{t-1}$	0.06	0.04	-0.16	
	(0.42)	(0.23)	(-0.57)	
$\Delta \ln Y_{t-2}$	0.23	0.23	**0.60***	
	(1.57)	(1.52)	**(1.98)**	
$\Delta \ln Y_{t-3}$	0.11	0.09	0.26	
	(0.77)	(0.56)	(1.32)	
$\Delta \ln Y_{t-4}$	0.13	0.12	0.01	
	(0.86)	(0.68)	(0.02)	
$\Delta \ln pop_{t-1}$		1.23	4.31	
		(0.35)	(1.01)	
$\Delta \ln pop_{t-2}$		-1.04	0.27	
		(-0.44)	(0.09)	
$\Delta \ln pop_{t-3}$		1.45	-1.91	
		(0.44)	(-0.52)	
$\Delta \ln pop_{t-4}$		-1.32	2.31	
		(-0.55)	(0.56)	
$\Delta \ln afford_{t-1}$			-0.09	
			(-1.40)	
$\Delta \ln afford_{t-2}$			-0.04	
			(-0.52)	
$\Delta \ln afford_{t-3}$			**0.14*****	**0.10*****
			(2.75)	**(2.73)**
$\Delta \ln afford_{t-4}$			-0.11	**-0.09****
			(-1.41)	**(-2.10)**
$\Delta \ln Y^e_{t+2}$			**0.01****	**0.00****
			(2.47)	**(2.23)**
ECT_{t-1}	**-0.07***	**-0.07***	**-0.09***	**-0.08****
	(-1.83)	**(-1.79)**	**(-1.92)**	**(-2.09)**
DW	1.99	2.01	1.93	1.96
R-squared	0.63	0.63	0.70	0.60

Note: * p<0.1; ** p<0.05; *** p<0.01. t values are in parentheses. Δ is one quarter difference. P^h_t is nominal house prices, cc_t is house construction costs, and lc_t is residential land cost, Y_t is gross domestic products proxying for total disposable income, i^m_t is mortgage rate imposed by banks, τ_t is income tax rate, pop_t is total population, ECT_t is the error correction term. The standard errors are based on the Newey-West autocorrelation and heteroskedasticity consistent covariance matrix. Y^e_{t+2} is GDP growth expectation which is from the Treasury Australia.

The result of the error correction model is shown in Column 1 of Table 4.3. Each of the variables of interest has four lags to account for the persistence of house prices. First, I can see that the coefficients of construction costs and land prices are not significant, implying that changes in construction costs and land price costs again do not influence the house price movements in the short run. However, I see that the coefficient of the error correction term is statistically significant at the 10 per cent, demonstrating that the long-term co-integration relationship has an impact on the short-term fluctuation of house prices. The magnitude of the ECT coefficient is relatively small (only 0.07) implying that there is a prolonged period of adjustment of house prices towards their long-term value determined by land costs and construction costs.

Other significant driving factors of house prices include house price lags and variable mortgage rates. The house price lags are significant and the coefficient values are large, confirming the predicted persistency of the house price growth rate. The frictions in housing markets usually explain this persistence in house price changes, as house markets do not clear immediately after a shock to the economy (Krainer, 2002). As aforementioned in the literature review, this is a reasonable result as people often expect house prices to continue to increase. For instance, Case and Shiller (2003) provide evidence that suggests that homeowners have price growth expectations. The interest rate coefficients have the expected negative signs; implying that, when the mortgage interest rates increase, the mortgage re-payment house buyers need to pay also increases, reducing the demand for housing and therefore leading to a decrease in house prices. The expected nominal GDP growth rate is not significant even though the signs are correct.

In Column 2 of Table 4.3, I add a population growth variable into the model to test if population plays an important role on house price changes in Australia. This is also done to find out if the GDP per capita or total nominal GDP is more relevant. Surprisingly, the regression results show that population is not statistically significant at the national level. However, there may be an explanation for this. The population figures I have are from the ABS, aggregated from the population figures of the states and are estimated given the figures from the population censuses carried out at ten-year intervals; that is, the figures are approximate values which may not reflect true quarterly population fluctuations. On the other hand, the results show GDP per capita is not a significant determinant of nominal house price movements, at least in quarterly data at the national level.

Column 3 is another extension of the model. Starting from my general model Equation 4.7, I use the affordability index variable as the proxy of the ratio between mortgage payment and disposable income, Ψ_t. The affordability index is the inversion of Ψ_t. When Ψ_t increases, or the proportion of the mortgage payment as a ratio of total disposable income increases, it will lead to a decrease in the affordability index. Affordability indices are used popularly by banks as measures of affordable mortgage repayments when granting loans to house buyers; thus, it also reflects the willingness of banks to lend given the disposable income of the applicant. Madsen (2011) argues that house buyers suffer from inflation illusion, which is a disinflation-induced reduction in the interest rate that leads to higher housing affordability, and thus to higher house prices in the behavioural model. It also means that the affordability index may be endogenous, thereby leading to endogeneity in the column 3 model. Column 4 is a restricted model of Column 3 model, obtained from using the general-to-specific procedure. The results of both columns again support our model, as we see that affordability, interest rates, expected income and error correction term are important for house price dynamics in Australia.

The results show that the second lead of expected income is significant; that is, the forecast figures for two quarters into to future (six months) are significant to today's house price movements. This is not surprising as, after releasing the first forecast on GDP growth, six months later, the Treasury announces the revision of the previous forecasts based on the present forecasts but with updated, more precise information. Therefore, forecasts of GDP for six months in the future will be more relevant.

4.6 Other Models of Australian House Price Dynamics

In this part I test the explanatory power of different models of house prices in Australia, using times series data of Australian house prices and other variables. The results of robustness tests are displayed in Table 4.4.

According to the conventional housing user-cost model, the buying decision is determined by the user-cost of houses; and in equilibrium, the user-costs are equal to the rents received from the tenants. Empirically, rents are often used as a proxy for user-cost of housing and examined in terms of their long-run relationship with house prices (e.g. Otto, 2008; Gallin, 2008). Therefore, this motivates me to test the explanatory power of the conventional user-cost model and the long-term relationship between rent and house prices. The results are shown in Column 2 of Table 4.4.

I also compute user-costs and regress these computed values on house prices. The Australian national measure of the cost of capital is estimated as: $C = i(1 - \tau) + \delta - \pi^e$, where i is the standard variable home loan interest rate; τ is the income tax rate used for interest deductions; δ is the depreciation rate, assumed to be 2.5 per cent annually - promulgated by the Australian Taxation Office (ATO) for dwellings; and π^e is expected house price inflation, measured as the average quarterly house price appreciation from 1970 to 2012 plus the expected rate of inflation (which is estimated by ADL model with lags of inflation, GDP growth rates, growth rate in M1, and time-trend). This measure is used as it captures the long-term expected house price change, the variable most relevant for real estate investors (see Hubbard and Mayer, 2009). The income tax rate is measured as the ratio between total direct income tax revenue and GDP. I do not have data on the property tax rates of Australia, so the rates are excluded from my model. Here the standard user-cost model specification includes house user-costs, rent and the error correction term from the long-term co-integration equation between house price and rent. Using the new user-cost measure, I run the regression again presenting the results in Columns 3 and 4 of Table 4.4.

Table 4.4: Regressions results of alternative models

Dependent variable $\Delta \ln P_{i,t}^{h}$	**(1)**	**(2)**	**(3)**	**(4)**
Constant	-0.00	-0.00	-0.00	0.00
	(-0.73)	(-0.61)	(-0.53)	(0.16)
$\Delta \ln P_{t-1}^{h}$	**0.70***	**0.70***	**0.74***	**0.81***
	(8.11)	**(7.63)**	**(8.29)**	**(9.93)**
$\Delta \ln P_{t-2}^{h}$	0.18	0.18	0.15	0.07
	(1.41)	(1.46)	(1.26)	(0.73)
$\Delta \ln P_{t-3}^{h}$	**-0.27**	**-0.26**	**-0.255*	**-0.31**
	(-2.11)	**(-2.06)**	**(-1.88)**	**(-2.52)**
$\Delta \ln P_{t-4}^{h}$	0.11	0.12	0.12	0.13
	(1.31)	(1.3)	(1.27)	(1.34)
$\Delta \ln i_{t-1}^{m}$	**-0.28***	**-0.30***	**-0.36***	
	(-2.70)	**(-2.66)**	**(-3.49)**	
$\Delta \ln i_{t-2}^{m}$	0.11	0.13	0.27	
	(0.75)	(0.81)	(1.28)	
$\Delta \ln i_{t-3}^{m}$	0.21	0.21	0.23	
	(1.55)	(1.44)	(1.23)	
$\Delta \ln i_{t-4}^{m}$	**-0.16*	-0.15	-0.11	
	(-1.69)	(-1.55)	(-0.95)	
$\Delta \ln Y_{t-1}$	0.06	0.03	-0.08	
	(0.79)	(0.35)	(-0.82)	
$\Delta \ln Y_{t-2}$	**0.16*	0.15	0.19	
	(1.77)	(1.55)	(1.46)	
$\Delta \ln Y_{t-3}$	0.05	0.07	0.19	
	(0.56)	(0.6)	(1.54)	
$\Delta \ln Y_{t-4}$	0.09	0.11	0.04	
	(1.22)	(1.21)	(0.37)	
$\Delta \ln rent_{t}$		0.08		
		(0.45)		
$\Delta \ln rent_{t-1}$		0.05		
		(0.37)		
$\Delta \ln rent_{t-2}$		0.07		
		(0.47)		
$\Delta \ln rent_{t-3}$		-0.27		
		(-1.38)		
$\Delta \ln rent_{t-4}$		0.01		
		(0.06)		
$\Delta \ln UC_{t}$			0.01	**-0.05**
			(0.29)	**(-2.24)**
$\Delta \ln UC_{t-1}$			**-0.08**	0.01
			(-2.30)	(0.78)
$\Delta \ln UC_{t-2}$			-0.01	**-0.06***
			(-0.22)	**(-3.97)**
$\Delta \ln UC_{t-3}$			-0.04	**0.04**
			(-1.44)	**(2.50)**
$\Delta \ln UC_{t-4}$				-0.01
				(-0.81)
$\Delta \ln inf_{t+1}^{e}$				**0.51**
				(2.20)
$\Delta \ln YP_{t-1}$				-0.11
				(-1.27)
$\Delta \ln YP_{t-2}$				0.12
				(1.08)
$\Delta \ln YP_{t-3}$				-0.05
				(-0.59)
$\Delta \ln YP_{t-4}$				-0.04
				(-0.46)
ECT_{t-1}	-0.01	-0.01	-0.01	-0.02
	(-1.07)	(-1.20)	(-0.97)	(-1.43)

DW	2.02	2.02	1.96	1.96
R-squared	0.64	0.64	0.67	0.67

Note: * p<0.1; ** p<0.05; *** p<0.01. t values are in parentheses. The same notation as in Table 4.3 is used. $inf^{e}_{i,t+1}$ is inflation expectations estimated by ADL model with lags of inflation, GDP growth rates, growth rate in $M1$, and time-trend. $YP_{i,t}$ is real income per capita. Estimation period may be different depending on the availability of data of variables and the sample period of ECT (as ECTs are estimated using DOLS with AIC criteria, the number of lead and lags identified by AIC maybe different amongst the columns). ECTs in Columns 1, 2, and 3 are residuals from the regression of the co-integration equation between the log of house prices and the log of rent. The ECT in Column 4 is from the co-integration equation between the log of house price and the log of nominal GDP per capita. The standard errors are based on the Newey-West autocorrelation and heteroskedasticity consistent covariance matrix.

The results from the first three columns do not seem very supportive for the user-cost model. First, neither of the ECTs in Columns 1 to 3 is significant. Furthermore, lags of disposable income in this model specification are also not significant. The user-cost, however, is significant with the expected negative sign along with the mortgage rates. The R-squared statistics of the estimates are high (ranging from 0.64 to 0.67), most likely due to the high explanatory power of the lags of house prices and the mortgage rate, or the non-significance of the coefficients in the models may come from the multi-collinearity issue.

The price-to-rent ratio increases in almost every single period during the sample, which does not comply with the prediction of the user-cost hypothesis, in which the increase of house price and rent should be one to one, or the price-to-rent ratio should be mean reverting. In a recent study, Otto (2007) uses similar price-to-rent ratio data as a proxy of the user-cost of houses, and finds a significant role of this proxy of user-cost; however, I did not find this ratio to be significant in my estimations. If the user-cost model indeed holds in Australia, the failure of the price-to-rent ratio as a proxy for user-costs in my study may come from the multi-collinearity issue in my model between the right-hand-side variables. In the quarterly data, the rents are much less volatile than house prices, thereby causing the fluctuation of the ratio to be very much correlated with house prices (correlation coefficient 0.87). Consequently, on the right-hand side of my model, the house price-rent ratio variable and the lags of the house price variables are highly correlated, causing the multi-collinearity bias.

Column 4 in Table 4.4 shows the results of the alternative income-based model, in which house price growth is regressed on the growth of real income per capita, expected inflation, and the user-cost of capital. The error correction term here is the residual from the regression of the log of nominal house prices on the log of per-capita nominal income. It is claimed in the literature that house prices are co-integrated to disposable income (Girouard, Kennedy, van den Noord and André, 2006). In addition, I test the relevance of the expected inflation $inf_{i,t+1}^{e}$, which is estimated by an ADL model incorporating lags of inflation rates, GDP growth rates, growth rates of M1, and a time-trend variable. Results show that the user-cost coefficients are significant and are of the expected negative sign. Expected inflation is also significant and positively correlated as predicted by the house user-cost based model; however, real income per capita does not have a significant impact on house prices. The test results show no significant long-term relationship between rent and nominal house prices, as neither error correction terms are significant.

4.7 Conclusion

The recent house price increase in Australia has been difficult to explain using a conventional model in which house prices are a function of real income per capita and the real user-cost of capital. House price movements in Australia's big cities and at the national level have been analysed using different models in this study, but the empirical model used extensively is the behavioural model. Unlike previous traditional models in which real variables are relevant, my focus in this chapter is on the nominal variables. The model is based on the principle of affordability, incorporating nominal variables to explain the dynamics of Australian house price movements during the last four decades, robust to both national and state level data samples. The empirical results provide evidence that the proposed theoretical model is capable of explaining the Australian house price movements substantially. The nominal variables are more relevant as predicted by the inflation illusion hypothesis. This study is the first to research the effects of nominal variables on nominal house prices in Australia. In general, my results suggest that in the short-run house prices are driven by demand factors (total nominal income and the nominal mortgage interest rate) and supply factors (nominal construction costs and land costs), while in the long-run they are co-integrated with house acquisition costs. Particularly, at the state level, the important factors are land costs, population growth, interest rates, and income; while, at the national level, the important factors are nominal interest rates and the long-term relationship between house prices and the nominal house acquisition costs. The co-integration framework works well with my behavioural model but fails with other models.

4A.1. Data Appendix

House Prices: The annual data of the house price index (HPI), Consumer Price Index (CPI) and the Real House Price Index (RHPI) for the period of 1970 to 1980 are from Abelson and Chung (2004) and has been converted to quarterly data using trend interpolation. Then the data was spliced with quarterly data from the Real Estate Institute of Australia (REIA) to obtain data for all capital cities' house prices from 1970Q3 to 2012Q3. The house prices in the state and territory capitals are derived from quarterly median house prices for established houses provided by REIA. Australian national house price index is from the ABS Catalogue. The alternative data used for robustness purposes, for the capital cities' house prices are from ABS house data.

House rentals: Rent indices of the eight capital cities and Australia are from Datastream for the following period: 1972Q2-2012Q3.

Construction Costs: Housing construction costs are based on the ABS price index of materials used in house production. These costs contain the inputs used in the Australian housing construction industry and were obtained from ABS cat. 6427.0, Table 18.

Affordability: The Home Loan Affordability Indicator (HLAI) used aims to capture the main factors influencing housing affordability—average incomes, the average size of a home loan, and average interest rates, produced jointly by the REIA and mortgage insurer MGICA, Ltd. It is published on a quarterly basis and is available at both the national and state levels. An increase in the indicator will result from either a rise in average incomes or a fall in the average loan repayments. Thus, a rise in the indicator means that home loans are more affordable.

Land prices: Annual agricultural land prices from 1977 are from the Department of Agriculture Economics, which is then converted into quarterly data using trend interpolation.

Disposable Income: State final, seasonally adjusted and nominal incomes are from the ABS cat. 5206.0 Australian National Accounts: National Income, Expenditure, and Product.

Taxes: Tax on income, profit, and capital gains revenue as a percentage of GDP is from the OECD tax database.

Population Growth: ABS cat. 3101.0 Australian Demographic Statistics.

Mortgage Rate: The standard variable home loan rates from the Reserve Bank of Australia historical statistics Table 10.

GDP Forecasts: The forecasts of GDP growth are made by Australian Treasury, which can be downloaded from Australian Reserve Bank website http://www.rba.gov.au/publications/rdp/2012/2012-07-data.html

4A.2. Table Appendix

Table 4.A.1: Unit root test results

	$\ln P_{i,t}^h$	$\Delta \ln P_{i,t}^h$	$\ln cc_{it}$	$\Delta \ln cc_{it}$	$\ln lc_{it}$	$\Delta \ln lc_{it}$	$\ln rent_{i,t}$	$\Delta \ln rent_{i,t}$
Sydney	-2.47	-4.78	-2.53	-4.82	-2.05	-3.15	-1.66	-2.32
Melbourne	-2.13	-6.79	-3.23	-5.44	-2.05	-3.15	-2.73	-1.53
Brisbane	-2.73	-5.17	-3.44	-5.61	-2.05	-3.15	-1.86	-2.38
Adelaide	-1.38	-5.87	-3.31	-5.18	-2.05	-3.15	-1.81	-1.56
Perth	-2.24	-8.52	-2.01	-4.08	-2.05	-3.15	-0.71	-2.83
Hobart	-1.45	-11.33	-3.47	-3.62	-2.05	-3.15	-1.50	-2.02
Darwin	-1.43	-7.67	-3.44	-5.61	-2.05	-3.15	-0.70	-9.95
Canberra	-2.49	-5.52	-2.53	-4.82	-2.05	-3.15	-1.61	-1.93
Australia	-1.81	-5.73	-1.63	-4.50	-2.09	-3.24	-1.68	-2.68

Note: ADF Critical statistic values for unit root rest with trend and intercept at the 1% level are -4.031, at the 5% level -3.445, and at the 10% level -3.147. Critical values without trend but with intercept at the 1% level are -3.482, 5% level -2.884, and 10% level -2.579. $\ln P_{i,t}^h$, $\ln lc_{it}$, $\ln rent_{i,t}$ and $\ln cc_{it}$ are tested with trend and intercept. $\Delta \ln rent_{i,t}$, $\Delta \ln P_{i,t}^h$, $\Delta \ln lc_{it}$, $\Delta \ln rent_{i,t}$ and $\Delta \ln cc_{it}$ are tested with intercept only. States series is the period from 1980Q1 to 2012 Q3. The Australian series is the period from 1970Q1 to 2012Q3.

Table 4.A.2: Unrestricted separate regression on individual states' time series

	Sydney	**Melbourne**	**Brisbane**	**Adelaide**	**Perth**	**Hobart**	**Darwin**	**Canberra**
Long-term relationship, dependent variable ln $P_{i,t}^h$								
$\ln cc_{i,t}$	1.97^{***}	1.26^{***}	1.51^{***}	0.80^{***}	1.10^{***}	1.63^{***}	1.56^{***}	0.91^{***}
	(5.80)	(10.57)	(3.05)	(8.51)	(5.38)	(2.81)	(6.67)	(6.74)
$\ln lc_{i,t}$	0.30^{**}	0.61^{***}	0.66^{***}	0.73^{***}	0.77^{***}	0.59^{**}	0.51^{***}	0.63^{***}
	(2.12)	(10.21)	(3.05)	(12.59)	(7.13)	(2.12)	(5.79)	(7.91)
Constant	-4.68^{***}	-3.47^{***}	-5.10^{***}	-2.45^{***}	-3.88^{***}	-5.39^{***}	-4.23^{***}	-2.08^{***}
	(-5.27)	(-10.09)	(-4.74)	(-14.77)	(-8.72)	(-5.18)	(-6.89)	(-6.84)
DF stat	-4.35^{***}	-2.25^{**}	-2.98^{***}	-2.25^{**}	-2.6^{***}	-4.11^{***}	-3.89^{***}	-2.32^{**}
Short-term dynamics, dependent variable Δ ln $P_{i,t}^h$								
Constant	0.01	-0.02	-0.03	0.00	-0.02	0.01	0.00	0.00
	(0.43)	(-1.34)	(-1.16)	(-0.21)	(-0.84)	(1.14)	(0.09)	(0.04)
$\Delta \ln P_{i,t-1}^h$	**0.22*****	**-0.29*****	0.14	-0.10	**0.34****	-0.26	-0.13	-0.09
	(2.05)	**(-2.87)**	(0.90)	(-0.66)	**(2.33)**	(-1.34)	(-0.96)	(-0.54)
$\Delta \ln P_{i,t-2}^h$	**0.31***	0.16	**0.23****	0.17	0.00	0.08	0.06	**0.33*****
	(1.95)	(1.49)	**(2.41)**	(1.79)	(-0.03)	(0.60)	(0.82)	**(2.98)**
$\Delta \ln P_{i,t-3}^h$	0.00	0.08	0.00	**0.35*****	**0.19***	0.21	**-0.29*****	0.05
	(-0.01)	(0.73)	(-0.01)	**(3.92)**	**(1.98)**	(1.24)	**(-2.71)**	(0.39)
$\Delta \ln P_{i,t-4}^h$	0.15	0.11	0.04	-0.01	0.13	**0.28***	0.15	0.09
	(1.41)	(0.80)	(0.38)	(-0.06)	(0.88)	**(1.78)**	(1.63)	(0.81)
$\Delta \ln cc_{i,t-1}$	-0.31	-0.57	-0.35	-0.11	**-1.24***	-0.38	0.39	0.01
	(-0.64)	(-0.66)	(-0.64)	(-0.34)	**(-1.72)**	(-0.52)	(0.56)	(0.01)
$\Delta \ln cc_{i,t-2}$	-0.45	-0.50	1.13	-0.30	0.99	0.97	0.30	-0.28
	(-0.96)	(-0.58)	(1.40)	(-0.70)	(1.41)	(0.87)	(0.33)	(-0.71)
$\Delta \ln cc_{i,t-3}$	0.62	-0.48	-0.27	0.49	-0.59	-0.59	-0.42	0.00
	(1.05)	(-0.48)	(-0.53)	(1.20)	(-0.78)	(-0.53)	(-0.71)	(-0.01)
$\Delta \ln cc_{i,t-4}$	-0.34	1.08	0.60	-0.10	**-1.36****	-0.64	0.44	0.17
	(-0.54)	(1.47)	(1.16)	(-0.24)	**(-2.06)**	(-0.74)	(0.89)	(0.40)
$\Delta \ln Y_{i,t-1}$	0.10	-0.03	0.00	-0.16	-0.08	**-0.37****	**-0.19***	0.19
	(0.40)	(-0.09)	(-0.00)	(-0.69)	(-0.35)	**(-2.15)**	**(-1.86)**	(1.37)
$\Delta \ln Y_{i,t-2}$	0.21	0.67	0.16	0.05	0.23	-0.29	-0.14	0.06

	(0.86)	(1.67)	(0.69)	(0.22)	(0.96)	(-1.57)	(-1.12)	(0.42)
$\Delta \ln Y_{i,t-3}$	0.65	0.47	-0.28	0.18	0.47	-0.21	0.10	0.21
	(1.58)	(1.70)	(-1.54)	(0.86)	(1.81)	(-1.05)	(0.87)	(1.43)
$\Delta \ln Y_{i,t-4}$	0.24	0.32	-0.08	0.09	0.18	0.01	**-0.25****	0.14
	(1.02)	(1.43)	(-0.47)	(0.53)	(1.09)	(0.05)	**(-2.21)**	(0.99)
$\Delta \ln[i^m_{i,t-1}]$	**-0.36*****	**-0.29***	-0.16	0.00	-0.01	-0.09	0.06	**-0.18***
	(-3.06)	**(-1.82)**	(-1.52)	(-0.06)	(-0.22)	(-0.56)	(0.54)	**(-1.84)**
$\Delta \ln[i^m_{i,t-2}]$	-0.08	-0.01	-0.07	-0.01	-0.02	-0.19	0.06	-0.06
	(-0.51)	(-0.05)	(-0.56)	(-0.16)	(-0.23)	(-0.69)	(0.45)	(-0.60)
$\Delta \ln[i^m_{i,t-3}]$	-0.38	-0.14	-0.08	**-0.16****	**-0.20***	-0.07	**-0.27***	0.02
	(-1.39)	(-0.77)	(-0.63)	**(-2.33)**	**(-1.74)**	(-0.30)	**(-2.00)**	(0.25)
$\Delta \ln[i^m_{i,t-4}]$	0.15	-0.02	0.02	0.08	0.05	0.15	-0.07	0.03
	(0.87)	(-0.24)	(0.27)	(1.20)	(0.52)	(1.05)	(-0.54)	(0.39)
$\Delta \ln pop_{i,t-1}$	-1.82	-0.36	-4.63	6.68	**11.17***	15.13	1.91	1.35
	(-0.31)	(-0.06)	(-0.96)	(1.08)	**(1.77)**	(1.42)	(0.74)	(0.74)
$\Delta \ln pop_{i,t-2}$	-4.63	-0.60	-6.07	**-15.05*****	5.84	2.86	**4.13****	-0.96
	(-0.87)	(-0.08)	(-1.45)	**(-2.99)**	(1.47)	(0.32)	**(2.31)**	(-0.46)
$\Delta \ln pop_{i,t-3}$	1.75	**16.49****	0.01	9.24	-6.94	5.98	-2.80	0.79
	(0.28)	**(2.32)**	(0.00)	(1.49)	(-1.56)	(0.94)	(-1.31)	(0.41)
$\Delta \ln pop_{i,t-4}$	-8.78	-8.42	**15.52*****	6.35	-2.02	-12.74	1.20	-2.84
	(-1.36)	(-1.32)	**(3.84)**	(0.94)	(-0.45)	(-1.37)	(0.50)	(-1.07)
$\Delta \ln rent_{i,t-1}$	**1.88***	1.46	1.10	0.61	-0.71	1.54	0.42	0.47
	(1.94)	(0.71)	(1.54)	(1.01)	(-1.11)	(1.55)	(0.84)	(1.06)
$\Delta \ln rent_{i,t-2}$	-0.84	-0.11	**1.71*****	-1.01	-1.00	-0.61	0.19	-0.45
	(-1.06)	(-0.08)	**(2.70)**	(-1.50)	(-1.59)	(-0.56)	(0.38)	(-1.46)
$\Delta \ln rent_{i,t-3}$	**2.05***	-0.68	-1.41	-0.60	0.02	-0.97	0.44	0.11
	(1.77)	(-0.37)	(-1.60)	(-1.40)	(0.03)	(-1.26)	(1.00)	(0.33)
$\Delta \ln rent_{i,t-4}$	**-2.09****	-1.12	**-1.41****	0.28	0.66	-0.49	**-0.82***	0.25
	(-2.17)	(-0.81)	**(-2.10)**	(0.68)	(1.02)	(-0.59)	**(-1.91)**	(0.68)
$\Delta \ln lc_{i,t-1}$	0.03	0.10	**0.44****	**0.29***	-0.05	**0.28***	0.30	**0.41*****
	(0.16)	(0.48)	**(2.65)**	**(1.89)**	(-0.21)	**(1.62)**	(1.32)	**(2.99)**
$\Delta \ln lc_{i,t-2}$	**-0.44****	0.04	**-0.46****	-0.02	0.14	0.29	**-0.57***	-0.27
	(-2.18)	(0.12)	**(-2.30)**	(-0.12)	(0.46)	(1.31)	**(-1.76)**	(-1.28)
$\Delta \ln lc_{i,t-3}$	**0.73*****	-0.21	**0.35***	-0.10	-0.52	-0.28	0.09	0.19
	(2.91)	(-0.93)	**(1.99)**	(-0.79)	(-1.64)	(-0.86)	(0.30)	(0.83)
$\Delta \ln lc_{i,t-4}$	-0.31	0.06	-0.07	-0.02	0.28	-0.05	0.40**	-0.32
	(-1.24)	(0.28)	(-0.58)	(-0.13)	(1.51)	(-0.17)	(2.06)	(-1.40)
$ECT_{i,t-1}$	**-0.29*****	**-0.06**	**-0.22*****	**-0.10*****	**-0.16*****	**-0.20***	**-0.17*****	**-0.08*****
	(-2.78)	**(-1.33)**	**(-3.21)**	**(-3.24)**	**(-3.11)**	**(-1.85)**	**(-3.33)**	**(-3.39)**
R^2	0.5689	0.4816	0.4952	0.4324	0.4327	0.3384	0.5214	0.3685
DW stat	2.03	1.98	1.98	2.00	1.97	2.07	2.13	2.07

Note: t-values are indicated in parentheses.*, **, and *** indicate 10%, 5%, and 1% significance, respectively. The standard errors are based on the Newey-West autocorrelation and heteroskedasticity-consistent covariance matrix. All equations have been tested for serial correlation using the LM test.

Table 4.A.3: Seemingly Unrelated Regressions

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra
Constant	0.01	-0.02	-0.03	0.00	-0.02	0.01	0.00	0.00
	(0.43)	(-1.34)	(-1.16)	(-0.21)	(-0.84)	(1.14)	(0.09)	(0.04)
$\Delta \ln P^h_{i,t-1}$	**0.22*****	**-0.29*****	0.14	-0.10	**0.34****	-0.26	-0.13	-0.09
	(2.05)	**(-2.87)**	(0.90)	(-0.66)	**(2.33)**	(-1.34)	(-0.96)	(-0.54)
$\Delta \ln P^h_{i,t-2}$	**0.31***	0.16	**0.23****	0.17	0.00	0.08	0.06	**0.33*****
	(1.95)	(1.49)	**(2.41)**	(1.79)	(-0.03)	(0.60)	(0.82)	**(2.98)**
$\Delta \ln P^h_{i,t-3}$	0.00	0.08	0.00	**0.35*****	**0.19***	0.21	**-0.29*****	0.05
	(-0.01)	(0.73)	(-0.01)	**(3.92)**	**(1.98)**	(1.24)	**(-2.71)**	(0.39)
$\Delta \ln P^h_{i,t-4}$	0.15	0.11	0.04	-0.01	0.13	**0.28***	0.15	0.09
	(1.41)	(0.80)	(0.38)	(-0.06)	(0.88)	**(1.78)**	(1.63)	(0.81)
$\Delta \ln cc_{i,t-1}$	-0.31	-0.57	-0.35	-0.11	**-1.24***	-0.38	0.39	0.01
	(-0.64)	(-0.66)	(-0.64)	(-0.34)	**(-1.72)**	(-0.52)	(0.56)	(0.01)
$\Delta \ln cc_{i,t-2}$	-0.45	-0.50	1.13	-0.30	0.99	0.97	0.30	-0.28
	(-0.96)	(-0.58)	(1.40)	(-0.70)	(1.41)	(0.87)	(0.33)	(-0.71)
$\Delta \ln cc_{i,t-3}$	0.62	-0.48	-0.27	0.49	-0.59	-0.59	-0.42	0.00
	(1.05)	(-0.48)	(-0.53)	(1.20)	(-0.78)	(-0.53)	(-0.71)	(-0.01)
$\Delta \ln cc_{i,t-4}$	-0.34	1.08	0.60	-0.10	**-1.36****	-0.64	0.44	0.17
	(-0.54)	(1.47)	(1.16)	(-0.24)	**(-2.06)**	(-0.74)	(0.89)	(0.40)
$\Delta \ln Y_{i,t-1}$	0.10	-0.03	0.00	-0.16	-0.08	**-0.37****	**-0.19***	0.19
	(0.40)	(-0.09)	(-0.00)	(-0.69)	(-0.35)	**(-2.15)**	**(-1.86)**	(1.37)
$\Delta \ln Y_{i,t-2}$	0.21	0.67	0.16	0.05	0.23	-0.29	-0.14	0.06
	(0.86)	(1.67)	(0.69)	(0.22)	(0.96)	(-1.57)	(-1.12)	(0.42)
$\Delta \ln Y_{i,t-3}$	0.65	0.47	-0.28	0.18	0.47	-0.21	0.10	0.21
	(1.58)	(1.70)	(-1.54)	(0.86)	(1.81)	(-1.05)	(0.87)	(1.43)
$\Delta \ln Y_{i,t-4}$	0.24	0.32	-0.08	0.09	0.18	0.01	**-0.25****	0.14
	(1.02)	(1.43)	(-0.47)	(0.53)	(1.09)	(0.05)	**(-2.21)**	(0.99)
$\Delta \ln[i^m_{i,t-1}]$	**-0.36*****	**-0.29***	-0.16	0.00	-0.01	-0.09	0.06	**-0.18***
	(-3.06)	**(-1.82)**	(-1.52)	(-0.06)	(-0.22)	(-0.56)	(0.54)	**(-1.84)**
$\Delta \ln[i^m_{i,t-2}]$	-0.08	-0.01	-0.07	-0.01	-0.02	-0.19	0.06	-0.06
	(-0.51)	(-0.05)	(-0.56)	(-0.16)	(-0.23)	(-0.69)	(0.45)	(-0.60)
$\Delta \ln[i^m_{i,t-3}]$	-0.38	-0.14	-0.08	**-0.16****	**-0.20***	-0.07	**-0.27***	0.02
	(-1.39)	(-0.77)	(-0.63)	**(-2.33)**	**(-1.74)**	(-0.30)	**(-2.00)**	(0.25)
$\Delta \ln[i^m_{i,t-4}]$	0.15	-0.02	0.02	0.08	0.05	0.15	-0.07	0.03
	(0.87)	(-0.24)	(0.27)	(1.20)	(0.52)	(1.05)	(-0.54)	(0.39)
$\Delta \ln pop_{i,t-1}$	-1.82	-0.36	-4.63	6.68	**11.17***	15.13	1.91	1.35
	(-0.31)	(-0.06)	(-0.96)	(1.08)	**(1.77)**	(1.42)	(0.74)	(0.74)
$\Delta \ln pop_{i,t-2}$	-4.63	-0.60	-6.07	**-15.05*****	5.84	2.86	**4.13****	-0.96
	(-0.87)	(-0.08)	(-1.45)	**(-2.99)**	(1.47)	(0.32)	**(2.31)**	(-0.46)
$\Delta \ln pop_{i,t-3}$	1.75	**16.49****	0.01	9.24	-6.94	5.98	-2.80	0.79
	(0.28)	**(2.32)**	(0.00)	(1.49)	(-1.56)	(0.94)	(-1.31)	(0.41)
$\Delta \ln pop_{i,t-4}$	-8.78	-8.42	**15.52*****	6.35	-2.02	-12.74	1.20	-2.84
	(-1.36)	(-1.32)	**(3.84)**	(0.94)	(-0.45)	(-1.37)	(0.50)	(-1.07)
$\Delta \ln rent_{i,t-1}$	**1.88***	1.46	1.10	0.61	-0.71	1.54	0.42	0.47
	(1.94)	(0.71)	(1.54)	(1.01)	(-1.11)	(1.55)	(0.84)	(1.06)
$\Delta \ln rent_{i,t-2}$	-0.84	-0.11	**1.71*****	-1.01	-1.00	-0.61	0.19	-0.45
	(-1.06)	(-0.08)	**(2.70)**	(-1.50)	(-1.59)	(-0.56)	(0.38)	(-1.46)
$\Delta \ln rent_{i,t-3}$	**2.05***	-0.68	-1.41	-0.60	0.02	-0.97	0.44	0.11
	(1.77)	(-0.37)	(-1.60)	(-1.40)	(0.03)	(-1.26)	(1.00)	(0.33)
$\Delta \ln rent_{i,t-4}$	**-2.09****	-1.12	**-1.41****	0.28	0.66	-0.49	**-0.82***	0.25
	(-2.17)	(-0.81)	**(-2.10)**	(0.68)	(1.02)	(-0.59)	**(-1.91)**	(0.68)
$\Delta \ln lc_{i,t-1}$	0.03	0.10	**0.44****	**0.29***	-0.05	**0.28***	0.30	**0.41*****
	(0.16)	(0.48)	**(2.65)**	**(1.89)**	(-0.21)	**(1.62)**	(1.32)	**(2.99)**
$\Delta \ln lc_{i,t-2}$	**-0.44****	0.04	**-0.46****	-0.02	0.14	0.29	**-0.57***	-0.27
	(-2.18)	(0.12)	**(-2.30)**	(-0.12)	(0.46)	(1.31)	**(-1.76)**	(-1.28)
$\Delta \ln lc_{i,t-3}$	**0.73*****	-0.21	**0.35***	-0.10	-0.52	-0.28	0.09	0.19
	(2.91)	(-0.93)	**(1.99)**	(-0.79)	(-1.64)	(-0.86)	(0.30)	(0.83)
$\Delta \ln lc_{i,t-4}$	-0.31	0.06	-0.07	-0.02	0.28	-0.05	**0.40****	-0.32

	(-1.24)	(0.28)	(-0.58)	(-0.13)	(1.51)	(-0.17)	**(2.06)**	(-1.40)
$ECT_{i,t-1}$	**-0.29***** **(-2.78)**	**-0.06** **(-1.33)**	**-0.22***** **(-3.21)**	**-0.10***** **(-3.24)**	**-0.16***** **(-3.11)**	**-0.20*** **(-1.85)**	**-0.17***** **(-3.33)**	**-0.08***** **(-3.39)**
R^2	0.57	0.48	0.50	0.43	0.43	0.34	0.52	0.37
DW stat	2.03	1.98	1.98	2.00	1.97	2.07	2.13	2.07

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1. ECTs are from individual DOLS estimations in Table 4.A.2 above.

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Chapter 5

What Drives Residential Investment in Australia?

Abstract

The chapter investigates the key drivers of private residential investment in Australia since the 1980s. A Tobin's *q* model of investment is augmented to account for the impact of demand factors and the effect of economic uncertainty on the house investment decision. Using quarterly data over the period from 1979 Q3 to 2011 Q4, the impact of Tobin's *q*, income, land prices and financial constraints on the house investment rate are then determined and examined. A long-term co-integration relationship between Tobin's *q* and the investment ratio, as posited by *q* theory is not found, while changes in *q* have an impact on investment in the short-term. The determinants extracted from the stock-flow model explain the movement of housing investment. Uncertainty and construction costs are revealed not to be highly significant for investment. There is evidence of a positive correlation between investment and business cycles.

5.1 Introduction

Residential investment is associated with the production of new dwellings, therefore, it adds to the existing stock of housing or the supply of houses. Residential investment is an important driver of economic development since residential construction is an economic activity with large multiplier effects. As house wealth accounts for an enormous percentage of total wealth, an increase of this housing stock has an impact on economic growth. Housing investment plays a leading role in business cycles (Topel and Rosen, 1988); that is, residential investment leads the business cycle (Iacoviello, 2005). In Australia, the value of new housing construction alone (not including renovations and other housing-related expenditure) exceeds four per cent of the country's gross domestic product (GDP) (Dowling, 2005). Residential housing investment has averaged about a third of total private fixed investment in Australia and 5.6 per cent of real Australian GDP during the 1959 to 2012 period, as calculated from the Australian Bureau of Statistics (ABS) data.

Given the important role housing investment plays in Australia, the research conducted on it is quite scarce. Recent empirical studies on Australian housing mainly focus on examining housing price dynamics, under the influences of demand factors such as income, population and interest rates and under the assumption of a sluggish supply. Below is a brief discussion of this literature. Bourassa and Hendershott (1995) estimate a model of six cities to explain the divergent real house price behaviour overtime. Abelson, Joyeux, Milunovich and Chung (2005) for the states of Australia use a co-integration model to examine the long-run relationship between real house prices and the fundamental variables claimed by housing literature; while, Otto (2007) also investigates house price dynamics at the state level. Kohler and Rossiter (2005) use household-level data to examine which determinants drive residential property ownership and the willingness of households to hold property debt in Australia. Fry, Martin and Voukelatos (2010) develop a structural VAR model for the Australian economy to investigate the determinants of house price fluctuations. They identify housing supply shocks to have very little effect, which provide some support for the notion that house prices are more dependent on demand-side variables. In contrast, the Productivity Commission's (2004) report examines the factors affecting the cost of housing supply and of the barriers that limit supply responses in the short-run, but they only conduct a descriptive examination not an econometric one. Moreover, in a recent study, Caldera and Johansson (2013) estimate the long-run price elasticity of housing supply of 21 OECD countries, including Australia. Specifically, they model the long- and short-term relationship amongst house prices, housing investment and their determining variables based on a system of demand-supply equations and an error correction framework and find that price responsiveness of Australian house supply is intermediate, about 0.53.

According to Yates (2011) very little attention has been paid to the factors that determine supply in the long-run. Also, existing literature on housing investment in Australian has not examined its dynamics, nor has it tested the implications of the widely used Tobin's *q* model for explaining the motivation to undertake new housing investment. DiPasquale (1999) argues that the lack of research on housing investment is partly due to modelling difficulties. Housing investment is perceived as a flow of housing services supplied; unfortunately, housing services are difficult to measure, as there is no standard unit. Housing investment (building of new houses and renovation of existing houses) is the outcome of a series of decision-making processes by builders and the owners of existing houses. In addition, no standard data set exists that permits us to observe the behaviour of those who build new housing, although information on the renovation and repair decisions of owner-occupants may be available from national surveys. The significant obstacles in regards to information prevent researchers from deepening their understanding of housing investment. However, recently the availability of new datasets (especially, at the state-level) permits us to observe the behaviour of housing investors in Australia, which have been seldom done so far.

This chapter contributes to empirical literature on housing investment in two folds: (1) revisiting the two prominent models, Tobin's *q* based model and the stock-flow model in explaining housing investment in Australia and (2) investigating the determinants of residential investment in Australia, at both the nationwide and the state-level. The study unveils several important findings. First, when a Tobin's *q* model of investment is augmented to account for the impact of demand factors and the effect of economic uncertainty on the house investment decision, the effects of Tobin's *q* on residential investment is found to be significant. However, no co-integration between Tobin's *q* and the investment ratio (the ratio between investment and capital stock) exists. Second, the traditional stock-flow approach is applied and appears to explain well the movement of investment flows. Investment is mainly driven by demand side variables, including income, population, the user-cost of house capital and mortgage rates. Uncertainty and construction costs are found to be significant for investment but the signs are ambiguous. However, there is strong evidence that business cycles effect housing investment.

The chapter is structured as follows. Section 2 provides a review on relevant literature on housing investment and a description of the empirical models that are used in this chapter. Section 3 describes the empirical models to be used. Section 4 provides data description. Regression results of the proposed models are displayed in Section 5. Section 6 offers a comparison of my model's explanatory power with the stock-flow model. The last section is the conclusion.

5.2 Literature Review

5.2.1 Factors affecting residential investment in empirical studies

Factors that drive housing investment can be classified into demand and supply side factors. Topel and Rosen (1988) using a supply model claim that housing investment in the US responds significantly to changes in the house price index and supply shifters that affect cost, such as the real interest rate and expected inflation. Existing literature, including Poterba (1984) and DiPasquale (1999) advocates that credit constraints, inflation expectations and out of equilibrium adjustments influence new housing investment. McCarthy and Peach (2004) use a structural model of investment when examining single-family housing. In their model, the investment ratio (residential investment divided by the housing stock) is a function of house price inflation, short-term interest rates, personal consumption expenditure, land prices, and a month's supply of new homes for sale. Their findings suggest that the transmission mechanism of monetary policy on housing investment has changed over time in the US house market. Dynan, Elmendorf, and Sichel (2006) examine the response of residential investment that is attributable to financial innovation, measured as the movements in the mortgage rate. They find that the response was considerably smaller after the mid-1980s compared to before; a phenomenon consistent with the increase of the interest rate ceiling that was imposed.

The relationship between the housing investment and the variables that are considered inputs in housing construction is also of interest. Inputs in housing construction include the cost of land, construction cost, tax and financial cost. As new housing investment accounts for less than 10 per cent of total existing house stock, new house prices are equal to existing house prices (controlling for access to facilities such as parks, shopping centres, recreational centres, etc.). A number of studies claim that land prices are equal to the residual between existing house prices and construction costs (e.g. Somerville, 1996; and Tse, 1998). While this claim is true for existing land plots located within urban areas where land is extremely limited, it is not true for new housing development projects. This is because agricultural land near developed urban areas can be converted into residential land by developers with relative ease; as such, agricultural land prices should be correlated with urban land prices.

Several researches have attempted to deepen their understanding of the role of land restrictions in housing investment; however difficulties have arisen in terms of measuring constraints on land use. For example, Fortura and Kushner (1986), Manning (1989), and Potepan (1996) incorporate land-use constraints imposed by local governments in their residential investment model, by using the ratio of the number of municipalities over total population. Pollakowski and Wachter (1990), on the other hand, proxy for land use constraints by using allowed residential-development ceilings. Ozanne and Thibodeau (1983) quantify government land use laws and regulations by using the number of municipalities per 100,000 households; a measure of the ability to restrict metropolitan-wide land use. They assume that areas with concentrated municipal powers will have a restricted land supply and a higher price, compared to areas where such powers are widely shared. The shortcoming of this method is that the number of municipalities seems to stay unchanged, while population growth makes the ratio smaller gradually over time. Therefore, the constructed measure is rather proxying for population than government land use laws.

The supply of new houses is inelastic in the short-run due to the delays involved in housing construction such as approval, construction, land regulation as well as supply constraints. In addition, as information is particularly costly in both the house transaction and in mortgage lending, there will be information asymmetry in the housing market. For the house investor, the risks involved are high when there is an existence of legal rigidities and when there is a long delay between the time the decision is made to start building, to the time the transaction is completed. All these characteristics contribute to uncertainty of housing investment. Bulan, Mayer and

Somerville (2009) using a sample of condominium developments in Vancouver, Canada built from 1979–1998, examine the extent to which uncertainty delays investment, and the effect of competition on this relationship. They find that increases in both idiosyncratic and systematic risk cause developers to delay new real estate investments.

5.2.2 The stock-flow model and Tobin's q in residential investment

The stock-flow model that is applied in house market research separates the stock of houses to the flow of new houses. Naturally, the flow of housing supplements the stock of housing by replacing the stock that is lost due to depreciation as well as it adds new houses. However, the stock in the short-run is rigid as house prices of the existing stock decide the flow of new houses. The supply of new homes relies on a buffer mechanism based on the unsold houses in the market; as such, the vacancy rate plays an important role in the investment decision. Furthermore, the supply of houses is rigid as investment cannot increase significantly due to adjustment costs that arise when resources are moved from one investment into another, the land limitation and government procedures that must be satisfied and of course the time it takes to build a new house.

General investment theories can be augmented making them applicable to residential investment. For example, the Tobin's *q* model of investment, where the market price of investment is compared with its replacement cost and where investment will continue until the marginal revenue equals marginal cost of new investment, is widely used in the investment literature. Similar to the *q* theory framework applied to general investment, the *q* model for residential investment identifies that new investment in housing is determined by the *q* ratio of housing, where investors compare the market price of housing with its construction costs (Poterba, 1984; Topel and Rosen, 1988; and Grimes and Aitken, 2006). Therefore, Tobin's *q*, the ratio between market value of a house and its replacement costs is used to describe investment behaviour. In a *q* model, the main variable is of course *q*, while other variables are included to control for possible market frictions which may lead to violations of two assumptions, homogeneity and perfect competition.

By employing the *q* theory framework, recent empirical studies find evidence of a significant relationship between *q* and residential investment. Some of these studies are discussed below. Jud and Winkler (2003), in their study of housing investment in the USA from 1979 to 2000, define their Tobin's *q* as the ratio between the price index of existing housing and the quality adjusted price index of new homes. They find empirical evidence in favour of Tobin's *q*, however they use a regression equation of *q* without controlling for any other variables. Berg and Berger (2006) reaffirm the role of *q* for the Swedish housing market. In Germany, Nitsch (2011) ascertains that for some real estate markets, around 75 per cent of investment can be described by Tobin's *q*. Haagerup (2009), in his study of Danish single-family houses from 1968 to 2008, also identifies a strong link between Tobin's *q* and housing investment. Similarly, Barot and Yang (2002) apply Tobin's *q* to the UK and Swedish housing market, defining *q* as the ratio of house prices to building costs, and find Tobin's *q* Granger causes housing investment.

5.3 Empirical Models

This section describes the empirical frameworks to be used for modelling Australia's residential investment behaviour. Existing empirical studies have attempted to identify what determines residential investment behaviour in an economy or across countries using two approaches: the Tobin's *q* approach and the stock-flow approach adjusted for costs.

5.3.1 q model

Before one examines formally the possible relationships, one needs to determine the time series econometric properties of each variable, by determining their order of integration. The standard tests used are the Dickey – Fuller (DF) and the augmented Dickey Fuller (ADF) test. The Zivot-Andrews Unit root test is also applied to account for any structural breaks of both intercept and trend. The results of the tests are in Appendix 1 showing that most of the series are integrated of order one. However, the test results also indicate that the investment ratio (I/K) is a stationary process, providing no support for a co-integration test on the long-term relationship between the investment ratio and Tobin's *q*.

As there is no co-integration between the investment ratio and other variables of interest, the first difference OLS regression model is used as it allows for richer short-run dynamics. Tobin's q theory and existing literature suggest (see Carrington and Tran, 2012 for a discussion) the following empirical equation:

$$\Delta \ln(I/K)_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \Delta\ln(q)_{t-i} + \sum_{i=1}^{m} \beta_i \Delta\ln(I/K)_{t-i} + \sum_{j=1}^{m} \gamma_i X_{t-i} + \varepsilon_t, \quad (5.1)$$

where I/K is the investment ratio, q is Tobin's q, X is a vector of potential exploratory variables and Δ stands for the first difference. The number of lags ranges from one to four to ensure that any serial correlation in ε_t is eliminated. Madsen (2012) and Greasley and Madsen (2013) suggest potential explanatory variables that should be included in the explanatory regression, including the q ratio, land prices, construction costs and uncertainty. Furthermore, Topel and Rosen (1988), Porteba (1984) and DiPasquale (1999) suggest that the house price index, supply fundamentals and credit constraints should also be accounted for when modelling housing investment based on the q approach.

Taking into consideration the suggestions of past research, the model in this chapter is an empirical q model in which the variables influencing the replacement cost of housing are added and extended with income, credit cost and constraint (proxied by the interest rate), and uncertainty. In the literature, it is clear that housing investment is influenced by demographics, income, short-term interest rates, construction costs, and the supply of new homes for sale before the investment decision is made. With the aid of this model we aim to examine how changes in the above mentioned variables affect the housing supply-and-demand conditions and how this leads to changes in the residential investment within an economy.

Therefore, the baseline Tobin's q model to be estimated is:

$$\Delta \ln(I/K)_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \Delta\ln(q)_{t-i} + \sum_{i=1}^{m} \beta_i \Delta\ln(I/K)_{t-i} + \sum_{j=1}^{m} \delta_i \Delta\ln(realhpi)_{t-i} + $$
$$+ \sum_{j=1}^{m} \theta_i \Delta\ln(mort)_{t-i} + \sum_{j=1}^{m} \vartheta_i \Delta\ln(realgdppc)_{t-i} + \sum_{j=1}^{m} \mu_i \Delta\ln(pop)_{t-i} + $$
$$\sum_{j=1}^{m} \varphi_i \mathrm{unc}_{t-i} + \varepsilon_t, \quad (5.2)$$

where I/K is the investment ratio (investment volume divided by the existing house stock), q is Tobin's (average) q, pop is population, $realhpi$ is the real house price index, *mort* is the mortgage interest rate, $realgdppc$ is the real GDP per capita and

unc is uncertainty, Δ is the one quarter difference. Except uncertainty, all variables are transformed into the natural logarithm form.

5.3.2 Stock-flow model

Unlike q theory, the stock-flow adjustment model claims that investment is based on the demand-supply equilibrium and the factors that cause house demand and supply curves to shift. Residential housing stock and the flow of residential investment are linked together through housing prices, however the model makes a distinction between the stock of housing and the flow of residential investment. The flow responds quicker to changes in macroeconomic conditions; while, the housing stock evolves slowly through construction and depreciation, presumably in response to the prices. Moreover, the stock does not jump to its long-run level at once, the adjustment takes time as a consequence of adjustment costs (Chirinko, 1993).

Analogue to standard neoclassical theories, we determine the ratio between the expected marginal revenue product and the real user-cost of capital for the investment decision; hence, in this context investment is driven by house prices and costs. In the long run, the demand and supply for housing determines the equilibrium price that clears the stock of housing. Housing demand is a function of exogenous factors such as, income, demographic characteristics, user-cost of housing and real house prices. Supply of houses is defined by a production function such as, a Cobb-Douglas production function of land and inputs such as labour, capital and building materials. The reduced form of the stock-flow approach is very similar to the equation of the Tobin's q approach; however, the difference lies in the role and form of q in the regressions.

As the above variables affect house prices and investment in both the short- and long-run, it is vital to examine the effects under both time horizons. Recent studies (such as, Hüfner and Lundsgaard, 2007; Rae and van den Noord, 2006; and Caldera and Johansson, 2013) estimate the price and investment equations in an error correction framework employing the Engle-Granger two-step estimation procedure (Engle and Granger, 1987), under the condition that all variables of interest are integrated of order one. Similarly, in this study, the empirical approach based on a possible co-integration relationship between investment and its determinants is as follows:

$$ln(I)_t = \alpha_0 + \alpha_1 \, ln \, realGDP_t + \alpha_2 \, ln \, realhpi_t + \alpha_2 \, ln \, mort_t + \varepsilon_t, \tag{5.3}$$

$$\Delta \ln(I)_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta \ln(I)_{t-i} + \sum_{j=1}^{n} \gamma_i \Delta \, ln \, realGDP_{t-j} + \sum_{j=1}^{n} \gamma_i \Delta \, ln \, realhpi_{t-j} + \sum_{j=1}^{n} \gamma_i \Delta \, ln \, mort_{t-j} + \tau \hat{\varepsilon}_{t-1} + v_t, \tag{5.4}$$

where I is real housing investment, $realGDP$ is real GDP, Δ is the one-quarter difference operator, $realhpi_t$ is the house price, $mort_t$ is the mortgage rate and $\hat{\varepsilon}_{t-1}$ is the first lag of the residual from Equation 5.3 regression.

The long-run relationship between the variables, reflected in Equation 5.3 is estimated using the Dynamic Ordinary Least Squares (DOLS) estimator of Stock and Watson (1993). There the first differences of the lags and leads, and concurrent values of the explanatory variables are included as additional regressors to allow for the dynamic path around the long-run equilibrium and to account for endogeneity. The Error Correction Term (ECT) in Equation 5.4 allows for shifts in investment that result from the adjustment to its equilibrium long-run level, as defined by the co-integrating relationship in Equation 5.3. On the other hand, in the short-term equation, Equation 5.4, I add new explanatory variables including changes in population to account for the effects of demographic changes.

Both Tobin's q and the stock-flow model are tested using quarterly panel data of Australian eight states and territories during the period from 1981Q1 to 2012Q4. The advantage of using panel data is to gain more efficiency and predictive power by controlling for the impact of omitted variables, uncovering dynamic relationships, and reducing the multicollinearity among the explanatory variables (Hsiao, 2007). At the state level, because the panel data set has small N=8 and large T=128, Feasible General Least Square (FGLS) estimator is used to account for the long nature of the data panel. The estimator also takes into account the possibility that regional housing investment is contemporaneously correlated across regions. This is likely to be the case because regional housing markets are not independent from one another due to competition among construction firms and among state economies, while worker mobility can contribute to inter-regional correlations.

5.4 Data

The empirical model in many cases is constrained by the characteristics and availability of data. In this chapter, two data sets have been used; one is aggregate data on Australian housing investment and other relevant variables, while the other is data on state level housing investment in Australia and other relevant variables. All data are quarterly, aggregate data is from 1979Q3-2011Q4 while state-level data is from 1980Q1-2012Q3. Data sources and the construction of variables are explained in the Data Appendix.

Here housing investment is measured in two ways. In the first method, investment is proxied by the investment ratio, calculated as the value of private residential investment divided by the initial housing stock for the period. The second measure of investment is the actual level of private residential investment, measured by the constant private gross fixed capital formation in dwellings. Both of these methods are widely used in empirical research. The data combines both types of investments, that is, new house construction and renovation/improvement, as housing stock includes both existing houses and new houses. House stock in this chapter is calculated using the perpetual inventory method. The details of the housing stock estimation can be found in the Data Appendix.

To simplify without losing generality, it is assumed that the investment behaviour for house improvement/renovation is the same as for new housing construction, so both kinds of investments are driven by the same q. Theoretically, q is the ratio between the market price of new capital and its replacement cost; hence, housing q is calculated as the expected market price of a new home divided by the cost of its production (a proxy for the replacement costs). As new houses account for a very small proportion of total existing houses, it is reasonable to assume that new house prices equal existing house prices. In order to obtain a measure of Tobin's q that represents national residential investment, I take the ratio between the market value of an existing representative dwelling, proxied by the national house price index and its replacement cost which is calculated based on a Cobb-Douglas function of land and construction inputs proposed by Madsen (2011).

Due to data constraints, the relative house price index is available but not the absolute level of prices. The same problem is encountered with land prices and construction costs. Therefore, I measure the change of q and define the average value of q for the period as unity. The advantage of calculating the change of q instead of the level is that the log-first difference does not depend on the unit of measurement of the variable.

Namely, in the short-run, Tobin's q is calculated as:

$$q_t = \frac{P_t^h}{\alpha lc_t^{\beta} cc_t^{1-\beta}} \tag{5.5}$$

where P_t^h is the house price, α is the construction technology, lc is the land cost and cc is the construction cost. Taking the natural log of both sides of the above formula yields:

$$\ln q_t = \ln P_t^h - \beta \ln lc_t - (1-\beta) \ln cc_t - \ln \alpha \tag{5.6}$$

Furthermore, if taking the first difference to measure the change of q, assuming technology and other factors do not change much during the quarter yield:

$$\Delta \ln q_t = \Delta \ln P_t^h - \beta \Delta \ln lc_t - (1-\beta) \Delta \ln cc_t \tag{5.7}$$

The estimates of beta (β) are obtained by estimating a co-integration regression between house prices, construction costs and land prices. The result of the co-integration relationship between Australian house prices, land prices and construction costs show that $\beta = 85$ per cent; which means that geometrical weights of land prices and construction costs are 85 per cent and 15 per cent, respectively. It also means that for Australia, an increase of house price is 85 per cent attributed to an increase of land price and only 15 per cent attributed to an increase of construction costs.

As aforementioned in the literature review, agricultural land values should be correlated with residual land prices. Furthermore, Capozza and Helsley (1989) and Madsen (2011) have shown that while agricultural land prices are not the singular force shaping residential land prices, agricultural land prices are good proxies for values of residential land, as house prices are significantly related to agricultural land values. Therefore, given the lack of residential land price data for Australia, agricultural land values are used as a proxy for the price of residential land.

Another method for calculating *q* is the ratio between the existing house price and the replacement cost of the new project home, which are proxied respectively by the established house price index and the project house price index provided by the Australian Bureau of Statistics (ABS cat. 6416). At the national level, the two series of *q* from the two methods are equivalent as their correlation coefficient is nearly 0.99. However at the state level, as there is no land price data, I cannot apply the first method of calculating *q*; hence, I use the *q* calculated by the second method.

For established house prices, the house price index (HPI) covers transactions for detached residential dwellings regardless of age (that is, including new houses sold as a house/land package as well as second-hand houses). Therefore, the change in prices reflects the total price of dwelling and land. In this chapter, the data source for house prices at the state level is the Real Estate Institute of Australia (REIA), starting from 1980 Q1. Other state level data are mainly sourced from the Australian Bureau of Statistics (ABS). The disposable income of households is proxied by the state final demand data from the ABS, volume chain measure starting from 1983 Q3. As aforementioned, Tobin's *q* for the state housing markets is the ratio between house price indices and the project house indices (proxyed for the cost of new houses built).

Previous empirical studies such as Episcopos (1995) and Serven (1998), find evidence of a significant relationship between investment and macroeconomic uncertainty. To test the role of uncertainty on Australian residential investment, in this study I use macroeconomic volatility, proxied by the conditional standard deviations obtained from a univariate GARCH (p,q) specification (following Bollerslev, 1986) of the forward looking Westpac Economic Index, as the uncertainty measure. The GARCH specification computes the conditional variance of the residual obtained from regressing the variable on its lagged values. Another common measure, the volatility of the stock market index is also used to proxy for uncertainty, computed as the moving average of the standard deviation of daily returns of the All Ordinaries Stock Index (AORD) (see Romer, 1990 for a discussion).

It is of interest to take a preliminary glance at the data of Australian private dwelling investment and its potential drivers over the last four decades - Tobin's *q* for the house market, income and uncertainty. Accordingly, graphs of these data series showing the relationship between the investment ratio, *q*, house prices, mortgage rates and income are presented in Figure B1 of this chapter's Appendix 2.

Figure 5.1: Australian housing investment and Tobin's *q* during 1960-2012

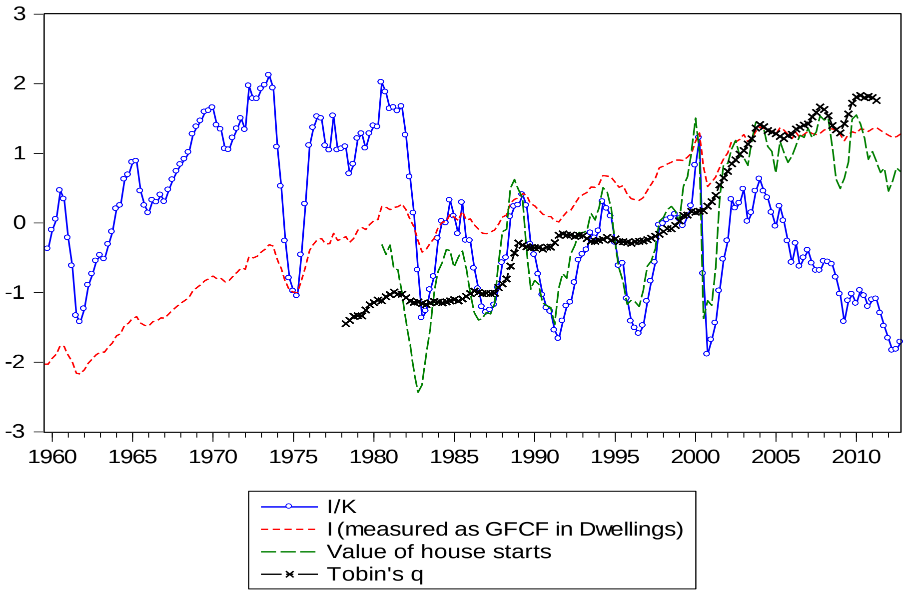
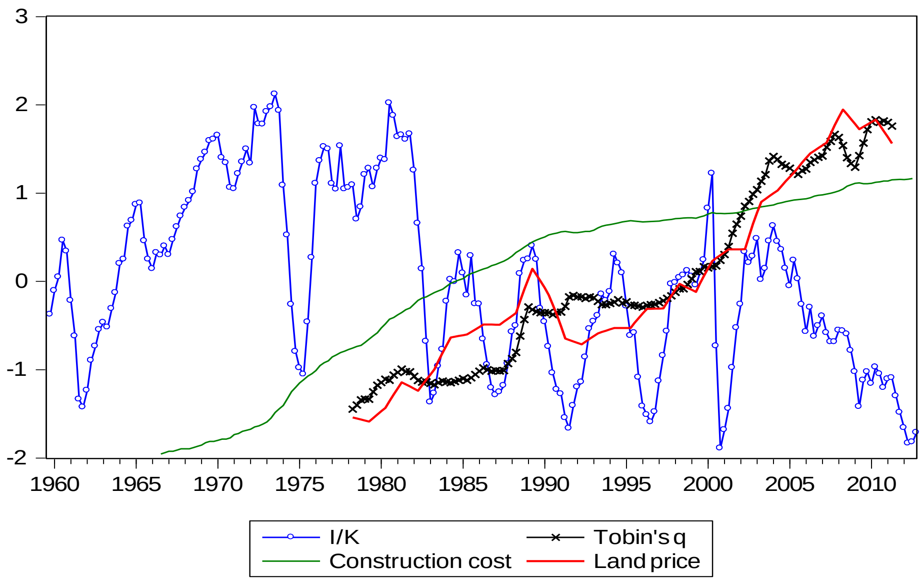


Figure 5.2: Australian investment, Tobin's *q*, land price and construction cost index during 1960-2012



Note: Investment ratio (I/K) is measured as the real private housing investment divided by a one-period lag of real private house stock. All variables are normalized to mean 0 for comparison purposes. GFCF is the gross fixed capital formation, another proxy for housing investment.

Figure 5.3: Investment ratios of eight Australian states and territories (1980–2012)

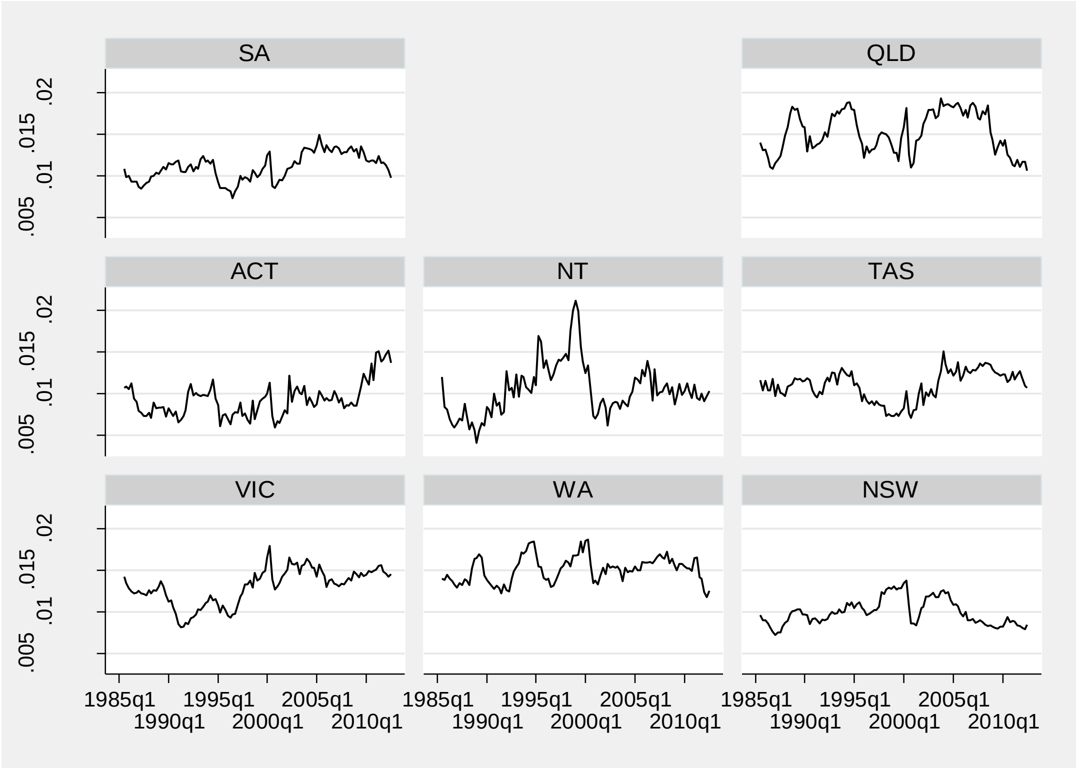
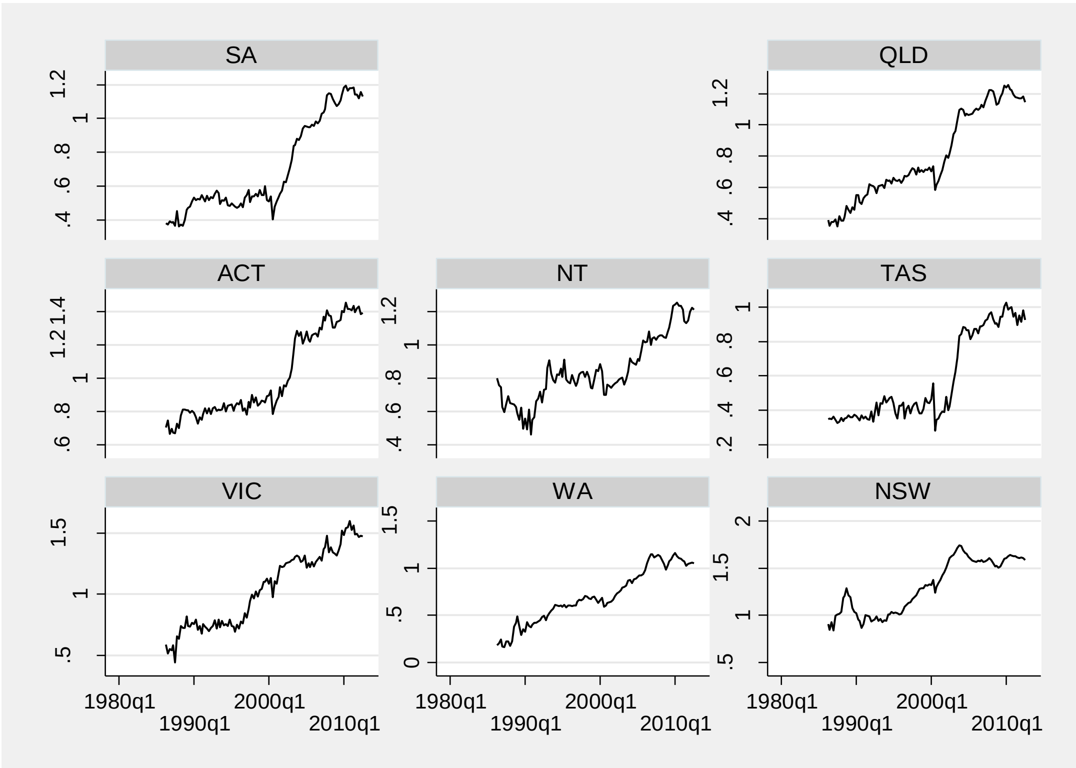


Figure 5.4: Housing Tobin's *q* ratios of eight Australian states and (1980–2012)



Figures 5.1 and 5.2 are graphs used to provide some intuition about how variables are related and how estimates of the coefficients are obtained from the data. The increase of Tobin's *q* in the period 1980–2012 corresponds closely with the increase in the housing construction volume (measured as the gross fixed capital formation (GFCF) in dwellings), but not the investment ratio. We see from Figure 5.1 that there seems to be no co-integration between Tobin's *q* and the investment ratio. We also see that both, the investment ratio and investment volume (GFCF in dwellings) show a cyclical pattern and that house prices had risen much more relative to the costs of building materials.

Figures 5.3 and 5.4 show the investment ratio and *q* of eight states. We can see clearly that there is no co-integration of *q* and the investment ratio and that the investment ratio series is stationary. *q* keeps increasing overtime in most of states.

In this study I use the Im, Pesaran and Shin (2003) panel unit root test and the ADF-Fisher panel unit root test of Maddala and Wu (1999), both of which assume an individual autoregressive unit root process. The unit root test results show that the investment ratios and construction costs of states are stationary (see Table 5A.3), while other variables are integrated of order one, including real house prices, real GDP, mortgage rates, population. Hence, the panel co-integration framework that estimates the long-run co-integrating relationship between Tobin's *q* and the investment ratio cannot be used here.

5.5 Empirical Results of *q* model

5.5.1 National data regression results

Table 5.1 shows the regression results of Equation (5.2), where growth of the investment ratio is regressed on the different sets of Tobin's *q* and other explanatory variables. In this table, Column 1 is the basic *q* regression of changes in investment given changes in its own lags and changes of Tobin's *q*. The inclusion of the lag of the dependent variable is done to control for persistency and to avoid the autocorrelation of the error terms in the model. We see that all of the lags of the dependant variable in all columns are significant. The significance of the lags of the dependent variable in all of the columns means that today's investment change is correlated with investment in previous periods; suggesting, persistency in housing investment behaviour. Given that the time it takes to build a new house in Australia is 2 to 2.5 quarters on average, may explain this persistency (Special report, ABS cat. 8752.0 - Building Activity, Australia, Jun 2011).

As predicted, the coefficient of *q* is positive and significant in all columns that contain Tobin's *q*. In fact, this result is consistent with those of previous studies on housing investment and *q* such as, Jud and Winkler (2003), Berg and Berger (2006), Nitsch (2011), Haagerup (2009), and Barot and Yang (2002). In Column 2, the model is augmented to account for the change in construction costs, land prices, mortgage rates and uncertainty; while, Tobin's *q* is replaced by changes in house prices to avoid the endogeneity issue between *q*, construction costs and land prices.

When both growth rates of house prices and Tobin's *q* for the housing market are included in the model, Tobin's *q* becomes non-significant while house prices stay significant. This can be explained as follows. The Tobin's *q* for housing at the national level is calculated using house prices as the numerator, and construction costs and land prices as the denominator. Therefore, to avoid the multicollinearity between Tobin's *q* and its determinants in the regression, I exclude Tobin's *q* in Column 2's regression and replace it by land prices and construction costs to test for their significance. For the aggregate time-series regression, the role of land costs is not evident, as when *q* is included, land prices are not a significant determinant of housing investment. However, later, a panel data regression shows a more significant role for land costs in determining housing investment behaviour in Australia.

In Column 3, the model is extended with changes of real GDP per capita and population, in order to test for the role of demand side factors. The significant coefficients of the demand variables, even when I incorporate Tobin's *q* show that, Tobin's *q* is not the sole determinant for housing investment, as predicted by the *q* model. Income, proxied by real GDP per capita has a positive and strong effect on house investment. The coefficient of the first lag of this variable is most significant, revealing that any change in income has an almost immediate impact on the housing market.

Table 5.1: Regression results of *q* based models on the Australian housing investment ratios

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant	-0.01	0.03	-0.02	-0.01	-0.03	0.04	-0.02	-0.03
	(-1.28)	(0.51)	(-0.31)	(-0.23)	(-0.41)	(1.15)	(-0.23)	(-1.53)
$\Delta\ln(I/K)_{t-1}$	**0.33*** **	0.01	-0.00	0.00	-0.07		0.07	
	(3.37)	(0.05)	(-0.05)	(0.01)	(-0.71)		(0.69)	
$\Delta\ln(I/K)_{t-2}$	-0.16	**-0.33** **	**-0.38** **	**-0.34** **	**-0.39** **	**-0.29*** **	**-0.38* **	**-0.33*** **
	(-0.97)	(-1.99)	(-2.04)	(-1.99)	(-2.46)	(-3.63)	(-1.82)	(-3.76)
$\Delta\ln(I/K)_{t-3}$	**0.16** **	0.03	0.06	0.07	0.01		0.01	
	(2.02)	(0.40)	(0.67)	(0.75)	(0.13)		(0.11)	
$\Delta\ln(I/K)_{t-4}$	**-0.22*** **	**-0.26*** **	**-0.27*** **	**-0.25*** **	**-0.28*** **	**-0.23*** **	**-0.29** **	**-0.30*** **
	(-3.27)	(-3.06)	(-2.82)	(-2.93)	(-3.27)	(-3.18)	(-2.19)	(-4.00)
$\Delta\ln(q)_{t-1}$	**0.42* **		-0.01	-0.04	-0.05		0.18	
	(1.97)		(-0.05)	(-0.18)	(-0.21)		(0.77)	
$\Delta\ln(q)_{t-2}$	0.44		0.40	0.49	0.30	**0.53** **	0.32	**0.53*** **
	(1.20)		(1.33)	(1.47)	(1.19)	(2.43)	(1.12)	(2.67)
$\Delta\ln(q)_{t-3}$	-0.27		0.48	0.32	**0.47* **		0.05	
	(-0.78)		(1.57)	(1.09)	(1.75)		(0.15)	
$\Delta\ln(q)_{t-4}$	0.08		0.52	0.55	0.53	**0.70*** **	0.37	
	(0.25)		(1.18)	(1.38)	(1.30)	(2.89)	(0.95)	
$\Delta\ln(landprice)_{t-1}$		0.09						
		(0.69)						
$\Delta\ln(landprice)_{t-2}$		-0.01						
		(-0.07)						
$\Delta\ln(landprice)_{t-3}$		0.11						
		(0.55)						
$\Delta\ln(landprice)_{t-4}$		-0.04						
		(-0.17)						
$\Delta\ln(cc)_{t-1}$		**2.09** **						
		(2.61)						
$\Delta\ln(cc)_{t-2}$		-0.83						
		(-1.17)						
$\Delta\ln(cc)_{t-3}$		-0.23						
		(-0.37)						
$\Delta\ln(cc)_{t-4}$		-0.65						
		(-0.77)						
$\Delta\ln(mort)_{t-1}$		**-1.07*** **	**-1.05*** **	**-0.99*** **	**-0.89*** **	**-0.70*** **		
		(-3.06)	(-2.97)	(-2.96)	(-2.77)	(-6.33)		
$\Delta\ln(mort)_{t-2}$		0.24	0.19	0.16	0.01			
		(0.56)	(0.36)	(0.30)	(0.01)			
$\Delta\ln(mort)_{t-3}$		0.62	0.41	0.44	0.32			
		(1.48)	(0.81)	(0.86)	(0.71)			
$\Delta\ln(mort)_{t-4}$		**-0.59*** **	-0.39	-0.30	-0.29			
		(-2.86)	(-1.34)	(-0.98)	(-1.18)			
$\Delta\ln(HPIreal)_{t-1}$		**0.40** **						
		(1.98)						
$\Delta\ln(HPIreal)_{t-2}$		**0.50** **						
		(2.00)						
$\Delta\ln(HPIreal)_{t-3}$		-0.16						
		(-0.61)						
$\Delta\ln(HPIreal)_{t-4}$		0.45						
		(0.99)						

Table 5.1: (contd.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
uncertainty $_{t-1}$		-1.43	14.22	0.50	16.99		14.12	
		(-0.16)	(1.45)	(0.84)	(1.68)		(1.44)	
uncertainty $_{t-2}$		-15.72	-13.08	-0.26	**-16.56***		-11.95	
		(-1.50)	(-1.27)	(-0.30)	(-1.98)		(-1.32)	
uncertainty $_{t-3}$		**19.57****	**21.38****	**1.57***	**22.12*****		**18.60****	
		(2.18)	(2.33)	(1.97)	(2.89)		(2.47)	
uncertainty $_{t-4}$		**-14.98***	**-23.01****	0.37	**-25.26*****	-13.64	**-21.54****	
		(-1.93)	(-2.54)	(0.49)	(-3.35)	(-1.76)	(-2.45)	
Δln(realGDPpc) $_{t-1}$			**1.52*****	**1.36*****	**1.46*****	**1.45*****	**1.32*****	**1.26*****
			(3.22)	(2.99)	(3.67)	(3.33)	(3.15)	(2.86)
Δln(realGDPpc) $_{t-2}$			0.73	0.76	**0.80***		**0.85***	**0.84***
			(1.28)	(1.56)	(1.70)		(1.74)	(1.81)
Δln(realGDPpc) $_{t-3}$			0.35	0.19	0.50		0.12	
			(0.76)	(0.38)	(1.27)		(0.26)	
Δln(realGDPpc) $_{t-4}$			-0.04	0.00	0.27		-0.60	
			(-0.13)	(0.01)	(0.87)		(-1.52)	
Δln(pop) $_{t-1}$			**16.29***	14.49	14.86	**13.31****	**17.38***	**17.29*****
			(1.69)	(1.33)	(1.64)	(2.15)	(1.76)	(2.66)
Δln(pop) $_{t-2}$			-1.24	-2.27	0.62		-7.02	
			(-0.25)	(-0.46)	(0.11)		(-1.13)	
Δln(pop) $_{t-3}$			**-12.03***	**-17.55****	-8.25	**-14.70****	-10.89	**-13.46****
			(-1.73)	(-2.62)	(-1.37)	(-2.36)	(-1.64)	(-2.14)
Δln(pop) $_{t-4}$			-4.08	-5.43	-4.24		1.12	
			(-0.79)	(-1.00)	(-0.77)		(0.21)	
Δ(Outputgap)					**1.92*****			
					(4.91)			
Δln(Usercost) $_{t-1}$							**-0.31*****	**-0.30*****
							(-3.93)	(-5.60)
Δln(Usercost) $_{t-2}$							-0.11	**-0.14****
							(-1.02)	(-2.52)
Δln(Usercost) $_{t-3}$							-0.11	**-0.14****
							(-1.14)	(-2.42)
Δln(Usercost) $_{t-4}$							-0.01	
							(-0.07)	
R^2	0.23	0.47	0.49	0.47	0.56	0.43	0.47	0.41

Note: * p<0.1; ** p<0.05; *** p<0.01. t-values are indicated in parentheses. The last column is done via the general-to-specific procedure of the regression, only significant coefficients are left after taking out insignificant variables from the equation regression. I/K is the investment ratio (investment volume divided by existing house stock). q is Tobin's (average) q. $landprice$ is the land price index, cc is the construction cost index, pop is population, $hpireal$ is the real house price index, $mort$ is the mortgage interest rate. $realGDPpc$ is real GDP per capita. All data sources and calculation are explained in the Data Appendix. Except for columns 6 and 8, the standard-errors are based on the Whites heteroskedasticity consistent covariance matrix. Uncertainty is measured by the GARCH model of the forward looking Westpac Economic Index. Uncertainty in Column 4 is measured as standard deviation of All Ordinaries Stock Index's daily change over the period. Column 8 is the reduced form of Column 7. Column 6 is the reduced form of Column 3. Column 5 is an extension of Column 3 with the output gap. Column 7 is Column 3 where the mortgage rate is replaced by the user-cost.

The coefficient of the nominal mortgage rate is statistically significant and negative. Our finding confirms the estimates in Berger-Thomson and Ellis (2004) who show that financing costs, as measured by the mortgage interest rate, negatively influence the residential investment in Australia. A higher long-term interest rate is reflected in higher mortgage rates, increasing the cost of owning a house and reducing the demand for houses, in turn leading to a decrease in house prices. The statistical significance of the mortgage rate coefficients is robust to the inclusion of the other variables. Changes in user-costs have a negative impact on residential investment as user cost increase would reduce investment. It is reasonable because the increase of user costs depresses the house demand, which in turn reduce the house prices and indirectly reduce house investment. Here the influential mechanism of user costs on house investment is through the demand side, which is similar to that of mortgage.

It is worth to investigate the impact of population growth (as a demand factor) on house price changes. In my regression of housing investment on population, I obtain a result that is partly similar to some research papers that find unclear or even negative effects of population growth on house prices (e.g., Hort, 1998; Engelhardt and Poterba, 1991). In my regression results, the population growth coefficient is significant, however its lags are of different signs; that is, the switch from positive to negative. This implies that it is the growth, rather than the change in population, that is important for influencing investment rates.

According to Column 3, uncertainty, measured by the conditional standard deviation estimated using a GARCH model of the Westpac Economic Index has a significant impact on housing investment; however, the sign is not clear as the coefficients change from positive to negative between lags three and four. This implies that it is not the magnitude of uncertainty, but rather the change in uncertainty that induces a change in housing investment. If uncertainty is proxied by the volatility of the Australian Stock Market Index returns, as shown in Column 4, we see that it does not play a significant role on housing investment as the coefficients of all four lags are not significant or are weakly significant (at 10 per cent level).

Column 5 is an extension of the model in Column 3 with the addition of the output gap (defined in the Data Appendix) to test for the impact of business cycles.

In the model, the coefficient of the first difference of the output gap is positive and significant, implying that business cycles have a strong impact on residential investment. When the first difference of the output gap increases, indicating a booming period or a smaller recession period, investment growth also increases.

Column 7 is a modification of Column 3 where the growth in the mortgage rate is replaced by the growth in the user-cost of a house. The result is similar to that of Column 3 as user-costs have a negative and significant effect on housing investment. Higher user-costs lower the demand for house ownership, leading to a decrease in investment. In Columns 6 and 8 of Table 5.1 are reduced models, refined from the full models from Columns 3 and 7 respectively, using the general-to-specific procedure. They confirm and strengthen the results of the full model as discussed above.

5.5.2 Panel data regression results

In this section, I investigate the determinants of housing investment using panel data from eight states and territories in Australia. As aforementioned, the advantages of using panel data in investigating econometric models is to gain more efficiency and predictive power, to control for the effects of omitted variables, to uncover dynamic relationships, and to reduce any multicollinearity among the explanatory variables (Hsiao, 2007).

Given that the investment ratio series of Australian states are stationary, we cannot use any co-integration model to investigate the relationship between the ratio and other variables of interest. Therefore, the first difference regression model, including Equation 5.2, where dependent variable is first difference of investment ratio (in natural log form) is regressed. The regression results in the table have some implications. First, in the Australian states, the growth of housing investment ratio (percentage change in the investment ratio I/K) is negatively correlated to its own lags, while the growth of volume of investment (I) is positively correlated. An explanation for this is that the fluctuation of investment growth exhibits a cyclical pattern. Second, q has positive and significant role on the change of investment.

Table 5.2: Panel analysis of house investment in Australian states and territories

Dependent Variable: X	(1) X=Δln(I/K)	(2) X=Δln(I/K)	(3) X=Δln(I/K)	(4) X=Δln(I/K)	(5) X=ln(I/K)	(6) X=Δln(I)
X_{t-1}	-0.30***	-0.29***	-0.27***	-0.29***		-0.22***
	(-7.24)	(-7.55)	(-6.94)	(-7.53)		(-5.63)
X_{t-2}	-0.04*	-0.048	-0.039	-0.05		-0.00
	(-1.71)	(-1.22)	(-0.97)	(-1.21)		(-0.01)
X_{t-3}	0.02	0.04	0.03	0.03		0.08*
	(1.45)	(0.89)	(0.82)	(0.71)		(1.95)
X_{t-4}	-0.16***	-0.11***	-0.13***	-0.12***		-0.08*
	(-5.09)	(-2.97)	(-3.29)	(-3.19)		(-1.95)
$\Delta\ln(q)_{t-1}$	0.15**	0.18***				
	(1.97)	(2.91)				
$\Delta\ln(q)_{t-2}$	0.21**	0.19***				
	(2.07)	(3.03)				
$\Delta\ln(q)_{t-3}$	0.15***	0.10				
	(2.76)	(1.61)				
$\Delta\ln(q)_{t-4}$	0.081*	0.086				
	(1.95)	(1.43)				
$\Delta\ln(cc)_{t-1}$			0.59			0.49
			(1.52)			(1.29)
$\Delta\ln(cc)_{t-2}$			0.022			-0.026
			(0.057)			(-0.07)
$\Delta\ln(cc)_{t-3}$			0.20			0.19
			(0.52)			(0.49)
$\Delta\ln(cc)_{t-4}$			-1.05***			-0.88**
			(-2.69)			(-2.30)
$\Delta\ln(landprice)_{t-1}$			0.53			0.31
			(1.46)			(0.93)
$\Delta\ln(landprice)_{t-2}$			-0.58*			-0.36
			(-1.66)			(-1.06)
$\Delta\ln(landprice)_{t-3}$			1.12			0.16
			(1.48)			(0.25)
$\Delta\ln(landprice)_{t-4}$			0.01			-0.39
			(0.03)			(-1.35)
$\Delta\ln(realGDPpc)_{t-1}$	0.26*	0.19	0.21	0.17	0.50***	0.13
	(1.67)	(1.42)	(1.52)	(1.28)	(3.22)	(0.95)
$\Delta\ln(realGDPpc)_{t-2}$	0.35**	0.18	0.14	0.15	0.76***	0.11
	(2.36)	(1.32)	(1.01)	(1.07)	(2.58)	(0.76)
$\Delta\ln(realGDPpc)_{t-3}$	0.05	-0.01	-0.02	-0.05	0.72**	-0.00
	(0.62)	(-0.097)	(-0.16)	(-0.35)	(2.34)	(-0.01)
$\Delta\ln(realGDPpc)_{t-4}$	0.16	0.013	0.11	-0.00	0.76**	0.08
	(0.63)	(0.095)	(0.81)	(-0.03)	(2.21)	(0.63)
$\Delta\ln(mort)_{t-1}$	3.59*	3.11***	-0.00	3.02***		-0.01
	(1.82)	(7.73)	(-0.02)	(7.60)		(-0.053)
$\Delta\ln(mort)_{t-2}$	-2.66	-2.28***	-0.13**	-2.17***		-0.14***
	(-1.58)	(-5.40)	(-2.26)	(-5.14)		(-3.11)
$\Delta\ln(mort)_{t-3}$	-1.86*	-1.60***	-0.36	-1.57***		0.25
	(-1.79)	(-8.36)	(-0.71)	(-8.33)		(0.63)

Table 5.2: (contd.)

Dependent Variable: X	**(1) X=Δln(I/K)**	**(2) X=Δln(I/K)**	**(3) X=Δln(I/K)**	**(4) X=Δln(I/K)**	**(5) X=ln(I/K)**	**(6) X=Δln(I)**
Δln(mort) $_{t-4}$	1.16**	1.04***	0.39	0.99***		-0.10
	(2.03)	(9.65)	(0.93)	(9.46)		(-0.31)
Δln(pop) $_{t-1}$	6.10***	3.43	2.98	3.24		
	(6.85)	(1.16)	(0.99)	(1.09)		
Δln(pop) $_{t-2}$	9.40***	4.43	5.46*	4.37		
	(3.67)	(1.41)	(1.72)	(1.39)		
Δln(pop) $_{t-3}$	-11.9***	-8.71***	-7.05**	-8.78***		
	(-15.0)	(-2.78)	(-2.22)	(-2.80)		
Δln(pop) $_{t-4}$	0.81	2.35	2.43	2.52		
	(0.40)	(0.79)	(0.81)	(0.84)		
Δln(unc)	-0.07*	-0.06***	-0.05	-0.06***		-0.02*
	(-1.71)	(-3.42)	(-0.34)	(-3.29)		(-1.69)
Δln(unc) $_{t-1}$	-0.20*	-0.17***	-0.10***	-0.16***		-0.07***
	(-1.72)	(-7.05)	(-4.80)	(-6.70)		(-4.69)
Δln(unc) $_{t-2}$	0.055	0.05**	-0.15***	0.04**		-0.08**
	(0.61)	(2.32)	(-3.30)	(2.18)		(-2.36)
Δln(unc) $_{t-3}$	-0.20*	-0.16***	-0.11	-0.15***		0.02
	(-1.81)	(-4.04)	(-1.26)	(-3.77)		(0.28)
Δln(unc) $_{t-4}$	-0.20	-0.17***	-0.09	-0.16***		0.053
	(-1.38)	(-7.10)	(-0.83)	(-6.91)		(0.64)
Δln(HPIreal) $_{t-1}$				0.14**		
				(2.40)		
Δln(HPIreal) $_{t-2}$				0.15**		
				(2.50)		
Δln(HPIreal) $_{t-3}$				0.08		
				(1.25)		
Δln(HPIreal) $_{t-4}$				0.07		
				(1.12)		
ECT $_{t-1}$						-0.10***
						(-4.82)

Note: t-statistics in parentheses. The same notation as in Table 5.1 is used. Constants are included but not shown. Estimators: Columns 1 and 5 use random effects, Columns 2, 3, 4 and 6 use Feasible General Least Squares. FGLS regression is allowed for inter-correlation, auto-correlation and heterogeneity in disturbances. All regressions include time dummies to account for business cycles and state dummies to account for time-invariant unobservable factors. ECT_t is the error correction term from the OLS regression of Eq. 5.3 between investment volume (I) and its determinants: real GDP, real house prices, mortgage rate, and state and time dummies. Columns 1 and 2 are regressions of the same Eq. 5.2 but with different estimators. Column 3 is a variation of Eq. 5.2 with Tobin's *q* replaced by land price and construction cost variables. Column 4 is a variation of Eq. 5.2 with Tobin's *q* replaced by real house price index. Column 5 is a regression of investment ratio on real GDP per capita to exam the role of business cycles on housing investment. Column 6 is a regression of Eq. 5.4.

The positive and statistically significant coefficient estimates of the changes in population and gross regional product are consistent with the notion that greater housing demand, induced by the growing population and higher income, will push up real-estate prices making housing investment by developers more profitable. Moreover, housing investment is positively correlated with lags of house prices. In the aggregate data regressions, the relationship between land prices and investment is not clear. However, at the state level, the regression results of investment on land prices exhibit a negative relationship. This suggests that higher land prices hinder housing investment, which may be explained as higher land costs lowering profits.

On the other hand, if I measure investment as the volume of investment, measured as GFCF in dwellings rather than the investment ratio (the ratio between the dwelling GFCF and the housing stock), I find the investment series is now integrated of order one, allowing me to test the co-integration relationship needed to see if it is appropriate to use the Error Correction Model in investigating house investment dynamics. The panel co-integration between the volume of investment, real GDP, mortgage rates, house prices and all the important drivers of investment as per the discussion in the literature section is found by using the Westerlund error-correction-based panel co-integration tests (Westerlund, 2007) (see the result of the test in Table 5.A.2 in Appendix 1). This provides a foundation for me to run the panel Error Correction Model regression as in Column 6, using $\Delta\ln(I)$ instead of $\Delta\ln(I/K)$ as the dependant variable.

From Column 6, we see that the coefficient of the ECT is negative and significant, confirming the co-integration relationship. Based on the results, it can be predicted that 10 quarters are needed for any short-term deviation from long-run equilibrium to be corrected, given its long-term trend. The results also indicate that Australian housing investment is positively related to real income and negatively related to the mortgage interest rate, even when we replace the mortgage rate by the short-term interest rate (90 day bill rate).

5.6 Stock-flow Model Analysis

Less research attention has been paid to long-run supply responses when there is a shock in the factors that determine supply (Yates, 2011). In this section, I look at the stock-flow model of the housing market, inspired by recent work of Caldera and Johansson (2013). Based on a discussion in the literature review section, I analyse a system of four equations, two for long-term and two for short-term relationships, in an error correction framework of house prices, housing investment and their corresponding determinants. This approach is different from the above approaches, as the system of equations is regressed simultaneously to take into account for the endogeneity amongst the variables. The equations represent both the demand and the supply side of the market, from which I can estimate the long-run price-elasticity of new housing supply. Given the slow adjustment of housing markets, the proposed system of equations incorporates an error correction process, for both supply and demand sides.

From literature review, I know that in the long-run, demand is influenced by expected or permanent income, demographical structure of population, the user-cost of housing (which are influenced by the interest rates, taxation and the expected capital gains of owning the house (Meen, 2002)). On the supply side, as seen from the stock-flow model literature, housing investment should be a function of cost variables, such as costs of production factors (i.e. land, labour and materials), housing policies, and real house prices. House prices create incentives to build new housing therefore should have an effect on residential investment.

The long-run equations include the demand equation for house prices and the supply equation for housing investment, and are as follows:

$$hpi_t = \alpha_0 + \alpha_1 gdp_t + \alpha_2 mortgage_t + \alpha_3 capitalstock_t + \alpha_3 population_t + ECT_{1,t}, \quad (5.7)$$

$$gfcf_t = \beta_0 + \beta_1 hpi_{t-1} + \beta_2 realcc_{t-1} + \beta_3 population_{t-1} + ECT_{2,t}, \quad (5.8)$$

Short-run equations are:

$$\Delta hpi_t = \gamma_0 + \gamma_1 \Delta gdp_t + \gamma_2 \Delta mortgage_t + \gamma_3 \Delta capitalstock_t + \gamma_4 \Delta population_t + \gamma_5 ECT_{1,t-1} + \epsilon_t \quad (5.9)$$

$$\Delta gfcf_t = \delta_0 + \delta_1 \Delta hpi_{t-1} + \delta_2 \Delta cc_{t-1} + \delta_3 \Delta population_{t-1} + \delta_4 ECT_{2,t-1} + \gamma_t \quad (5.10)$$

where, in the demand equation hpi_t denotes the natural logarithm of real house prices, in the supply equation $gfcf_t$ is the natural logarithm of the real GFCF in dwellings, which is real gross residential investment, $capitalstock_t$ is real residential stock,

$population_{t-1}$ is population and $realcc$ is the natural logarithm of real construction costs; other abbreviations are detailed in the note of Table 5.1. The error term $ECT_{1,t}$ captures the disequilibrium between the actual and equilibrium house prices. The estimated residuals $ECT_{1,t}$ and $ECT_{2,t}$ are included as ECTs in the equations explaining the short-term evolution of prices and investment. The coefficient of the $ECTs$, δ_4, is the fraction of the deviation in investment from the equilibrium that is corrected over the next period.

Table 5.3: Estimates of the demand-supply system on Australian housing market

	Variables	Coefficient	t-stat.	Prob.
Long-run equations				
Eq. (5.7) Dependent variable**:** hpi_t				
α_0	Constant	6.51	0.43	0.67
α_1	gdp_t	**1.38*****	3.49	0.00
α_2	$mortgage_t$	0.02	0.39	0.70
α_3	$capitalstock_t$	0.85	1.38	0.17
α_4	$population_t$	-1.60	-1.21	0.23
Eq.(5.8) Dependent variable**:** $gfcf_t$				
β_0	Constant	-2.79	-0.90	0.37
β_1	hpi_{t-1}	**0.57*****	7.29	0.00
β_2	cc_{t-1}	-0.35	-1.02	0.31
β_3	$population_{t-1}$	**0.58*****	2.83	0.00
Short-run equations				
Eq. (5.9) Dependent variable**:** Δhpi_t				
γ_0	Constant	-0.03	-2.28	0.02
γ_1	Δgdp_t	**0.34***	1.72	0.09
γ_2	$\Delta mortgage_t$	**-0.23*****	-4.99	0.00
γ_3	$\Delta capitalstock_t$	**2.67*****	2.99	0.00
γ_4	$\Delta population_t$	2.63	1.19	0.24
γ_5	ECT_{1t-1}	**-0.06*****	-3.57	0.00
Eq.(5.10) Dependent variable**:** $\Delta gfcf_t$				
δ_0	Constant	0.02	1.27	0.21
δ_1	Δhpi_{t-1}	**0.92*****	5.48	0.00
δ_2	Δcc_{t-1}	0.57	1.57	0.12
δ_3	$\Delta population_{t-1}$	-6.03	-1.36	0.17
δ_4	$ECT_{2,t-1}$	**-0.29*****	-8.67	0.00

Note: Δ denotes the first difference, small letter denotes the natural logarithm of variables. hpi_t denotes real house prices, $gfcf_t$ is the real GFCF in dwellings (which actually is volume of housing investment), $realcc$ is the real construction costs. Other abbreviations are detailed in the note of Table 5.1. Four equations are estimated simultaneously using Seemingly Unrelated Regression (SUR) estimator.

The system approach has an advantage as it allows for feedback between the supply, demand and the interaction between the variables. Four equations are estimated simultaneously using Seemingly Unrelated Regression (SUR) estimator to account for endogeneity, heteroskedasticity and contemporaneous serial correlations in the error terms across equations.

The result of the system of regressions reported in Table 5.3 shows some interesting results. In the long-run, GDP per capita determines house prices. Housing investment is cointegrated with housing prices and population. In the short run, the error correction mechanism holds as both $ECTs$ have negative and significant coefficients as expected, showing the existence of an adjustment process towards a long-term relationship. The results are consistent with the result in Column 6, Table 5.2, where the error correction terms (generated from cointegration regression between investment and real GDP, house prices and mortgage rate) play a significant role in converging house investment to its long-term equilibrium.

It is usually expected that increases in housing stock will lower house prices. However, here the capital stock does not show a significant and negative relationship with house prices. The result is plausible because house stock seems to increase gradually while house prices also increase, but at a much higher speed, over the last three decades. The increase in the pace of housing stock is slower than that of house prices, given that house prices have large volatility with boom and bust episodes.

Compared to the previous model Tobin's q analysed previously, the stock-flow approach as above has some similar implications. In the short-run, the change in housing investment is strongly determined by house price changes, and not by real construction costs. The coefficient of the construction cost variable in the long-run equation is not significant, implying the insignificant role of construction costs in house investment, which is confirmed by the q model. But in contrast, in the long run, according to the stock-flow model regression, investment is determined by demand variables (house prices and population). The Tobin's q model on the other hand does not have a strong power in explaining the long-run equilibrium of investment in the Australian context. Instead, Tobin's q seems to affect house investment in the short run.

The fact that the stock-flow model better than Tobin's *q* model in explaining housing investment has some implications. Tobin's *q* prime theory says investment is decided by *q*, investment keeps on going if *q* keep larger than one or a certain triggering threshold (maybe higher than one to compensate for uncertainty). In the other words, if the market value of an asset (present value of stream of future rentals imputed to the asset) is higher than its supply cost (or replacement costs), investment is carried out to make profit. The stock of asset will increase and make the future rentals of asset decrease, consequentially make asset market value decrease. Capital stock in the long run will reach to its long-run steady state or long-run equilibrium, where *q* is also stable and has no incentive to change.

According to *q* theory, *q* will drive investment including housing investment especially in the long run. However, according to the above empirical results, explanation power of *q* and of *q* based models in explaining housing investment dynamics seems to be moderate. This could be because of some reasons. First, *q* model bases on some assumptions shaping the housing market. One assumption is housing market combine radical investors to create an atomistic market producing houses with constant returns to scale. The housing market is assumed to be informational efficient, which means current prices represent all the information necessary for the investment decisions. These assumptions are often violated. According to DiPasquale and Wheaton (1994) housing investment is lumpy as building takes time and depreciation of the housing stock is slow. That leads housing stock adjusts slowly to changes in demand. The heterogeneity of housing generates search and transaction costs which make it difficult for households to react quickly to price signals. These inefficiencies of housing markets lower the capability of *q* model in explaining housing investment.

Stock-flow approach on the other hand explains well the housing investment dynamics, partially because it is not stuck with unrealistic assumptions of *q* model. The approach of stock-flow model has an important advantage that it accounts for the natures of the slow adjustment stock of housing and the lumpy flow of housing investment. The approach also eases dealing with housing dual role as a consumption good and as an asset, as well as explaining the price clearing mechanism in both short- and long-terms.

5.7 Conclusion

For a long time, residential investment has been considered an important driver of economic development. Using national and state level quarterly data from 1979 Q3 to 2011 Q4, this study investigates the main drivers of private residential investment in Australia. The Tobin's *q* model augmented with disposable income per capita, population, the mortgage rate and uncertainty is used, and the results suggest that the Australian aggregate residential investment growth rate is influenced by the change of Tobin's *q*. There is also evidence that at the national level, investment is influenced by the mortgage rate, the change in income per capita but not land prices. Findings also suggest that a change in uncertainty has an impact on housing investment. At state level, residential investment is influenced by *q* and mortgage rates. The findings also indicate that house investment is in line with business cycles. However, there is no long-term co-integration relationship predicted by the conventional *q* theory between the investment ratio and *q*. When the stock-flow model is applied, it appears to explain well the movement of investment flows. According the findings from this model regression, investment is mainly driven by demand side variables, including income per capita, population, the user-cost of house capital and mortgage rates.

5A.1. Data Appendix

Housing investment is measured as private GFCF in dwellings, at constant prices (Volume Chain Measure), already adjusted for seasonality. This data is from the ABS cat. 5206, Table 3. The data dates back to 1959 Q4. The ABS provides data on both, new house construction and renovation of existing housing stock. State level investment is from ABS cat. 5206.

Private house capital stock K_t is calculated using the perpetual inventory method as follows:

$$K_{t+1} = K_t(1-\delta) + I_{t+1}$$

where δ is the depreciation rate and I_t is investment. Following standard practice in the literature (see, for example, Coe and Helpman, 1995), the initial housing stock K_0 is interpolated based on the house investment data, its average growth rate and the depreciation rate as follows:

$$K_0 = \frac{I_0}{\delta + g}$$

where I_0 is the investment in physical capital in the initial period under consideration and g is the average geometric growth rate over the period 1979-2012. The rate of depreciation (δ) is assumed to be 2.5 per cent annually or 0.6% quarterly for Australian residential houses as used by the ABS (see ABS 1364.0.15.003 - Modellers' Database for detail).

House prices are from two main sources of quarterly house price indices: the ABS and the REIA. Aggregate house price data for Australia are from the ABS. The data consists of indices on the median house prices of cities in Australia. An overall house price index is constructed as a weighted average of the house prices of the cities. In this chapter, the data source for house prices at state level is from REIA dating back to 1980 Q1.

Housing construction cost data is from the ABS date back to 1966 Q3. Housing construction costs are based on the ABS price index of materials used in housing production. To convert housing construction costs and house prices into real terms, the CPI index is used as the deflator.

Rural land price data is from the Agricultural Bureau of Agricultural and Resource Economics back to 1978Q2.

The user-cost of owning a house consists of the mortgage interest rate, property tax, maintenance costs, tax deductibility of mortgage interest payments and an additional risk premium estimated by the following formula: $C = i(1-\tau) + \delta - \pi^e$, where i is the standard variable home loan interest rate; τ is the income tax rate used for interest deductions; δ is the depreciation rate, assumed to be 2.5% annually which is promulgated by the Australian Taxation Office (ATO) for dwellings; and π^e is the expected house price inflation, measured as the average quarterly house price appreciation from 1970 to 2012, plus the expected rate of inflation. This measure is used because it captures the long-term expected house price changes, a factor most relevant for house investors (see Hubbard and Mayer, 2009). The income tax rate is measured as the ratio between total direct income tax revenue and GDP. I do not have the data on property tax rates of Australia, so the rates are excluded from my model.

The output gap is measured as the residual from real GDP scaled by potential GDP obtained using the Hodrick-Prescott filter method with a smoothing parameter of 1600 (see Hodrick, and Prescott, 1997, for the calculation method) and then scaled by the GDP trend. Business cycles can be proxied by a measure of the GDP gap, defined as the difference between real GDP and potential GDP, scaled by potential GDP. The change in this difference arguably proxies for expectations regarding the overall economic outlook, as explained in previous empirical studies (Sundararajan and Thakur, 1980; and Ang, 2009). Thus, the larger the difference between the potential GDP growth and observed GDP growth, the greater the expectation that there will be an increase in GDP growth in the future, and vice-versa.

Uncertainty is measured by the Westpac Leading Index, provided monthly by the Westpac Melbourne Institute of Economic Activity Indices. The data is obtained from Datastream, starting from January 1960. A GARCH (1,1) model for the monthly annualized growth rate is estimated. The estimated variance is then used as uncertainty in the investment model as the average of conditional variances estimated from a GARCH model of the respective months. My method is similar to Episcopos (1995).

5A.2. Appendix 1

Table 5.A.1: Unit root test statistics

Variables	Augmented Dickey–Fuller		Zivot-Andrews test on level		Results
	Level	1st difference	Level	Break point	
	t-Stat	t-Stat	t-Stat		
$ln(K)$	-2.30	-2.87*	-4.72	1978q4	I(1)
$ln(cc)$	-2.91**	-2.12	-4.20	1986q4	I(0)/I(1)
$ln(GDPperca)$	-0.00	-8.74***	-3.97	1997q2	I(1)
$ln(realGDP)$	-2.52	-5.43***	-4.94	1974q1	I(1)
$ln(I)$	-2.39	-6.69***	-5.86***	1982q1	I(0)/I(1)
$ln(HPIreal)$	-0.27	-6.09***	-4.05	2000q4	I(1)
$ln(I/K)$	-2.82*	-6.80***	-6.62***	1982q1	I(0)/ I(1)
$ln(mort)$	-1.77	-2.82*	-4.24	1991q3	I(1)
$ln(population)$	0.64	-2.00	-2.62	2001q2	I(1)
$ln(q)$	0.019	-6.19***	-3.30	2001q2	I(1)

Note: For ADF test, MacKinnon critical values for rejection of hypothesis of a unit root: are used *10%=−2.59; **5%=−2.91; ***1%=−3.55. The selection of appropriate truncation lag lengths in the estimated regression equation was determined on the basis of Akaike's AIC criterion. For Zivot-Adrews test, critical values are: 1%: -5.57 5%: -5.08 with a break point allowed in both trend and intercept. Null hypothesis of both ADF and Zivot Adrews tests is there exist a unit root in the time series being tested.

Table 5.A.2: Westerlund panel co-integration test results on four variables: housing investment ($ln(I)$), the mortgage rate ($ln(mort)$), real GDP ($ln(realGDP)$) and real house price ($ln(HPIreal)$)

Statistics	Value	*z*-value	*p*-value
Gt	-3.38	-3.43	0.00
Ga	-18.78	-3.14	0.00
Pt	-8.84	-3.23	0.00
Pa	-17.33	-4.26	0.00

Panel co-integration test was conducted using the Westerlund error-correction-based panel co-integration test (Westerlund, 2007). The underlying idea is to test for the absence of co-integration by determining whether there are error corrections for the individual panel members. There are four panel cointegration tests, and their results confirm the existing of a co-integrating relationship amongst four variables, as the null hypothesis of absence of co-integration is rejected (all p values are smaller than 0.01).

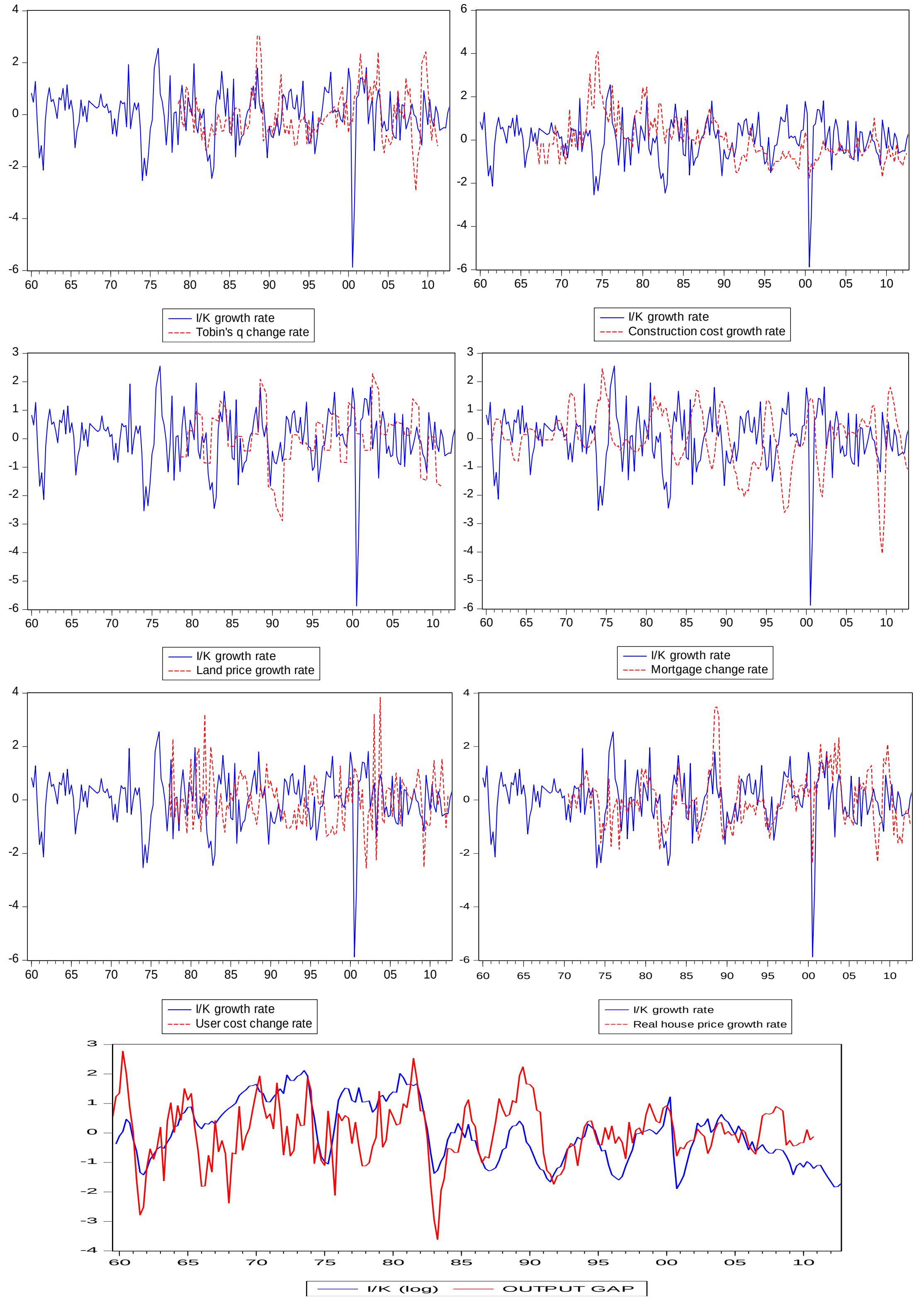
Table 5.A.3: Panel unit root test statistics

	Im-Pesaran-Shin test		ADF-Fisher panel unit root test		Result
	Level	First difference	Level	First difference	
	p-value	p-value	p-value	p-value	
$Ln(HPIreal)$	1.00	0.00***	1.00	0.00***	I(1)
$Ln(realGDP)$	1.00	0.00***	1.00	0.00***	I(1)
$Ln(cc)$	0.00***	0.00***	0.00***	0.00***	I(0)
$Ln(mort)$	1.00	0.00***	1.00	0.00***	I(1)
$Ln(I/K)$	0.00***	0.00***	0.02***	0.00***	I(0)
$Ln(GDPperca)$	0.72	0.00***	0.81	0.00***	I(1)
$Ln(q)$	0.99	0.00***	1.00	0.00***	I(1)
$Ln(I)$	0.45	0.00***	0.71	0.00***	I(1)
$Ln(K)$	1.00	0.00***	1.00	0.02***	I(1)

Note: *** p<0.01. Because panel unit root tests provide many statistics, only p-values are shown. In the Fisher-type test, PPerron option with four legs is chosen. The p-values are of Inverse chi-squared statistics.

5A.2. Appendix 2

Figure 5.A.1: Patterns in private residential investment growth, residential Tobin's *q*, construction costs, land prices, mortgage rates and user costs



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Chapter 6

Conclusion

Using data on Australia, this thesis has focused on investment dynamics at various levels and sectors. Specifically, the thesis examines dynamic patterns of investment growth over the past four decades at the state and the national level in Australia. Also, by identifying determining factors that affect house prices, an attempt has been made to try and understand the short-term and long-term movements of house prices overtime, at the state and national level. The contribution of this thesis is in public policy matters, as it offers valuable insights for the Australian government, aiding in developing new policies for investment and housing.

Main findings

This thesis is a collection of four related papers. The first paper, Chapter 2, examines the application of Tobin's *q* model in aggregate investment in Australia. A major contribution of this chapter is the construction of the aggregate Tobin's *q* data for Australia using the method developed by Laitner and Stolyarov (2003) and Wright (2004). Then Tobin's *q* model is augmented with demand constraint variables, fundamental value of firms and uncertainty. The overall results indicate that, *q* is found to be a highly significant driver of long-term investment. Furthermore, the magnitude of the coefficient of *q* is large and strongly dominates, pertaining to the fundamental value of the representative firm as proxied by cash flow. Thus, abstracting from business cycle fluctuations, the Australian capital market is relatively strongly driven by the fundamental value of capital.

Particularly, results of Chapter 2 suggest that changes in the level of uncertainty in the equity market, as measured by the fluctuations in the volatility of stock prices, are revealed to be significantly associated with investment. It shows that it is the change in the level of uncertainty observed in the stock market, rather than the level of uncertainty itself, that is important in driving short-term decisions pertaining to investment. Moreover, as stock market volatility only accelerates prior to investment down turns, uncertainty is found to be a key driver of investment downturns. The final result of Chapter 2 is that income per capita significantly affects investment during business cycle fluctuations. However, I find that the persistence in the rate of growth of investment is only triggered by a continual corresponding increase in the rate of growth of income per capita. These results reveal that investment rates are likely to only increase when the economy is at the initial and accelerating phase of its cyclical upswing and that rigidities pertaining to the demand side of the economy can have a substantial impact on the timing and magnitude of investment fluctuations.

In Chapter 3, a rigorous examination of the key factors that are expected to impact on firms' investment activities is carried out; in particular, I examine the effects of uncertainty on Australian firms' investment. The existing literature shows conflicting evidence on the relationship between investment and uncertainty, while also providing inconclusive results of the Tobin's *q*. Therefore, the chapter examines *q* theory and the role of uncertainty in Australian firms, by applying the Generalised Method of Moment (GMM) technique for my panel data set, 1987-2009. Moreover, unlike previous studies I employ uncertainty proxies that have been used very recently in only small number of countries. Although, the primary measure of uncertainty is the volatility of firms' stock price returns, the chapter additionally incorporates a new CAPM based method of measuring idiosyncratic uncertainty.

Regression results in Chapter 3 show that there is a negative relationship between investment and uncertainty, while its effect depends on the different proxies used and the characteristics of firms. The other explanatory variables found to be important for firms' investment decisions are, Tobin's *q*, cash flow, leverage and sales. The coefficient of the variable measuring uncertainty is consistent and significant with alternative models (static Tobin's *q* and the dynamic panel data model). It is found that the sign and strength of the relationship depends upon the market power of the firm and the degree of financial constraints it faces. The effects of uncertainty also vary with firm size. While, after controlling for fundamental variables, firm specific uncertainty is more relevant for investment decisions than macroeconomic uncertainty.

Aimed at analysing house price movements, Chapter 4 tests the robustness of an empirical model developed from a theoretical behavioural model of house price similar to that of Madsen (2012). This research is the first attempt to analyse the role of nominal variables on house prices and to use land prices, proxied by agricultural land prices, in the long-term co-integration relationship of house prices and their acquisition costs in Australia. Additionally, this chapter employs a much larger database than previous studies analysing the Australian housing market.

The empirical model has been regressed using both national and state-level data. Results of Chapter 4 suggest that a long-term relationship of house prices, land prices and construction costs exists. Also, apart from the user-cost of capital model, the empirical model, named a behavioural model, seems to explain price movements in Australia more effectively than the other conventional models. There is evidence that the increases in house prices are due both to the short-run effects of demand variables (for example, income, the mortgage rate and financial commitments) and long-run effects of supply variables such as, construction costs and land prices.

Chapter 5 revisits two popular models of housing investment, the *q* model and the stock-flow model, to explain housing investment in Australia. A first difference OLS regression model based on *q* theory is estimated using data at the national level and at the state level. In this chapter, the Tobin's *q* model of investment is augmented to account for the effect of economic uncertainty on housing investment in Australia.

Overall, findings of Chapter 5 suggest that Tobin's *q* concept is important in housing investment decisions in Australia. However, no co-integration relationship between Tobin's *q* and the investment ratio exists. The traditional stock-flow approach is applied and appears to better explain the movement of investment decisions. Results show that investment is mainly driven by demand side variables, including income, population, the user-cost of housing and financial costs. Uncertainty and construction costs are also revealed to be significant for investment but with vague signs, whereas business cycles have a very distinct impact on housing investment.

The importance of investment and housing for the wider and micro economy justifies the research undertaken in this thesis. An important issue that arises in the history of investment in Australia that has been addressed in this thesis is to find an accurate empirical explanation for the movements in investment over time. Tobin's q again proves to be a good theoretical as well as an empirical model in explaining investment at the aggregate level when the noise and heterogeneity has been phased out. In regards to the housing market, housing investment does not follow q theory, however an increase of the q ratio does provide some incentives for investment. Given the empirical results of this thesis in terms of housing investment, a theoretical model that incorporates the interaction between supply and demand forces, and particular characteristics of houses is most required. Therefore, this thesis has filled a large gap in the investment literature in regards to the Australian market. However, the results obtained lead us to pose new questions, paving the way for greater research on the investment dynamics in Australia.

Thesis limitations and suggestions for future research

The limitations of the thesis can provide background for the further research in the future. Regarding Chapters 2 and 3, the theoretical set up is very conventional, highly simplified and clearly designed to make the solution process and estimation easier. The equations and proofs are limited to only those that set up the optimisation problem and those that summarize the key results and form the basis of the empirical investigation that follows. In Chapter 2, in addition to GDP, more determinant variables which could be important for investment could be added in the main models. For instance, user cost of capital, which could be measured as real interest rates, should be a variable of interest. Moreover, different methods of measuring fundamental values of firms could be used as in Greasley and Madsen (2006). The usage of new measures of fundamental values of firms could shed new light on the roles of fundamentals on business investment.

In Chapter 3, one of main novelties of this chapter is the use of new and very informative databases. The regression models and results are the same as the ones found in published works. However, other questions could also be addressed as well; instead of rather replicating previous results with the new data. For example, there should be research on how firm specific and macroeconomic uncertainties affect small and large firms' investment decisions differently in Australia. The same question could be applied to resource and non-resource firms.

Theoretically measure of uncertainty should capture uncertainty regarding future returns to investment. A controversial point in the thesis is whether it is sufficient to use variance or volatility on market returns or other past variables to measure uncertainty about the future. The current approaches have the same limitation when used for forecasting, that they are rather ex-post. The future research could be applying new rather ex-ante methods to measure uncertainty, such as using risk premium embedded in the term structure of interest rates (e.g. in Ferderer, 1993) or implied volatility from firm options price.

Of course there are justifications for the usage of stock return volatility as proxy for uncertainty. The value of firms on the stock market should reflect all current concerns regarding future expected returns to investment; any information available in the current period regarding future expectations will be incorporated into the price of stocks today. Accordingly, should there be any expectations regarding policy uncertainty with respect to a certain industry or highly uncertain or variable expectations regarding future economic conditions, corresponding stock values and the volatility of these should price these potential costs and the variability of these costs based on uncertain expectations. The shortcoming here is volatility of stock prices is reflective of rather general uncertainty, and it is not specified whether this uncertainty is caused by policy uncertainty, increased industry risk or firm specific risk, uncertainty future cash flows or uncertain investment environment. There are opportunities for further research regarding investment behaviour under the impacts of different types of uncertainty that are specific to Australia.

The fact that Chapters 4 and 5 focus only on Australian context could create certain biases in the chapters' empirical tests and implications. Australian economy and firms have particular characteristics which if not being controlled properly can lower the significance of empirical findings as well as the robustness of the models used. In the future research, it would be advised to perform empirical tests for the proposed models under different markets and different market conditions.

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