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Uncertainty and investment dynamics in the Australian mining industry

Yiqun Ma
University of Wollongong

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Uncertainty and Investment Dynamics in the Australian Mining Industry

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Associate Prof. Charles Harvie

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School of Accounting, Economics and Finance

October 2016
Declaration

I, Yiqun Ma, declare that this thesis submitted in partial fulfilment of the requirements for the conferral of the degree Ph.D. in Economics, from the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.

Yiqun Ma
October 17, 2016
Abstract

The relationship between uncertainty and investment in the Australian mining industry remains unclear, especially after the global financial crisis. Similarly, research on the extent to which Australian private investment is affected by uncertainty and other macroeconomic, microeconomic and industry wide factors are sparse.

The goal of this thesis is to examine the impact of uncertainty, user cost of capital, demand shocks, and firm features on Australian private investment at different levels. To achieve this goal, this thesis applies empirical models such as the Generalised Autoregressive Conditional Heterogeneity (GARCH) model, the Ordinary Least Squares (OLS) method, and the Generalised Method of Moments (GMM). This study also examines how Australian investment responds over time to macroeconomic, industry-level and firm-level uncertainty.

Using the method of Bloom et al. (2007), this study reaches some novel conclusions on Australian private investment behaviour. At the macroeconomic level, the significantly positive effect of demand uncertainty on macroeconomic investment is only observed in the long term, while the negative effect of uncertainty in terms of trade is significant and persistent in both the short and long terms. In addition, the relationship between Chinese GDP growth uncertainty and macroeconomic investment, while expected to be negative, in fact is positive in the long-run estimation. By contrast, the relationship between nonlinear demand shocks and macro investment is negative. The long-term and positive effects of changes in company income tax and terms of trade are also captured. At the industry level, the test shows that uncertainty in demand, uncertainty in exchange rate expenses, and uncertainty in
Chinese GDP growth have no significant effects on investment. Across all different industries, the significant effects on investment at the macroeconomic level are reduced. At the firm level, demand uncertainty is not the only factor to have a negative impact on investment in the mining industry. Moreover, when considered along with the features of mining firms, the effect of demand uncertainty on the short-run investment response to demand shocks is positive. The effect of changes in exchange rate costs is also positive, while the effect of firm size and the long-run effect of demand uncertainty is negative. In addition, firm investment is driven by small firms with large market capitalisation and Chinese ownership. Some results are consistent with the highlights in the reviewed literature. Interpretation of these results helps in understanding Australian private-investment behaviour in the mining industry, and the industrial sector in general.

**Keywords:** Irreversible Investment; Uncertainty; Australian Mining Industry
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Abbreviations

ABS  Australian Bureau of Statistics
ARCH Autoregressive Conditional Heteroskedasticity
ARMA Autoregressive Moving Average
ARIMA Autoregressive Integrated Moving Average
ECM  Error Correction Model
FE   Fixed Effects
GARCH Generalised Autoregressive Conditional Heteroskedasticity
GLS  Generalised Least Squares
GMM Generalised Method of Moments
IV   Instrumental Variable
NBSC National Bureau of Statistics of China
OLS  Ordinary Least Squares
RBA  Reserve Bank of Australia
RE   Random Effects
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Chapter 1

Introduction

1.1 Introduction

In economics, research on investment has received considerable and long-lasting attention. Economic theories, at the macro level, have declared that investment is one of the main sources of economic growth. At the micro level, investment (capital input) is also considered to be a crucial factor for productivity.

To explore how economic growth is driven by investment, it is worth drawing attention to theories of economic growth. The principal elaboration on the source of economic growth is the Solow model, which is also the departure point for many growth theories. As noted by Romer (1996), the Solow model is built on four variables: output ($Y$), capital ($K$), population ($L$), and technological progress ($A$). The fundamental conclusion of the Solow model is that in a steady state the economic growth in different variables ($Y, K$) is determined by the constant rates of technological progress ($g$) and population ($n$). As argued by Romer (1996), in the long run the growth in population and technology helps economic growth converge to a steady state, while in the short term an increase in investment may cause higher-than-normal economic growth. This has motivated economists to rethink the role of investment in economic growth.

In the short term, the Solow model may not provide a convincing explanation for the recently observed Australian economic growth, especially the boom that until
recently dominated the mining sector. In practice, the Australian economy is closely linked with private investment (fixed capital formation). As shown in Figure 1.1, Australian private investment increased sharply from nearly AU$38 Billion in 2003 to around AU$90 Billion in 2012. This was accompanied by an increase in the share of investment in nominal GDP from 18% in 2003 to 24% in 2012. These years are in line with the period of the mining boom. Australian private investment rose sharply between 2000 and 2012 compared to its levels in 1980–2000. Notably, the period of the Australian economic expansion appears to be consistent with the period of the mining boom.

The main driving force of the Australian economy since the 2000s has been the mining industry. The Australian mining industry produces a range of bulk commodities, such as coal, iron ore, bauxite, copper, and gold, in large quantities. Since 2000, its contribution to Australian economic growth has risen rapidly. In addition, the close relationship between the mining industry and the Australian economy is evident from four aspects: exports, revenue, employment and investment.

Figure 1.2 depicts the prominent role of the mining industry in the Australian economy.

---

1This is a rough comparison of growth in investment between 2000–2012 and 1980–2000. All detailed descriptions are discussed in Chapter 2. In addition, for the purpose of consistency with other graphs for background discussion, the ending year is 2012 unless otherwise stated.
1.1. INTRODUCTION

economy. After 2010, both export volumes and export values in the mining industry stood at above 50% of total exports. After 2005, mining added more than 9% of gross value to the whole economy. After the trough in 2000, the employment rate in the mining industry recorded a high of 2.2% of total employment in 2012. Since 2000, the share of mining investment in GDP has grown rapidly, at an annual average rate of 3%. More fundamentally, the value of private mining investment accounted for approximately 30% of Australian GDP in 2012, which was unprecedented.

Figure 1.2: Contribution of Mining Industry to the Australian Economy, 1980 to 2012 (measured by nominal price in 2012).
Source: Graphed using data from ABS (2012) and author’s calculation.

During this period, the growth of the Australian mining industry was also driven by strong demand from China, and led to a steep incline in Australian mining invest-
1.1. INTRODUCTION

ment. Figure 1.3 shows the trend for the share of Australian mining investment in total mining revenues, which corresponds to the movement of the share of mining investment in Australian GDP (Figure 1.2). Along with this magnitude of investment, prices and volumes of bulk commodities exported to China rose rapidly. Despite the overwhelming increase in mining investment beginning in 2000, there were two notable declines during 1997–2000 and 2009–2010. These periods correspond to the Asian economic crisis and the global financial crisis. The variation in mining investment is also in line with the volatility of downstream demand. Consequently, demand shocks seem to have influenced investment and earnings in the Australian mining industry.

![Figure 1.3: Share of Australian Mining Investment in Total Mining Revenues, 1987–2012 (measured by nominal price in 2012)](image)

Source: Graphed using data from ABS (2012) and author’s calculation.

Although they are operating within the context of a historical high in total mining investment, many Australian mining companies may be cautious about investing substantial amounts after the global financial crisis. For example, due to unexpected demand volatility in the commodity market, appreciation in exchange rates, and increased tax pressures, Australia’s largest mining producer, BHP Billiton, announced that its US$20 billion copper and uranium project at Olympic Dam would cease on August 22, 2012 (Duffy, 2012). Furthermore, the large sunk cost
1.2. RESEARCH QUESTIONS

may have compounded entrepreneurs’ concerns about investing under conditions of demand uncertainty.

To analyse the relationship between investment, uncertainty and irreversibility, Dixit and Pindyck (1994) claim that high demand uncertainty may delay the timing of irreversible investment. However, using both firm-level and plant-level data, Bloom et al. (2007) argue that under high uncertainty demand shocks have a convex impact on firms’ investment. There seems to be less consensus on the effect of uncertainty and irreversibility on investment, especially in the Australian mining industry.

The goal of this thesis is to explore the nature of investment in the Australian mining industry, and to empirically test the relationship between uncertainty, irreversibility and investment in Australian mining companies over the business cycle.

1.2 Research Questions

This thesis systematically examines the impact of uncertainty and irreversibility on private investment by testing Australian mining data at the firm, industry and macroeconomic levels. To achieve this objective, the following questions are examined:

1. What are the determinants of Australian investment behaviour at the macroeconomic, industry and firm levels?

2. What is the relationship between uncertainty, irreversibility and investment in Australia at each level?

3. Does the mining industry have a significant impact on the Australian economy?  

---

2 An irreversible investment is one that has a large sunk cost. The cost of this investment cannot be recovered once it is installed.

3 As early as Knight (1921), uncertainty has been defined as a key risk to investment. This study accepts the broad concept, that is, volatility over the macro indices, such as GDP growth, interest rates, and taxes, which are addressed in the subsequent analysis. As specified by Bloom (2014), uncertainty can be provoked by both endogenous factors, such as slow economic recovery, and exogenous factors, such as financial panic, wars, and surges in resource prices. Variables of uncertainty, irreversibility and investment are also defined in Chapter 4.
1.3 Contributions

These research questions are the starting points for a comprehensive study of Australian private investment behaviour at various levels. Based on time series data and panel data, the data description delineates the volatile behaviour of different investment variables. The Generalised Autoregressive Conditional Heteroskedasticity (GARCH) method is adopted to derive uncertainty measures. In terms of these uncertainty measures, and other relevant data, investment estimations at various levels are empirically conducted using the error-correction model (ECM). The ordinary least squares (OLS) method, the fixed-effects (FE) method, and the generalised method of moments (GMM) are used to test the robustness of results.

The main empirical results show that at the macroeconomic level, demand uncertainty has a long-run positive effect on investment, while the long-lasting effects of uncertainty in terms of trade is negative. The effect of Chinese GDP growth uncertainty on macroeconomic investment was expected to be negative, but in fact the long-run estimation shows it to be positive. Similarly, the presumed concave relationship between demand shocks and investment is revealed as convex. The effects of changes in income tax and terms of trade on macroeconomic investment in two tests are significant and positive. At the industry level, linear demand shocks and uncertainty in company income tax are found to have a positive effect. At the firm level, investment has a positive response to demand shocks, due to the effect of Chinese ownership. The firm-level estimation shows a positive relationship between changes in exchange rate costs, market capitalisation, Chinese ownership and investment. Demand uncertainty positively affects the short-run investment response to demand shocks. However, the results show a negative relationship between firm size, long-run effect of demand uncertainty and investment.

The primary contribution of this study is that it is the first to extend the scope of the analysis of Australian private investment at the macroeconomic level to disaggregated estimates at the industry and firm levels. The empirical models are tailored to the observable features of Australian private investment behaviour at
1.3. CONTRIBUTIONS

various levels. The results of these models have numerous implications for adjusting investment under different economic circumstances, and understanding relationships between key economic factors and investment. The findings of this study are novel for understanding the Australian mining industry.

The investment estimations at the macro, industry and firm levels accommodate detailed analyses at both the aggregated and disaggregated levels. To this extent, the estimation of investment behaviour can be compared and discussed. More importantly, the analyses at both the aggregated and disaggregated levels are useful for implementing relevant policies at the macroeconomic, industry and firm levels.

The examined period for investment behaviour at different levels covers 1990–2012. The 1990–2012 period corresponds to structural changes in the Australian economy and the mining industry, the sharp rise in Chinese demand, and other major economic events. Apart from that, the comparison of investment behaviour over the 1960–2012 and 1990–2012 periods helps in understanding short-term and long-run investment determinants.

The selection of consistent explanatory variables reduces the heterogeneity of investment analyses at different levels, and increases the accuracy of the analyses. Intuitively, this study provides a comprehensive picture of Australian investment behaviour. Furthermore, the interacted uncertainty is used at industry and firm levels to examine the effect of uncertainty on investment at the disaggregated level.

This study is organised sequentially as follows. Chapter 2 discusses the background of the Australian economy and the mining industry. Chapter 3 briefly reviews related theoretical and empirical literature. Chapter 4 discusses some useful approaches to establishing the appropriate empirical models. Chapter 5 estimates investment behaviour at the macroeconomic level. Chapter 6 estimates investment behaviour at the industry level. Chapter 7 estimates the investment behaviour at the firm level. Chapter 8 concludes.
Chapter 2

Australian Economy and its Mining Industry

2.1 Introduction

This chapter introduces the underlying nature of Australian mining investment, which provides a context for the empirical modelling in subsequent chapters. The discussion ranges from the relationship between the sources of Australian economic growth to the role of the Australian mining industry. Firstly, an overview of the Australian economy identifies some of its dominant drivers. These include structural changes in the Australian economy, the relationship between these changes and rising Chinese demand, and monetary and fiscal policies to secure economic stability. Secondly, this chapter describes some impacts of the Australian mining boom on the economy as a whole. This deepens the understanding of the significance of the mining industry to the Australian economy.

This chapter is organised as follows. Section 2.2 explores structural changes in the Australian economy. Section 2.3 discusses the role of investment in Australian macroeconomic growth. Section 2.4 deconstructs the discussion of the relationship between the mining industry and the Australian economy into GDP, employment and trade.
2.2 Australian Macroeconomic Changes

This section briefly presents some historical changes in the Australian macroeconomy. These changes are related to factors, such as GDP, the labour force, investment performance and international trade. These changes have constituted some main components of the growth of the Australian economy. More significantly, an analysis of changes in the Australian macroeconomy may also assist in explaining the development of the Australian mining industry.

2.2.1 GDP Growth and GDP Components

Figure 2.1 depicts the growth in Australian GDP from 1960 to 2012. From the 1960s through the 1980s, the Australian GDP grew overall, albeit with large swings, and then tended to be steady in the 1990s and early 2000s. The difference between two periods may primarily be due to the adoption of a floating exchange rate in 1983, the implementation of inflation targeting in 1993, and strong economic growth in China in the 2000s.

![Figure 2.1: Real Australian Economic Growth, 1960–2012](Source: Graphed using data from ABS (2012)).

More specifically, the period between 1960 and 1970 recorded the first long period of Australian GDP growth. During this period, the growth rate continuously
increased from 2.91% in 1966 to 7.25% in 1967. In addition, the growth rate was above 5% for the period, with the exception of 1966.

The 1970s saw comparatively slow growth, with an average growth rate of 3.3%, followed by volatility in the 1980s. During the period 1982–1984, the rate declined to –0.39% in 1982, and then rose to 6.58% in 1984, and again in 1986 and 1987.

The Australian economy in the years 1990–2009 was marked by long-lasting and stable growth. Except for the recession in 1991, the growth rate over these 20 years was positive, and ranged between 2 and 5%. Therefore, Australia was not severely affected by the crises in 1997 and 2008.

The reasons for differences in Australian GDP growth between the 1960s–1980s and 1990s–2000s are threefold. Firstly, the floating exchange rate was introduced in 1983 with the aim of stabilising the domestic economy against foreign shocks: when overseas economies were overheated, the Australian dollar could now rise to ease the pressures of inflation; by the same token, it could fall to cushion the effects of negative shocks in times of when overseas economies were overheated. Similarly, when the Australian dollar was falling, it cushioned the effects of negative shocks in times of global economic downturns (Kearns and Lowe, 2011).

Secondly, the introduction of inflation targeting in 1993 guaranteed strong confidence among investors on the future development of the economy. To prevent any distortion in price levels, the Reserve Bank of Australia began to maintain the inflation rate at a sufficiently low level of 2–3% on average. This policy diminished market uncertainty and corrected the expectations of businesses and households (Kearns and Lowe, 2011), thus protecting investment against internal shocks.

Thirdly, rising Chinese demand for Australian resources has contributed to the mining boom and unprecedented mining exports since the 2000s. In particular, industrialisation and urbanisation in China, as well as Australia’s proximity to Asian markets, has led to the substantial export of coal, oil and gas, and iron ore. These mining exports also helped Australia maintain a strong economy during the economic crises in 1997 and 2008.
2.2. AUSTRALIAN MACROECONOMIC CHANGES

The solid growth of the Australian economy seems to be overwhelmingly driven by strong private consumption. As shown in Figure 2.1, private consumption accounted for nearly 50% of GDP for over 50 years. In turn, stable economic growth has led to moderate rises in employment and wages, resulting in robust rises in domestic-assets prices. These rises, coupled with the stable economic conditions, have made households willing to spend and to apply for loans for housing and the stock market.

Net exports and fixed investment took different paths. Net exports were around 10% of GDP until the end of 1990. From 1991 to 1997, the volume of net exports grew rapidly to 22% of GDP, while in the 2000s it remained steady at around 21%. On the other hand, fixed investment stayed at about 16% between 1960 and 2000, and rose from 18% in 2001 to 27% in 2011. The increase in investment was in line with the timing of the mining boom. Subsequent sections explain this in more detail. Notably, over 50 years, there was no large variation in Australian government consumption.

In summary, there has been solid economic growth in Australia, especially between 1990 and 2000. This growth may be attributable to the series of changes in monetary policies (the floating exchange rate in 1983, and inflation targeting in 1993), and surging demand from the Chinese economy. To further interpret this economic growth, the changes in the Australian macroeconomy are discussed below.

2.2.2 Changes in the Australian Macroeconomy

This section discusses the background to changes in the Australian macroeconomy. Table 2.1 shows the evolution of economic indicators in Australia (for example, investment, employment and balance of trade) and their influence on Australian economic growth.

The pace and size of GDP per capita growth has not been consistent with GDP growth (Table 2.1). Although GDP growth was steady at roughly 3% between 1970 and the early 2000s, GDP per capita fluctuated between a low of 1.48% in the 1970s
to a high of 2.39% in the 1990s, and grew less overall than GDP. One reason may have been the increasing population, resulting in a large inflow of labour and decline in unemployment.

The accumulation of capital was another notable factor. The changes in the proportions of fixed and private investment show a similar pattern. They began at 30% and 22%, respectively, in the 1960s and decreased to 27% and 20%, respectively, in the 1970s and 1980s. A drop in both types of investment in the 1990s was followed by a sharp increase in the 2000s. Private investment made up the majority of capital inputs.

Table 2.1: Breakdown of the Australian Macroeconomy (decade averages, percent)

<table>
<thead>
<tr>
<th></th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
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<tr>
<td>Real GDP growth</td>
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<td>3.31</td>
<td>3.46</td>
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<td>Real GDP per capita growth</td>
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<td>1.48</td>
<td>2.07</td>
<td>2.36</td>
<td>1.96</td>
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<td>Employment growth</td>
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<td>1.66</td>
<td>2.38</td>
<td>1.29</td>
<td>2.26</td>
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<tr>
<td>Unemployment rate</td>
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<td>3.92</td>
<td>7.6</td>
<td>8.81</td>
<td>5.48</td>
</tr>
<tr>
<td>CPI inflation</td>
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<td>9.79</td>
<td>8.4</td>
<td>2.51</td>
<td>3.17</td>
</tr>
<tr>
<td>Fixed investment (% of GDP)</td>
<td>30.63</td>
<td>27.91</td>
<td>27.35</td>
<td>24.45</td>
<td>26.41</td>
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<tr>
<td>Private investment (% of GDP)</td>
<td>22.28</td>
<td>20.10</td>
<td>20.04</td>
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<td>21.77</td>
</tr>
<tr>
<td>Public investment (% of GDP)</td>
<td>8.42</td>
<td>7.73</td>
<td>7.33</td>
<td>5.31</td>
<td>4.68</td>
</tr>
<tr>
<td>Domestic saving (% of GDP)</td>
<td>30.72</td>
<td>28.69</td>
<td>25.83</td>
<td>23.98</td>
<td>25.25</td>
</tr>
<tr>
<td>Export growth rate</td>
<td>8.72</td>
<td>16.43</td>
<td>11.14</td>
<td>6.39</td>
<td>9.41</td>
</tr>
<tr>
<td>Current account (% of GDP)</td>
<td>-1.83</td>
<td>-1.14</td>
<td>-4.08</td>
<td>-3.97</td>
<td>-4.68</td>
</tr>
<tr>
<td>FDI (% of GDP)</td>
<td>1.71</td>
<td>1.04</td>
<td>0.69</td>
<td>0.96</td>
<td>1.41</td>
</tr>
<tr>
<td>External debt (% of GDP)</td>
<td>N.A.</td>
<td>6.18</td>
<td>19.88</td>
<td>37.70</td>
<td>46.94</td>
</tr>
<tr>
<td>Trade Weighted Index (May 1970=100)</td>
<td>N.A.</td>
<td>99.17</td>
<td>72.10</td>
<td>55.90</td>
<td>59.79</td>
</tr>
</tbody>
</table>

Notes: Data for external debt from 1960s to 1970s is missing.
Domestic saving is defined as total investment (fixed and variable) plus current account
Source: ABS (2012), RBA (2012) and author’s calculation

In contrast to the changes in the two types of investment, the unemployment rate and the inflation rate seemed to behave differently. According to the Phillips Curve 4,

4The Phillips Curve is a historical inverse relationship between rates of unemployment and relevant rates of inflation in an economy. In a simple AD-AS model, a decreased unemployment rate (in other words, an increase in employment) in an economy will correlate with higher rates of inflation (Romer, 1996).
a rise in CPI is accompanied by a fall in the unemployment rate. However, there was no obviously positive or negative relationship between CPI and the unemployment rate (Table 2.1). The unemployment rate rose between the 1960s and the 1990s, and peaked at 8.81% in the 1990s, while CPI recorded a high of 9.79% in the 1970s and dropped to 2.51% in the 1990s. After the 1990s, the low CPI growth was maintained at 2–3%, while the unemployment rate rapidly decreased from 8.81% in the 1990s to 5.48% in the 2000s. Nevertheless, the growth in employment did not keep pace with the fall in the unemployment rate. Since 2000 the mining boom has resulted in a greater rise in capital inputs than labour inputs. Inflation targeting established a low-inflation environment that appealed to investors.

The gap between investment and domestic saving from the 1980s to the 2000s was primarily financed by current account deficits through external debt. Given that the gap between investment and domestic saving was around 1% for the period, the growth of FDI was also steady at 1%. At the same time, external debt rose dramatically from 19.88% to 46.94%. Despite the sharp growth in exports, the current account turned out to be in deficit over the whole period. Simultaneously, external debt increased accompanied by growth in exports and private investment. This was due to increasing demand from the Asian investors (Japan and China) for Australian mining resources. Therefore, the increase in private investment, especially mining investment, was driving the increase in the external debt. In addition, the period of the mining boom witnessed an appreciation in the Australian dollar, which was evident from the increase in the Trade Weighted Index (TWI)\(^5\) from 55.90 in the 1990s to 59.79 in the 2000s.

In all, the changes in the Australian economy in the 1990s–2000s were characterised by sharp growth in private investment, an increasing rate of exports, a large volume of external debt, and an appreciation of the Australian dollar. These changes may be closely related to the resource-intensive growth of the Chinese economy.

\(^5\)The Trade Weighted Index is an alternative form of the effective exchange rate index, which is weighted by the trade index. An increase in the TWI means a rise in the purchasing power of that currency.
2.2.3 Relation with Chinese Economic Growth

Chinese GDP growth has averaged 10% per year since 2003. Figure 2.2 presents historical Chinese GDP growth. After the introduction of economic reform, Chinese GDP growth ranged from 15.2% in 1984 to 3.8% in 1990. After the economic shock in 1997, Chinese GDP growth accelerated. From 2003 to 2007, this rate surged from 10% to 14.2% without any fluctuations. After the adjustment of the global financial crisis in 2008, Chinese GDP growth still remained at roughly 10%.

The high growth in Chinese GDP after 2003 was accompanied by high demand for natural resources. As shown in Figure 2.2, there was a steep increase in the Chinese share of world steel production after 2003. During this period, the large quantity of steel production was driven by Chinese industrialisation and urbanisation. This implies that Chinese GDP growth relied heavily on a large amount of resource consumption, such as iron ore, coal, and copper.

Figure 2.3 compares the evolution of economies with different steel intensities. The United States and Japan went through a phase of industrialisation and urbanisation during the nineteenth and twentieth centuries. Notably, when real GDP per capita increased to US$15,000–US$20,000, it produced as much as 40–50 tonnes per million US GDP. For the period 1980–2010, although real GDP per capita was US$10,000, Chinese steel production rose to around 50 tonnes per million US GDP. This suggests that there was a rising Chinese demand for resource imports to promote rapid economic growth.

The large resource intensity of the Chinese economy has boosted mining investment in Australia since 2005. Due to its proximity to China and its considerable reserves of resource products, Australia has gained tremendous profits from the mining economy. As shown in Figure 2.2, Australian private mining investment rose from 1% of GDP in 2005 to 4% in 2011. However, private investment did not rise by as much in 2003, when there was strong resource demand in China. This slow reaction may arise from both external and internal uncertainty; for example, the

---

6For a detailed analysis of steel production intensity and economic development (Figure 2.3), see Holloway et al. (2010).
Figure 2.2: Relationship between Chinese Economic Growth and Australian Private Mining Investment and Exports (1960–2012)
Source: Graphed using data from ABS (2012) and author’s calculation.
low commodity prices after the burst of the US Internet bubble in 2000 and mining companies’ subdued operating conditions.

The high demand for resources in China has also induced a substantial increase in Australian exports since 2003. As illustrated in Figure 2.2, Australian mining exports experienced two long periods of growth: from 10% in 1960 to 40% in 1980, originating from strong economic growth in Japan; and a doubling of mining exports to nearly 70%, after 2003, due mainly to strong Australian exports to China (30%). Strikingly, the increase in Australian exports since 2003 has been characterised by the increase in commodity prices rather than increased volumes. It was evident that during the period 1960–1980 the Australian terms of trade stayed steady at around 60, while in the period 2003–2011 it rose, surprisingly, to 110.

In short, the rapid growth in the Chinese economy has encouraged continuous growth in Australian mining exports and investment, which has resulted in the sound growth of the Australian economy. This growth is also attributable to changes in the exchange rate regime and effective monetary and fiscal policies.
2.2. AUSTRALIAN MACROECONOMIC CHANGES

2.2.4 Exchange Rate and Monetary Policy

Changes in the Australian exchange rate regime and monetary and fiscal policy are designed to achieve internal balance, including economic growth, low rates of inflation, low unemployment rates, and controlled foreign debt. Traditionally, the floating exchange rate that has been in place since 1983 has counteracted the external shocks initiated by other countries, and has worked as an auto-stabiliser for the domestic economy. Similarly, the Reserve Bank of Australia (RBA) in 1993 implemented inflation targeting to dampen the impacts of internal shocks.

The floating exchange rate and inflation targeting strengthened the resilience of the Australian economy. The Australian inflation rate was moving up in the 1970s; this was associated with the fixed exchange rate, due to the impact of strong resource demand from Japan. After 1983, two external shocks challenged the stability of the economic environment in Australia; the mining boom beginning in 2003 and the global financial crisis in 2008. During these periods, the historically high exchange rate weathered the pressure of rising domestic product prices, while the flexible low exchange rate helped to reduce the deterioration of foreign demand.

Along with the flexibility of the exchange rate, the inflation targeting provided a promising environment for Australian economic growth. As shown in Figure 2.4, the inflation rate after 1983 seldom floated outside the band of 2–3%. From 2003 to 2007, the inflation rate remained steady within the target region, accompanied by the consistently increasing cash rate (5–7%) (Weber, 2012). Conversely, due to the impact of the global financial crisis, the RBA swiftly cut the cash rate to roughly 3% to curb the slump in inflation in 2009.

Owing to fluctuation in the exchange rate and the intervention of inflation targeting, the inflation rate and the unemployment rate were steady between 2000 and 2010.
2.2. AUSTRALIAN MACROECONOMIC CHANGES

2.2.5 Tax and Fiscal Policy

Tax revenue is one of the important components of Australian government budget and fiscal policy. Over the business cycle, variation in Australian tax revenue coincides with fluctuation of the Australian macroeconomy. In turn, taxes, along with discretionary fiscal policy, affect economic activity. Over the last 40 years, sound fiscal policy has been devoted to attaining internal balance, associated with a low level of external debt.

Over 50 years, the swing of the government budget for the period 1990–2010 was larger than that for 1960–1990. In particular, the average budget surplus for 2000–2010 replaced the deficit for 1990–2000. This switch in the budget was primarily driven by the mining boom, with a large inflow of mining tax revenues. After the global financial crisis, the deficit budget was deployed by the government to stimulate the economy. In the period from 2003 to 2010, a radical change in Australian tax revenues reshaped and challenged the macroeconomy.

For the Australian federal government, the main source of tax revenue is company income tax \(^7\), while for state governments, it is mining royalties \(^8\). Figure

\(^7\)Company income tax is the largest ad valorem tax on taxable profits, which is imposed by the federal government at the time of a transaction.

\(^8\)Royalties is the license tax to allow an owner to obtain the ongoing use of an asset, which is
2.2. AUSTRALIAN MACROECONOMIC CHANGES

Figure 2.5: Government Underlying Cash Balance (1960–2012) (measured by the percent of nominal GDP)
Source: Graphed using data from ABS (2012).

2.6 portrays the share of company income tax and royalties in nominal GDP from 1969 to 2012. From 1970 to 2002, company income tax exhibited a high degree of homogeneity with royalties, with the share of company income tax in the nominal GDP fluctuating within the region of 0–4%, and the share of royalties accounting for 0–0.5%. For the period of 2003–2008, the two taxes rose sharply to 6% and 0.9%, respectively. After 2008, the homogeneity between the two taxes ended: company income tax dropped to 4% in 2010, while royalties continued to increase to 0.9% (Guj, 2012).

This significant change in Australian tax revenue from 2003 to 2010 was attributed to the mining boom and the global financial crisis. The mining boom boosted the profits of mining companies, and consequently the revenue from company income tax and royalties. Similarly, due to the global financial crisis, declines in commodity prices shrunk revenues from company income tax. However, royalties were levied on the usage of mining assets, which were less sensitive to the impact of commodity prices. Royalties continued to behave differently from company income tax after 2008.

charged by the state government for an economic activity, such as production or transactions.
2.2.6 Foreign Direct Investment and External Debt

The discretionary fiscal policy has led to a narrowed deficit in the Australian current account for several decades. As shown in Figure 2.7, the notable decrease in the current account after 2003 was associated with the fall in foreign direct investment (FDI). Conversely, there was a steep increase in external debt. From the perspective of saving-investment, these changes have reflected correspondingly larger volumes of national investment than national saving. After 2003, the excessive demand for bulk commodities required vast capital inputs in mining production capacity. To meet the funding needs, the mining industry relied on FDI and external debt. Large mining companies had sufficient internal funding from their operations, along with access to external debt. For small companies, the lack of cash flow resulted in their preference for FDI.

The performance of FDI was more volatile than that of the current account balance and external debt. In particular, the current account balance was in long-term deficit except for a minor surplus in 1973–1974. After 1990, this balance oscillated within a small band from −2% to −6%. After 2008, the deficits in the current account balances narrowed, indicating that national saving recovered more
quickly than national investment. On the other side, the strong upswing in external
debt provided a considerable impetus for the growth of the Australian economy and
the mining boom. The share of external debt in nominal GDP surged from 8% in
1976 to more than 50% in 2008. The remarkable increase in external debt may have
been supported by the huge profitability of the large mining companies during the
mining boom. In contrast, a more frequent oscillation was observed in FDI after
2000. Specifically, apart from the small proportion of FDI in the nominal GDP,
fluctuated from 6%, to –3%, and then to 4% in the period 2004–2006 (Arsov et al.,
2013).

In short, strong growth in the Chinese economy was an impulse for structural
changes in Australian exports, monetary policy, fiscal policy, and foreign investment.

2.3 Macroeconomic Growth and the Role of Mining Investment

The focus of this section is on the linkage between mining investment and Australian
macroeconomic growth. In particular, attention is drawn to the behaviour of mining
investment and the Australian economy over 30 years.

Investment is an abundant source for Australian capital to fund resource projects, infrastructure and activities. It has been estimated that in Australia total private investment rose from AU$7 billion in 1980 to around AU$90 billion in 2012. This dramatic increase reached 24% of GDP in Australia. Correspondingly, Australia’s private investment is simultaneously shared by different sectors. As shown in Figure 2.8, over 30 years, real mining investment went through a steep increase, while the increases in manufacturing, transportation and communication were steady. In 2012, mining investment amounted to AU$100 billion, followed by transportation and communication investment to AU$26 billion, and manufacturing investment to AU$21 billion.

Figure 2.8 shows a number of significant characteristics of different mining investments. Firstly, in the long term, real private investment and industry investment trended upward from 1990 to 2012, while in the short run, real private investment experienced some declines, which seem to be associated with economic downturns. Secondly, investment in the mining industry has outperformed that of other industries, confirming the mining boom in Australia since 2005.

In short, during the period 2000–2012, Australian economic growth has been aligned with the behaviour of mining investment. At an industry level, from the period of the mining boom onwards, growth patterns of investment have diverged across different Australian industries.

2.4 Mining Industry and the Australian Economy

This section explores the importance of the mining industry in the Australian economy. The Australian mining boom in the 2000s coincided with a number of interrelated structural and cyclical changes. Such changes have been driven to a large extent by the boom in production, exports and revenue in the mining industry.
2.4. Mining Industry and the Australian Economy

Figure 2.8: Real Australian Private Investment by Industry, 1980 to 2012
(adjusted by the GDP deflator in 2005)
Source: Graphed using data from ABS (2012) and author’s calculation.

2.4.1 Mining Production

Abundant mining resources characterise the Australian economy as a resource-related economy, which is favoured by the rise in the demand of mining products. A massive quantity of exploration and extraction is observed in coal, iron ore, bauxite, copper and gold products (Convey, 2012). A brief record of the outputs of these products is shown in Table 2.2. From 1990 to 2011, the reserves in mining products resulted in a large share of global outputs. However, this pattern was different for reserves of oil and gas. Meanwhile, the share of global production of copper and gold remained stable, while the shares of coal and bauxite fell and those of iron ore and gas rose. The changes in mining production over 20 years may mirror the shift in downstream demand from coal and bauxite products to iron ore and gas products.

Owing to urbanisation and industrialisation in China, the demand for Australian mining products has grown rapidly since 2003. The Australian mining boom has also led to a dramatic increase in bulk commodity prices and Australian terms of trade. Compared to the two price indices in Figure 2.9, Australian mining investment indicates two notable features. Firstly, from 1980 to 2000, both the bulk commodity price and the terms of trade seemed to move downward while Australian mining
Table 2.2: Australia’s Mining Reserves and Production

<table>
<thead>
<tr>
<th></th>
<th>Share of global reserves in 2011 (%)</th>
<th>Share of global production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1990</td>
<td>2011</td>
</tr>
<tr>
<td>Coal</td>
<td>9.66</td>
<td>21.91</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>7.28</td>
<td>11.29</td>
</tr>
<tr>
<td>Bauxite</td>
<td>15.79</td>
<td>36.64</td>
</tr>
<tr>
<td>Copper</td>
<td>9.15</td>
<td>3.65</td>
</tr>
<tr>
<td>Gold</td>
<td>26.36</td>
<td>11.19</td>
</tr>
<tr>
<td>Oil</td>
<td>5.66</td>
<td>0.42</td>
</tr>
<tr>
<td>Gas</td>
<td>2</td>
<td>0.1</td>
</tr>
</tbody>
</table>


investment stayed steady. There seemed to be no notable decline in mining investment when negative demand shocks occurred. Secondly, from 2010 to 2012, there was a distinct divergence between the two price indices and mining investment. The behaviour of mining investment is also related to the boom in exports and revenue.

Figure 2.9: Comparison of Real Australian Mining Investment, Real Bulk Commodity Price, and Real Terms of Trade, 1980–2012

2.4.2 Mining Exports

Australia remained important in global exports of mining products from 2000 to 2010. Table 2.3 shows relevant statistics for Australian mining products. In Table
2.4. MINING INDUSTRY AND THE AUSTRALIAN ECONOMY

2.3, increases were observed in export volumes of coal, iron ore, and gas between 2000 and 2010. In contrast, in the same period, bauxite, copper and gold exports fell sharply. Notably, due to the gradual depletion of Australia’s oil reserves, the annual growth rates in both export volumes and values of oil slowed between 2000 and 2010 by –0.32% and –0.59%, respectively. This reduction was offset by the increasing annual rate in the export volumes of gas (Connolly and Orsmond, 2011).

These changes reflect the strong preference of downstream demand for iron ore and gas.

<table>
<thead>
<tr>
<th>Table 2.3: Australia’s Mining Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average growth rates (%)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Coal</td>
</tr>
<tr>
<td>Iron Ore</td>
</tr>
<tr>
<td>Bauxite</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Gold</td>
</tr>
<tr>
<td>Oil</td>
</tr>
<tr>
<td>Gas</td>
</tr>
</tbody>
</table>

<sup>a</sup> These are annual average growth rates for the period 2000–2010.


The vast growth in mining exports has driven Australian terms of trade to historically high levels. As reflected by the changes in the Australian macroeconomy, in 2010 Australian terms of trade rose to a record high of 110. The positive relationship between the boom in the mining exports and the high terms of trade resulted from the smooth macroeconomic adjustment in the exchange rate regime (Bishop et al., 2013). The adoption of the floating exchange rate improved the flexibility and resilience of the Australian exchange rate against foreign shocks. Aside from the adjustment in the foreign exchange regime, inflation targeting led to stable changes in interest rates and well-anchored inflation expectations. This contributed to relatively low financing costs in the mining industry (Lawson and Rees, 2008).
2.4. MINING INDUSTRY AND THE AUSTRALIAN ECONOMY

2.4.3 Mining Revenue

A continuous increase was identified in Australian mining revenues over 30 years. In 2010, mining revenue made up 9.5% of total Australian GDP. Table 2.4 provides the evolution of mining revenue from 1991 to 2012. At the aggregated level, mining revenue doubled to AU$35,364 million in the period 2001–2002, compared to 1991–1992. In 2011–2012, mining revenue rose to AU$132,955 million. However, at the disaggregated level, in 2001–2002 the increase in mining revenue was primarily driven by the extraction of oil and gas. Similarly, in 2011–2012, despite slight changes in the revenues of other mining products, the source of the rise in mining revenues shifted to iron ore transactions. The strong increase in iron ore revenue was aligned with the boost in iron ore prices after 2000.

Table 2.4: Australia’s Mining Revenue and Investment, percentage share and real value, 1991–2012

<table>
<thead>
<tr>
<th>Share of Revenue (%)</th>
<th>Share of Investment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>25.61</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>39.17</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>12.26</td>
</tr>
<tr>
<td>Copper</td>
<td>2.21</td>
</tr>
<tr>
<td>Gold</td>
<td>10.55</td>
</tr>
<tr>
<td>Bauxite</td>
<td>2.68</td>
</tr>
<tr>
<td>Other Ores</td>
<td>7.52</td>
</tr>
<tr>
<td>Mining Services</td>
<td>NA</td>
</tr>
</tbody>
</table>

Real value of total mining

<table>
<thead>
<tr>
<th>Mining Revenue (AU$M)</th>
<th>Mining Investment (AU$M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19183</td>
<td>35364.4</td>
</tr>
<tr>
<td>132955</td>
<td>3294.9</td>
</tr>
<tr>
<td>6188.3</td>
<td>77953</td>
</tr>
</tbody>
</table>


Due to the boom in mining revenue and capital intensity, mining investment has witnessed a significant increase since the 1990s. As mentioned above, strong mining investment provided sufficient funding for the expansion of mines, project development, and the purchase of mining equipment. In 2012, mining revenue was AU$132,955 million. Nearly 60% of mining investment (AU$77,953 million) was de-
2.4. MINING INDUSTRY AND THE AUSTRALIAN ECONOMY

Table 2.5: Australia’s Mining Employment, 1991–2012

<table>
<thead>
<tr>
<th></th>
<th>Numbers employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>27450</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>5049</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>8390</td>
</tr>
<tr>
<td>Copper</td>
<td>2349</td>
</tr>
<tr>
<td>Gold</td>
<td>7595</td>
</tr>
<tr>
<td>Bauxite</td>
<td>2065</td>
</tr>
<tr>
<td>Other Ores</td>
<td>8747</td>
</tr>
<tr>
<td>Mining Services</td>
<td>NA</td>
</tr>
<tr>
<td>Total mining</td>
<td>61644</td>
</tr>
</tbody>
</table>


Derived from mining revenue. In Table 2.4, over two-thirds of mining investment (AU$51,970 million) was pooled in coal, oil and gas, and iron ore mining over three decades. Thus, the dominant price increases in those products caused substantial returns for mining investment and the Australian economy. Accordingly, when exposed to negative demand shocks, prices for mining products suffered large falls. The decrease in mining product prices gave rise to severe volatility of mining investment and the entire resource-related economy. This suggests that demand shocks affect mining investment to a greater extent.

Contrary to the striking changes in investment, the changes in mining employment were relatively slight from 1991 to 2012. As shown in Table 2.5, the majority of employed labour was centred in coal mining, iron ore mining and related mining services, associated with the evident decline in coal mining employment from 27,450 in 1991–1992 to 17,256 in 2001–2002. As a whole, the comparatively small changes in mining employment are attributable to capital intensity, rather than labour intensity, in the mining industry over the long term. Most mining products are undifferentiated in the international market. Thus, Australian mining producers are broadly recognised as price takers, and are sensitive to cost control (Convey, 2012). Simultaneously, with the use of advanced technology, the need for highly skilled workers in mining exploration and extraction also hinders increases in other
2.4.4 Income Effect

The mining boom has generated higher exports and revenues, which in turn have led to higher incomes for investment at the aggregated level. Meanwhile, the surge in mining exports and revenues have also resulted in growth in tax revenues and royalties, such as the Minerals Resource Rent Tax and the expanded Petroleum Resource Rent Tax (Convey, 2012). The rise in tax revenues and royalties to the government from the mid-2000s coincided with the boom in mining investment (Connolly and Orsmond, 2011).

At the disaggregated level, since the mining boom, higher mining incomes have contributed to large firms’ cash flow as retained earnings for investment (Lawson and Rees, 2008). However, because many Australian firms have majority foreign ownership, not all earnings are retained in Australia (Bishop et al., 2013). Moreover, investment in mining projects is characterised by a long-term construction phase. In this respect, the magnitude of the income effect in the mining industry over the long run depends on long-run demand shocks and demand expectations (Ye, 2008).

2.4.5 Transfer Effect

Notably, due to the dominance of the transfer effect, not all Australian industries have benefited from the mining boom. The reallocation of labour and capital are not equivalent for all industries. Most resources have been restricted within the mining industry. The part of the tradable sector most directly exposed to the mining boom has experienced a reduction in competitiveness (Bishop et al., 2013). In addition, all industries have been exposed to domestic cost pressures, fueled by high prices for mining products (Baumeister et al., 2010). For example, although

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This is also known as the Dutch Disease: the relationship between the development of natural resources industry and a decline in other industries, such as the manufacturing industry. The mechanism is that an increase in natural resource revenues will strengthen the nation’s currency, and result in expensive exports of other products and less competitive power in other industries (Bruno and Sachs, 1982).
the manufacturing industry is supported by the higher incomes associated with the mining boom, this benefit is impeded by the appreciation of the exchange rate. Overall, due to the existence of the Dutch disease, the net effect of the mining boom may be moderate.

2.4.6 Uncertainty

Although the macro wide factors and the nature of the mining industry may well explain past Australian investment behaviour, they have insufficient precision to predict future behaviour. As documented by Blundell and Stoker (2005), using aggregate variables to forecast future changes is difficult because there is too much uncertainty in influencing underlying processes and policies. In this sense, it is crucial to consider various types of uncertainty from the aggregated level to the disaggregated level.

To be precise, after the global financial crisis, Australian mining firms raised concerns about the uncertain economic environment. As the annual report of Sims Metal Management (2012, p.5) suggests:

Our operations and performance depend significantly on global economic conditions. The global financial markets have experienced increased volatility due to uncertainty surrounding the level and sustainability of the sovereign debt of various countries. Despite aggressive measures taken by certain governments and central banks, economic recovery has been slow. A significant risk remains that these measures may not prevent the global economy from falling back into an even deeper and longer lasting recession.

As noted by Sims Metal Management (2012, p.5), at the aggregated level, Chinese demand has been increasingly important since China has become the largest consumer of world commodities. Any future actions and policies affecting expectations of Chinese growth rates and foreign exchange rates can substantially affect a firm’s business.
Simultaneously, Sims Metal Management’s (2012, p.5) exposure to uncertainties in interest rates, company income tax, exchange rates, and cash flow will lead to lower, yet consistent and steady, revenues.

To summarise, Chinese demand for commodities has inspired structural changes in the Australian macroeconomy and the boom in the mining industry. To a large extent, changes in exports, exchange rates, taxation, production, revenue, and investment have been observed at the aggregated and disaggregated levels. Concurrently, the implementation of the floating exchange rate and inflation targeting has laid a solid foundation that has cushioned Australia against foreign shocks. Notably, the mining boom has had varied impacts on different industries. These impacts depend on the strength of long-run demand and demand expectations.
Chapter 3

Literature Review

3.1 Introduction

This chapter reviews a variety of investment theories and empirical models to better understand the detailed classification and optimal magnitude of capital stocks and investment from two aspects. Firstly, investment is categorised as either macro investment or firm investment. Allocation of resources to existing capital (in production and research) or future capital influences optimal investment. Secondly, the optimal magnitude of investment arises from an intertemporal equilibrium between current consumption (investment) and future consumption (saving). Classical economists argue that the interest rate is a key variable in maintaining this equilibrium. However, Keynesian economists contend that expectation of future demand plays a more important role in adjusting investment.

In particular, Classical and Keynesian investment theories at both macro and firm levels, such as the accelerator theory, the neoclassical theory, the cash flow theory, and Tobin’s q theory, are examined. The uncertainty theory is introduced, providing an effective tool to shed light on the nature of investment. The uncertainty theory and the empirical model in Bloom et al. (2007) provide a framework for the empirical estimation in subsequent chapters.

The literature review is organised by both theoretical and empirical sections. Section 3.2 discusses some theoretical models of investment theories. Section 3.3
investigates the empirical evidence on investment behaviour.

3.2 Theoretical Models of Investment

Investment theories and models attempt to explain some main determinants of the dynamics of investment and to indicate the extent to which investment is affected. At the firm level, changes in investment are related to changes in firm values, and thus in investment demand.

Two main theories broadly attempt to explain investment behaviour: the Classical investment theory and the Keynesian investment theory (Table 3.1). These theories and their respective explanations of the dynamics of investment in practice are discussed in several papers (Abel and Eberly, 1999; Caballero, 1991; Dixit and Pindyck, 1994).

3.2.1 Classical Investment Theory

The basics of investment theory were established by classical economists. As noted, the first investment theory was asserted by Adam Smith (1863) who stated that profit from investment was accompanied by risk and was affected by long-term interest rates. On a broader scale, changes in interest rates drive variations in saving or investment, which result in changes in gross wealth. In this respect, the macroeconomic equilibrium primarily depends on interest rates.

In the Classical investment theory, net investment is driven by adjustments in capital stock. The balance between investment and capital stock is deliberately sustained by interest rates through market mechanisms. Thus, the gross investment function is constructed as shown in Equation 3.1 (Whittaker, 2011).

\[
I^* - I = a(K^* - K) = f(V, 1/i) \tag{3.1}
\]

where \( I^* \) is the desired investment, \( I \) is the actual investment adjusted to reach the optimal capital stock, \( K^* \) is the desired capital stock, \( K \) is the existing capital stock,
### Table 3.1: Synthesis of Different Investment Theories

<table>
<thead>
<tr>
<th>Theory</th>
<th>Main Concepts</th>
<th>Main Determinants</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical</td>
<td>Profits from investment are affected by interest rates</td>
<td>Interest rates</td>
<td>Interest rates are the key to maintaining the balance between investment and capital stock.</td>
<td>Insufficient to explain investment performance over the business cycle</td>
</tr>
<tr>
<td>Keynesian</td>
<td>Intervention in entrepreneurs' expectations on future demand influences investment</td>
<td>Interest rates, demand expectation</td>
<td>The negative relationship between investment and interest rates is demonstrated</td>
<td>Only external factors determine investment, while adjustment costs have no effect on investment.</td>
</tr>
<tr>
<td>Keynes's Accelerator</td>
<td>With constant returns to scale, desired investment is proportional to the expected demand output.</td>
<td>The change in the expected demand</td>
<td>The role of expected demand is important in explaining the variation of investment in the long-run.</td>
<td>Not fit for the case where the profits from additional capital are low but the demand expectation is high.</td>
</tr>
<tr>
<td>Neoclassical Jorgenson</td>
<td>Investment can be affected by demand expectation and the user cost.</td>
<td>User cost</td>
<td>Investment function is represented by the present profit function.</td>
<td>Only internal and present factors matter, and perfect competition is assumed.</td>
</tr>
<tr>
<td>Neoclassical Market Imperfection</td>
<td>Firms with financial constraints can finance investment from internal sources.</td>
<td>Cash flow</td>
<td>Sufficient cash flow can ensure the supply of investment.</td>
<td>Only internal and present factors matter.</td>
</tr>
<tr>
<td>Tobin's q</td>
<td>The ratio of market value to replacement cost determines the timing of investment</td>
<td>Marginal and average q cost</td>
<td>All information (internal and external) is included in the q cost, and additional capital stock affects the present value of profits.</td>
<td>All available information is certain.</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>With high uncertainty and irreversibility, firms may delay investment and wait for more information in the future</td>
<td>Uncertainty, Irreversibility</td>
<td>Uncertainty is negatively related to investment</td>
<td>The uncertainty-investment effect is not clear at different levels, such as the macro and firm levels</td>
</tr>
</tbody>
</table>

3.2. THEORETICAL MODELS OF INVESTMENT
3.2. THEORETICAL MODELS OF INVESTMENT

and \( a \) is the adjustment parameter. The net investment is closely related to profit \( V \) and interest rate \( i \). This model suggests that if adjustment is instantaneous, \( K \) will adjust to \( K^* \) through the adjustment in \( I \).

The classical investment theory argues that investment demand and capital supply can be balanced by adjusting the interest rate. Furthermore, savings, rather than the incentive of project value, are the source of investment in the market. The classical investment theory is the starting point for the analysis of investment decisions at the micro foundation. However, this theory may not satisfactorily explain the aggregate performances of investment over the business cycle.

3.2.2 Keynes’s Investment Theory

The Great Depression in the 1930s challenged the classical investment theory, as savings and capital stocks were rapidly depleted even when interest rates were extremely low. Under these circumstances, Keynes (1937) believed that entrepreneurial expectations are one of the key determinants of investment. He argued that in an economic downturn, the government should implement appropriate monetary and fiscal policies to influence investors’ expectations of future demand. When positive expectations are formed, the marginal efficiency of capital is equal to the interest rate. This equilibrium also results in an optimal level of capital stock and investment.

As advocated by Keynes, not only the interest rate, but also the supply of money, or other financing instruments is required to affect expectations of aggregate demand. These important variables in investment are represented in Equation 3.2 (Keynes, 1937).

\[
I^* - I = a(K^* - K) = f(D(u), 1/i)
\]  

(3.2)

where \( I^* \) is the desired investment, \( K^* \) is the desired capital stock, \( K \) is the existing capital stock, \( I \) is the actual investment adjusted to reach the optimal capital stock, and \( a \) is the adjustment parameter. The net investment is closely related to aggregate demand \( D \) and interest rate \( i \), \( u \) is the effective demand expectation. This model suggests that if adjustment is instantaneous, \( K \) will adjust to \( K^* \) through the
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This result indicates that interest rates inversely affect desired investment, holding other prices and output constant. Moreover, the expectation of demand appears to be an effective tool to motivate investment in the macroeconomy. In this sense, even for an individual firm, the net investment is explicitly determined by both demand expectations and the interest rate.

In the spirit of Keynes’s investment theory, Clark (1917) and Koyck (1954) articulated the accelerator theory, arguing that with constant returns to scale, desired investment is proportional to expected demand output. To that extent, desired investment demand is closely linked with the change in expected demand output rather than the level of that output. The desired investment function of the accelerator theory is expressed in Equation 3.3 (Clark, 1917).

\[ I^* - I = a(K^* - K) = \alpha \Delta Y \]  

(3.3)

where \( I^* \) is the desired investment, \( K^* \) is the desired capital stock, \( K \) is the existing capital stock, \( I \) is the actual investment adjusted to reach the optimal capital stock, \( \alpha \) is a constant, \( \Delta Y \) is the change in expected demand output, and \( a \) is the adjustment parameter. This model suggests that if adjustment is instantaneous, \( K \) will adjust to \( K^* \) through the adjustment in \( I \).

In this model, maintaining high demand for investment requires a rise in demand output. In this sense, Keynes’s investment theory emphasises the role of expected demand, rather than interest rates, in explaining variations in investment in the long run. However, this theory may not satisfactorily explain how low profits from additional future capital and high demand expectations together hinder a firm’s investment.
3.2.3 Neoclassical Jorgenson Theory

Contrary to Keynes’s theory, the neoclassical economists focus on the self-adjustment process, such as the user cost of capital, which is related to levels of interest rates and investment. Neoclassical investment theory was introduced by von Böhm-Bawerk (1890); Wicksell (1907); Fisher (1930), and later Jorgenson (1963) extended the neoclassical theory and asserted that optimal capital stock and investment levels may be encouraged by profit maximisation and user cost. The user cost refers to both fixed and flexible costs, including the cost of capital inputs, the cost of labour services and the cost of production. Therefore, the desired capital stock is a function of output, capital finance (both external and internal funding), and cost associated with capital depreciation, capital accumulation, and tax.

Jorgenson (1963) assumed that the capital market was perfect, and that investment decisions were made based on a fully observable demand. Thus, under the assumption of no cost adjustment or depreciation, a firm’s investment would depend on the difference between the marginal productivity of capital and the cost of capital (interest rate). From the perspective of productive inputs, firm investment would also be related to the difference between the marginal productivity of labour and the cost of labour (wages). When the marginal productivity of capital and labour are greater than their respective costs, investment could be undertaken. With the availability of demand information, a firm could maximise the current value of the sum of future profits $V(K, L)$, which is shown in Equation 3.4 (Jorgenson, 1963, p.248):

$$V(K, L) = \int_0^\infty [pQ(K, L) - wL - p_k(dK/dt + \delta K)]e^{-\rho t} dt$$

(3.4)

where $w$ is the wage rate, $p_k$ is the price of capital inputs, $p$ is the sale price, and $Q$ is the output, given that the firm is a price taker under perfect competition. Through the Euler conditions, the marginal productivity of capital inputs ($Q_k$) and the marginal productivity of labour inputs ($Q_L$) are specified (with the discount rate
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$\rho$ and the depreciation rate $\delta$) as shown in Equation 3.5:

$$Q_k = \frac{p_k(\rho + \delta)}{p} = \frac{c}{p}, \quad Q_L = \frac{w}{p} \quad (3.5)$$

where $c$ is the cost of capital. These are the static expressions of the marginal productivity of capital inputs and labour inputs. The right-hand side of the above expressions are constant, implying that the user costs (capital inputs and labour inputs) are important to achieving the desired capital stock and investment. Jorgenson examined the effect of user cost on firms’ investment decisions using the production function. However, these results are instantaneously derived under assumptions of perfect competition, no taxes or transaction costs, and the availability of full information. In addition, the impacts of these related factors on investment are only tested in the current period. Therefore, desired results may be different from actual results.

### 3.2.4 Neoclassical Theory of Market Imperfection

The Jorgenson model assumes that firms face perfect competition, and that capital is unrestricted. In practice, firms with asymmetric information may compete in an imperfect market. Undesirable market conditions may cause financial constraints for firms. Meyer and Kuh (1966) justified the importance of internal financing in the inflow of investment, asserting that a wedge between the internal and external cost of capital could be considered as a financial constraint. An increase in the wedge may result in a relative increase in financial constraints. Internal financing tends to be an important source of investment that guards against exposure to imperfect capital markets and irrational expectations. This internal finance can be measured by the firm’s cash flow.

As the source of internal finance, cash flow has a crucial role in firms’ investment, given that interest rates and capital markets are exogenously determined. The nexus
between the cash flow and investment is presented in Equation 3.6.

\[ I^* - I = b(K^* - K) = f(CF, v(1/i)) \] (3.6)

where \( I^* \) is the desired investment, \( K^* \) is the desired capital stock, \( K \) is the existing capital stock, \( I \) is the actual investment adjusted to reach the optimal capital stock, \( CF \) is the cash flow, \( i \) is the interest rate, and \( b \) is the adjustment parameter. This model suggests that if adjustment is instantaneous, \( K \) will adjust to \( K^* \) through the adjustment in \( I \).

The theory of market imperfection provides only limited explanation for firms’ investment behaviour, particularly in instances where market behaviour is inconsistent with macroeconomic performance. The issue of whether the effect of internal financing can alleviate the disruption of investment caused by external elements (external financial constraints, irrational expectations, and lack of demand information) is not clear.

### 3.2.5 Tobin’s q Theory

Tobin (1969) contended that the Tobin’s q ratio – the ratio of the market value of a firm to its replacement cost – is the centre of investment behaviour, and can be used to predict the profitability of a firm’s investment. Based on this, Carrington and Tran (2012) proposed a simplified investment model, assuming that in a frictionless market investment opportunity depends solely on the q ratio.

Tobin’s q is used in many empirical studies because it relates expected investment profits with the observable market value of a firm’s asset (Smith, 2008). As indicated by Carrington and Tran (2012), Tobin’s q is measured as the current market value of aggregate total private firm equity and liabilities divided by the replacement cost of the net capital stock of private businesses. The simplified investment model
of Tobin’s q is shown in Equation 3.7 (Carrington and Tran, 2012).

\[
\frac{I_t}{K_t} = \alpha_0 + \alpha_1 q_t + \alpha_2 q^*_t + Var_t + \epsilon_t \tag{3.7}
\]

where \( I_t \) is investment, \( K_t \) is the capital stock, \( q_t \) is Tobin’s q or average q, the ratio between market value of capital and its replacement cost (it is expected that \( \alpha_1 > 0 \)), \( q^*_t \) is a measure of the fundamental value of a firm, \( Var_t \) is uncertainty and \( \epsilon_t \) is the error term. This equation suggests that Tobin’q ratio has a positive impact on firm investment.

Tobin’s q is measured as the current market value of aggregated total private firm equity and liabilities divided by the replacement cost of the net capital stock of private businesses (Carrington and Tran, 2012). Alternatively, the calculation of Tobin’s q ratio for a firm’s investment can be examined through the information in the financial market (Smith, 2008). This exclusive application expands the horizon of empirical investment tests.

There are several criticisms of Tobin’s q model. Firstly, although more variables have been incorporated into the model, the empirical evidence is still insufficient, compared with other empirical models. Bo (1999, p.3) claims that Tobin’s q model does not carry all the information relevant to investment decisions. Secondly, the use of the stock price may generate noise that cannot be easily removed (Bloom et al., 2007). Thirdly, the model may not take into account the effect of the opportunity to invest, which may relate to the values and costs of future profits (Bo, 1999). Fourthly, it is not clear whether the uncertainty in different factors in Tobin’s q model has an effect on the level of investment (Yoon and Ratti, 2011).

### 3.2.6 Investment Uncertainty Theory

The concerns about Tobin’s q model suggest that it is worth examining the effect of uncertainty on investment. The uncertainty theory may provide an insight into
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investment behaviour. Uncertainty-investment 10 theories are put forward to expand on and improve the explanation of investment behaviour suggested by the Neoclassical and Keynesian theories.

The fundamental perspective of the uncertainty theory is the dynamic process of investment under uncertainty. It is assumed that a firm has a forward-looking attitude towards the future value of its investment. Under high uncertainty, a firm may delay investment decisions, while low uncertainty may trigger investment decisions.

Dixit and Pindyck (1994) added real options to the uncertainty theory to characterise the optimal investment rule. In this model, the opportunity to invest is taken as an option asset in the financial market. Once committed, the investment in a project cannot be recovered. The firm has the option to invest in this period or wait for more information in subsequent periods, which depends on the threshold value of \( q \) (Carrington and Tran, 2012).

Neoclassical theories are more concerned about interest rates and user cost of capital (Fisher, 1930; Jorgenson, 1963). In contrast, Keynesian theories focus on demand expectation (Keynes, 1937; Koyck, 1954). These models assume that there are no market constraints, and that the market for investment decisions is totally certain. Although theoretical results from these models are appealing, empirical results are not. The real option theory developed by Bernanke (1983); Dixit and Pindyck (1994) has shown that high levels of uncertainty can increase investment costs and delay irreversible investment decisions. Given some boundary conditions, Dixit and Pindyck (1994) showed that investment decisions depend on a threshold value under uncertainty, which is a gap between the cost and the value of the investment. The brief expression of the threshold value of investment under uncertainty is shown in Equation 3.8 (Dixit and Pindyck, 1994, p.141) 11.

\[
V^* = \frac{\beta}{\beta - 1} I
\]  

10 The uncertainty theory consists of fundamental and classical uncertainty theory. Classical uncertainty assumes that firms are uncertain about the values of variables, but know their probability distribution. Thus, only the fundamental uncertainty theory can be applied in empirical tests.

11 A more detailed discussion of real option theory can be found in Dixit and Pindyck (1994)
3.3. **Empirical Evidence on Investment**

where when the threshold value $V^* > 1$, and the investment return is greater than the investment cost, and thus investment is implemented. \[
\beta = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{\left(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right)^2 + 2\rho/\sigma^2},
\]
\[
\rho
\]
is the risk-free interest rate, \(\delta\) is a parameter, and \(\sigma^2\) is the variance of share returns representing uncertainty.

As shown, the optimal investment rule uncovers the wedge between the critical value $V^*$ and $I$ under the impact of uncertainty. The trigger of optimal investment suggests that the investment decision is sensitive to the uncertainty of the project value. Simultaneously, the irreversible variable may aggravate the caution with which investment decisions are undertaken. Without sufficient information, a firm is more likely to delay the investment decision.

In summary, a number of theoretical papers have set up a broad framework on how investment at the macroeconomic and firm levels evolve. Among them, the roles of uncertainty and irreversibility may not only raise the hurdle for level of investment, but also affect hedging costs with different demand shocks. The relationship between investment, uncertainty and irreversibility needs to be empirically tested and corroborated.

### 3.3 Empirical Evidence on Investment

Estimating the investment relationship empirically helps in identifying the optimal scope and magnitude of investment at the macroeconomic and firm levels. Investment is affected by various key factors, including the user cost of capital, the adjustment cost of capital, irreversibility and uncertainty. Uncertainty theory has gained importance in explaining investment behaviour in empirical studies.

According to the theoretical analysis of Dixit and Pindyck (1994), an increase in uncertainty deters firms’ decisions on investment, and thereby reduces desired capital stocks. Along with the constraint of irreversible capital, firms may be unwilling to undertake a large amount of investment in the long run.

The reviewed literature on uncertainty theory is summarised in Table 3.2.

The following section discusses three main issues of investment at the macroe-
### Table 3.2: Overview of Literature of Uncertainty Theory

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Relation with Investment</th>
<th>Uncertainty Source</th>
<th>Measuring Uncertainty</th>
<th>Other Control Variables</th>
<th>Control</th>
<th>Other Control Variables</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregated Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price (1995)</td>
<td>Negative</td>
<td>Demand</td>
<td>GARCH</td>
<td>Financial constraints, time variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serven (1998)</td>
<td>Negative</td>
<td>GDP growth, price of capital, inflation, real exchange rate, terms of trade</td>
<td>GARCH</td>
<td>Financial constraints, time trend</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guo and Kliesen (2005)</td>
<td>Negative</td>
<td>Oil price</td>
<td>Price variance</td>
<td>Unemployment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disaggregated Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slade (2013)</td>
<td>Mixed</td>
<td>Copper price</td>
<td>Std.dev. of stock returns</td>
<td>Time to build, timing of structural changes, firm features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pattillo (1998)</td>
<td>Negative</td>
<td>Surveyed demand expectation</td>
<td>Std.dev. of surveyed demand</td>
<td>Irreversibility, financial constraints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloom et al. (2007)</td>
<td>Convex</td>
<td>Stock returns</td>
<td>Std.dev. of stock returns</td>
<td>Firm size, financial constraints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huizinga (1993)</td>
<td>Mixed evidence</td>
<td>inflation, real wage, profit rate</td>
<td>Univariate ARCH model</td>
<td>Material prices, real output prices</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. What are the main sources of uncertainty and irreversibility for investment?

2. Is there a significant relationship between uncertainty, irreversibility and investment?

3. What are the proxies of uncertainty in empirical studies?

### 3.3.1 Uncertainty and Macro Investment

In empirical studies, economists first attempted to explain the performance of investment according to the Neoclassical model and Keynes’s model. To empirically test the effectiveness of the Keynesian theory, Hein and Ochsen (2003) estimated the coefficients of the investment function for France, Germany, the UK and the USA to determine whether in those regimes interest rate variations had positive impacts on investment and profit rates from the 1960s to the mid-1990s. Following the approach of Lavoie (1993), Hein and Ochsen (2003) considered the effects of distribution and costs of production together with a monetary interest rate in the investment function. Then, the rate of capital accumulation was assumed as the ratio of net investment to proportion of capital stock, depending on the expected profit rate and the interest rate. The investment function with the effect of interest rate is shown in Equation 3.9 Hein and Ochsen (2003, p.17):

\[
g_{t+1} = \alpha + \beta y_t + \tau h_t + \theta i_t + \epsilon_t
\]  

(3.9)

where \( g_{t+1} \) is the capital accumulation measured by the growth rate of the real gross capital stock in the private sector, \( y_t \) is the growth rate of GDP, \( h_t \) is the profit share, \( i_t \) is the real long-term interest rate, and \( \epsilon_t \) is the error term.

Hein and Ochsen (2003) show that in periods of accumulation the real effects of interest rates vary between countries. Over the whole period, interest rate variations had an inverse impact on output, investment and profit rate in France and
Germany whereas the impact in the UK and the USA was positive due to rentiers’ lower propensity to save and a lower responsiveness of investment. This varying relationship between real interest rates and investment is worth further studying.

Similarly, Bischoff, Bosworth and Hall (1971), and Clark et al. (1979) systematically compared a variety of Neoclassical models and Keynes’s model on the determinants of business investment. As elaborated, the Neoclassical model performs better than Keynes’s model in simulating investment. This aligns with the finding in the theoretical analysis that the desired capital stock depends not only on expected output but also on the ratio of output price to the implicit rental price of capital goods. In this sense, the firm’s investment model for the Neoclassical model is expressed as shown in Equation 3.10 (Bischoff et al., 1971, p.17):

$$I_t = b_0 + \sum_{i=0}^{n} b_{1,i}(p/c)_{t-i-1}Q_{t-i} + \sum_{i=0}^{n} b_{2,i}(p/c)_{t-i-1}Q_{t-i-1} + b_{n+1}K_{t-1} + \mu_t \quad (3.10)$$

where $I$ is investment, $p$ is output price, $Q$ is output, $K$ is net capital stock, and $c$ is the adjustment cost. Their analysis, incorporates the mean reverting process for capital stock in the long term; thus the Neoclassical model is robust and consistent with the observation and theory of a firm’s real operation.

However, the empirical analysis explained by the Neoclassical model is at odds with the fact that a firm’s decision on investment is generally delayed by an uncertain environment, especially after economic downturns. To comprehensively account for investment behaviour, the uncertainty theory has been proposed.

At the macroeconomic level, demand uncertainty is widely measured and has been shown to significantly affect aggregate investment. Moreover, Price (1995) claims that aggregate uncertainty has a large effect on investment at the firm level. Any small changes in the uncertainty of aggregate output may amplify or reduce the marginal productivity of capital and, in the long run, expected investment.

The Generalised Autoregressive Conditional Heteroskedasticity model offers an appealing measure of dynamic uncertainty when there is evidence of volatility clustering over time. For example, Price (1995) used the GARCH-M model to estimate
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the conditional variance of GDP as uncertainty on manufacturing investment in the UK. This method is targeted at high frequency variables or long time series. The model to measure GDP uncertainty is shown in Equation 3.11\(^\text{12}\) (Price, 1995, p.149).

\[
e = y - f(x, \beta) - \delta h, \quad e \sim N(0, h) \tag{3.11a}
\]

\[
h = \gamma_0 + \sum_{i=1}^{p} \gamma_1_i h_{-i} + \sum_{j=1}^{n} \gamma_2_j (e_{-j})^2 \tag{3.11b}
\]

where \(y\) is a function of a set of variables \(x\) and \(h\) with associated error \(e\), with \(h\) as the variance of the error term. The second equation states that \(h\) is the function of lagged values of \(h_{-i}\) and lagged squared residuals \(e_{-j}\). This model is defined as a GARCH-M\((p, n)\) model. The model to test the relationship between investment and uncertainty is shown in Equation 3.12 (Price, 1995, p.150).

\[
\Delta K_t = \varphi(L)\Delta K_{t-1} + \mu(L)Z_{t-1} - \lambda(K - K^*)_{t-1} \tag{3.12}
\]

where \(K_t\) is the capital stock, \(K^*\) is desired capital, and \(Z_{t-1}\) is a set of uncertainty variables.

The coefficient of uncertainty in the Price (1995) investment model shows that a one\% increase in long-run uncertainty induces a reduction in investment by an average of five\%. However, there were notable decreases of 48\% and 38\% in investment in 1974 and 1979, respectively. This result confirms the findings in the theoretical analysis that with high uncertainty, firms are reluctant to conduct irreversible investment.

The differences in the fall in investment suggest that demand uncertainty cannot cover all the influences on aggregate investment. In addition, modelling uncertainty with the GARCH model requires the existence of the ARCH effect in the conditional variance, which may limit the scope of application.

Serven (1998) studied a large cross-country time series data set, comprising

\(^{12}\)Hereafter, the referred equations come from the original papers, unless clearly stated otherwise.
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94 developing countries over the years 1970–1995. In this paper, he examined the relationship between aggregate investment and five aggregate uncertainties: demand growth, price of capital goods, inflation, terms of trade and real exchange rates. This uncertainty-investment relationship provides a way to investigate which government policy has a significant impact on aggregate investment. The model specification is represented in Equation 3.13 (Serven, 1998, p.14).

\[
I_{it} = \lambda I_{i,t-1} + X_{it} \beta + \mu_{it}, \quad \mu_{it} = \alpha_i + \varepsilon
\]  

(3.13)

where \(X_{it}\) is a vector comprising both the regressors (relative price of capital, credit flow and real interest rate) and the uncertainty measures (inflation uncertainty, terms of trade uncertainty, real exchange rate uncertainty, price of capital uncertainty and GDP growth uncertainty), \(\alpha_i\) denotes a time-invariant country-specific disturbance possibly correlated with the columns of \(X\), \(\varepsilon_{it}\) is random noise, and the parameters of interest are \(\lambda\) and vector \(\beta\).

In the above model, Serven (1998) relied on the GARCH model, which allows for testing simultaneity, country-specific effects and parameter heterogeneity across countries. This estimation shows that there is a significant cost-of-capital effect, confirming the assumption of the user cost in the Neoclassical Jorgenson model. Furthermore, given that parameter heterogeneity is dominant across countries, uncertainty in the price of capital has a negative impact on investment. With the application of the pooled estimation method, this negative effect is diminished.

The effects of different uncertainties on investment are uneven across specific countries in Serven’s (1998) specifications. The results suggest that the aggregate variables in each country are more likely to be subject to different effects. However, the adverse relationship between investment and uncertainty is empirically identical across specific countries.

For the mining industry, macroeconomic uncertainty may have an asymmetric effect on investment. Guo and Kliesen (2005) measured the influence of oil price uncertainty on investment and other macroeconomic activity, using daily prices of
crude oil futures traded on the New York Mercantile Exchange (NYMEX) over the period 1984–2004. To check this influence, Guo and Kliesen (2005) aggregated daily data to the quarterly level and examined whether volatility in daily data or quarterly data was linked with the occurrence of macroeconomic activities. This estimation was followed by Granger Causality methods where different variables were tested: real GDP growth, macroeconomic investment and oil-price volatility.

The results show that oil price uncertainty first leads to a fluctuation in macroeconomic demand. Thus, this demand variation, rather than the financial market, has an influence on macroeconomic investment. To that extent, aggregate demand is a significant channel that affects the relationship between aggregate uncertainty and investment. In addition, the conventional relationship between aggregate uncertainty and investment is challenged. As shown, macro uncertainty has an asymmetric effect on investment due to different frequency of data sets. These data sets may amplify or dilute the uncertainty effect on investment. This can be explained by the Hartman-Abel effect. In a competitive market, if the marginal product of capital is convex in price, an increase in price variance raises the expected return on the marginal product of capital and therefore drives investment. Consequently, high uncertainty may induce investment in the short run or delay investment in the long run. Simultaneously, the selection of a future oil price instead of the current price is significant, implying that the computation of uncertainty data at the macroeconomic level can be interpreted as expected uncertainty. The examination of additional features in the mining industry may challenge the negative relationship between uncertainty and investment.

To further analyse the impact of uncertainty on investment, Jongwanich and Kohpaiboon (2008) aimed to explain why private investment in Southeast Asia did not immediately recover to the previous level after the 1997 financial crisis. They built a private investment equation based on Thailand to examine the patterns and determinants of private investment between 1960 and 2005.

To control for heterogeneity of each observation, Jongwanich and Kohpaiboon
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(2008) picked up panel data across different sectors in Thailand to test for overall effects. To examine the slow recovery in Thailand after the crisis, they tested the effects of uncertainties of output growth, inflation, real exchange rate and terms of trade on investment. Their investment model is shown in Equation 3.14 (Jongwanich and Kohpaiboon, 2008, p.1714).

\[
I_t^* = b_0 + \sum_{j=0}^{J} \theta_{1,j} g^y_{t-j} + \sum_{j=0}^{J} \theta_{2,j} g^c_{t-j} + \sum_{j=0}^{J} \theta_{3,j} PDC_{t-j} + \sum_{j=0}^{J} \theta_{4,j} GI_{t-j} \\
+ \sum_{j=0}^{J} \theta_{5,j} UC_{t-j} + \sum_{j=0}^{J} \theta_{6,j} OUTG_{t-j} + \sum_{j=0}^{J} \theta_{7,j} RER_{t-j}
\] (3.14)

where \( g^y \) is output growth, \( g^c \) is growth of real cost of capital, \( PDC \) is the availability of financing, \( GI \) is real public investment, \( UC \) is the set of uncertainty about output growth, inflation, real exchange rate and terms of trade, \( OUTG \) is the output gap, and \( RER \) is the real exchange rate.

The empirical test suggests that a 1% increase in overall uncertainty reduces private investment by 0.03% in the short run and 0.45% in the long run. Uncertainty in output growth and the real exchange rate have significant effects on investment. This may be interpreted by the fact that Thailand’s economy is primarily driven by export growth.

The analysis in Jongwanich and Kohpaiboon (2008) distinguished the effects of different uncertainties on investment, which is mainly characterised by temporary or permanent effects. As indicated, uncertainty about output growth and the real exchange rate may be the main variables that impede investment decisions in the long run. In addition, in the short term, an increase in investment is driven by the impact of replacing capital rather than demand growth. However, the above estimation is established at the aggregated level, and thus the situation at the disaggregated level is not clear.

3.3.2 Uncertainty and Firm Investment

Slade (2013) empirically investigated the uncertainty-investment relationship using
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US industry level data for the copper industry from 1835 to 1986. Slade (2013) regressed the timing of investment with the variables of industry production and timing of structural changes for testing the effects of industry demand and aggregate economic events. Besides that, the long time period taken to build and capital intensity were specified as other key features in the US copper industry. After assessing price uncertainty from the standard deviation of industry and stock market returns, Slade (2013) compared the industry-wide results with the results of copper mines to explore variation in investment behaviour. The investment model used in Slade (2013, p.7) is shown in Equation 3.15:

\[
(I/K)_{it} = a\sigma_{it} + b_i + c_t + d^T x_{it} + \mu_{it}
\] (3.15)

where $I/K$ is the ratio of investment expenditure to capital stock, $\sigma_{it}$ is uncertainty, $b$ and $c$ are firm and year fixed effects, and $x$ is a vector of other explanatory variables such as Tobin’s $q$.

It is worth stressing that the results obtained by Slade (2013) contradict general predictions of a negative uncertainty-investment relationship in some empirical papers. Slade (2013) shows that at the disaggregated level, high uncertainty discourages investment. This effect is intensified by firm features, such as the long time period taken to build and capital intensity. However, aggregate data shows a reversal of the negative relationship between uncertainty and investment. A possible reason is that at the aggregated level, resources from industry exposure to high uncertainty are reallocated to low uncertainty industries, increasing the incentive to invest (Slade, 2013).

Pattillo (1998) quantified the effect of surveyed entrepreneurs’ forward demand expectation on irreversible investment based on Ghanaian manufacturing firms. Combining the user cost with the marginal revenue product of capital in the theoretical analysis, Pattillo (1998) defined the ratio of the marginal revenue product of capital to the sales price as a trigger for firms’ investment. When this trigger is greater than one, investment is undertaken; otherwise no investment is observed.
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The specific model in Pattillo (1998, p.535) is shown in Equation 3.16.

\[
\text{inv/capital} = \beta_0 + \beta_1 U + \beta_2 C + \beta_3 Y + k_i \lambda + \eta
\]  

(3.16)

where \( U \) is expected demand uncertainty, \( C \) is cost of capital variables, \( Y \) is the change in value added over the capital stock, \( \lambda \) is the selection variable controlling for positive investment, and \( \eta \) is the error term. The empirical results support the prediction that firms are cautious about undertaking investment until the marginal revenue product of capital exceeds the cost of investment under uncertainty.

The use of survey data in Pattillo (1998) serves to measure the effect of forward-looking uncertainty, instead of ex-post uncertainty, on investment. The approach to this uncertainty is applied by either the standard deviation or the regression with other forecast variables. Pattillo (1998) surveyed managers in Ghanaian manufacturing firms about the subjective probabilities of future demand growth.

Apart from measuring uncertainty, Pattillo (1998) also tested the effect of irreversibility on the relationship of investment-uncertainty, considering the ratio of the real sales value of capital stock to its real replacement value. In the reduced form of the Tobit equation, Pattillo (1998) implies that with irreversibility, uncertainty has a significantly negative effect on investment, while with reversible capital the negative effect is insignificant.

Bloom et al. (2007) tested the volatility of stock returns as a proxy for uncertainty based on UK manufacturing companies. The advantage of the use of volatility of stock returns is elaborately annotated to help economists capture thorough information, which incorporates both the ex-ante and the ex-post expectations of investors. In addition, analysing stock returns helps to distinguish between the effects of aggregate demand shocks and those of idiosyncratic demand shocks at the firm level. The specific model, which assumes no fixed effects (Bloom et al., 2007,
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Equation 3.17 shows:

\[
\frac{I_{i,t}}{K_{i,t-1}} = \beta_1 \Delta Y_{i,t} + \beta_2 (\Delta Y_{i,t})^2 + \beta_3 (SD_{i,t} \ast \Delta \log Y_{i,t}) + \gamma_1 SD_{i,t} + \gamma_2 \Delta SD_{i,t} \\
+ \theta (\log Y_{i,t-1} - \log K_{i,t-1}) + A_i + B_t + \delta_i + \nu_{i,t}
\]  

(3.17)

where \( Y_{i,t} \) is demand, \( SD_{i,t} \) measures the standard deviation of uncertainty in the returns on company shares, \( K_{i,t-1} \) is the lagged capital stock, \( A_i, B_t \) are unobserved firm-specific and time-specific effects, \( \delta_i \) is the firm-specific depreciation rate and \( \nu_{i,t} \) is the error term.

After comparing the results for plant and firm level investment, they concluded that in the long run demand shocks may have a nonlinear effect on a firm’s investment. The results from this model are in line with the prediction that firms slowly react to changes in demand when high uncertainty prevails.

As indicated by Bloom et al. (2007), firm-level volatility in stock returns is closely related to a range of alternative uncertainty variables, such as sales growth volatility and financial uncertainty. Under the impacts of different uncertainties, investors’ responsiveness is marked by cautionary investment. More interestingly, unlike the linear response of investment to demand shocks, Bloom et al. (2007) suggest that demand shocks have convex effects on firms’ investment. This convexity is observed in the short term when firms undertake investment at the plant level (Bloom et al., 2007, p.401). Unfortunately, Bloom et al. (2007) only test demand uncertainty. Thus, the question remains as to whether other uncertainties have effects on investment decisions.

Although investment is subject to inflation uncertainty, real wage uncertainty, and uncertainty of real price of output, it is not clear whether there is a link between these uncertainties. Huizinga (1993) investigated the connection between inflation uncertainty, real wage uncertainty, and uncertainty about real price of output, arguing that these have multiple effects, rather than a single effect, on disaggregated investment.

To check the linkage and the effects, Huizinga (1993) used a univariate ARCH
model to compare different time series evidence of uncertainty across the US manufacturing companies. A bivariate ARCH model was used to track the performance of different types of uncertainty and to exhibit their different features during the same period. The bivariate ARCH model is shown in Equation 3.18 (Huizinga, 1993, p.529).

\[
Y_t = \rho_0 + \rho_1 Y_{t-1} + \rho_2 Y_{t-2} + \rho_3 Y_{t-3} + \rho_4 Y_{t-4} + \varepsilon_t
\]

\[
\Pi_t = \rho_{11} + \rho_{12} \Pi_{t-1} + \rho_{13} \Pi_{t-2} + \rho_{14} \Pi_{t-3} + \rho_{15} \Pi_{t-4} + \varepsilon_t
\]

\[
E(\varepsilon^2_{Y_t} | \Phi) = \gamma^2_0 + \gamma^2_1 (\varepsilon^2_{Y_{t-1}} + \varepsilon^2_{Y_{t-2}}) + \gamma^2_2 (\varepsilon^2_{Y_{t-3}} + \varepsilon^2_{Y_{t-4}})
\]

\[
E(\varepsilon^2_{\Pi_t} | \Phi) = \gamma^2_{11} + \gamma^2_{12} (\varepsilon^2_{\Pi_{t-1}} + \varepsilon^2_{\Pi_{t-2}}) + \gamma^2_{13} (\varepsilon^2_{\Pi_{t-3}} + \varepsilon^2_{\Pi_{t-4}})
\]

where \( Y \) is demand, \( \Pi \) is the mean of each uncertainty, and \( \varepsilon \) is the conditional variance of each uncertainty.

The results from the above model show that the correlation between inflation uncertainty and real wage uncertainty is 0.45, and that between inflation uncertainty and profit uncertainty is 0.18. In contrast to most papers, these results suggest that US inflation uncertainty is highly positively correlated with real wage uncertainty, but weakly with profit uncertainty over time. One possible explanation is that the use of time series data cannot provide a complete picture of the uncertainty-investment relationship. Apart from the correlation, Huizinga (1993) tested the magnitude and persistence of the impacts of various types of uncertainty on investment based on cross-sectional evidence. The relevant model is shown in Equation 3.19 (Huizinga, 1993, p.543).

\[
IRMN = \alpha_0 + \alpha_1 SDRW + \alpha_2 SDMP + \alpha_3 SDRP + \alpha_4 TTRQ + \nu
\]

where \( IRMN \) is the mean of the ratio of investment to capital stock over time, \( SDRW \) is the standard deviation of the residuals of real wages, \( SDMP \) is the standard deviation of the residuals of materials prices, \( SDRP \) is the standard deviation of the residuals of real output price, and \( TTRQ \) is the time trend of real output growth.
The results show that there is a negative correlation between investment and uncertainty in real wages and real materials prices, while there is a positive relationship between investment and uncertainty in real output price. This positive relation is interpreted as the future movement of real output price which is predicted by the investors. In addition, as argued by Huizinga (1993), the issue of endogeneity that arises in cross sectional data may also lead to a positive uncertainty-investment relationship.

As suggested by Huizinga (1993), although inflation uncertainty has a correlation with real wage uncertainty, it is not sufficient to conclude that reducing inflation uncertainty through policy changes will reduce relative price uncertainty. This potential conclusion needs more careful consideration.

The association between uncertainty and investment is worth further investigation. According to semi-aggregated firm balance sheet and profit and loss accounts (1987–2002), Drakos and Goulas (2006) demonstrated that the impacts of disaggregated variables on investment varied across different uncertainties, market power, irreversibility, and decreasing returns to scale in three different groups of manufacturing industries from 10 different countries. In this paper, Drakos and Goulas (2006) computed the price-cost margin as market power, a dummy variable where the variance of its industry labour-capital ratio is below the median value as irreversibility, and a dummy variable where the sum of coefficients from a Cobb-Douglas production function is less than 1 as decreasing returns to scale. Concurrently, they assumed that these manufacturing firms were subject to both firm-level and economy-wide uncertainties. The investment model is shown in Equation 3.20 (Drakos and Goulas, 2006, p.172).

\[
\frac{I_{it}}{K_{i,t-1}} = \delta_0 + \delta_1 \frac{I_{i,t-1}}{K_{i,t-2}} + \delta_2 (\Delta \log \frac{S_{it}}{K_{i,t-1}}) + \delta_3 \frac{CF_{it}}{K_{i,t-1}} + \delta_4 ECM_{i,t-2} + \delta_{unc}\sigma_{it} + \delta_{MP}\sigma_{it} * MP_{it} + \delta_{IRR}\sigma_{it} * IRR_{it} + \delta_{RS}\sigma_{it} * RS_{it} + \sum_{t=1987}^{2002} \iota_t \text{ (time dummies)} + \varepsilon_{it}
\]
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\[
\left( \frac{\partial (I/K)}{\partial (\sigma)} \right)_{MP=IRR=RS=1} = \delta_{\text{unc}} + \delta_{\text{IRR}} + \delta_{\text{RS}} + \delta_{\text{MP}} < 0 \tag{3.21}
\]

where \( I_{it} \) is investment, \( K_{it} \) is the capital stock, \( \Delta \log \frac{S_{K_{i,t}}}{K_{i,t-1}} \) is the growth rate of sales, \( \frac{CF_{i}}{K_{i,t-1}} \) is cash flow, \( ECM_{i,t-2} \) is the difference in the logarithm of capital stock and sales, \( \delta_{\text{unc}} \) is uncertainty at different levels, and \( MP, IRR, \) and \( RS \) are market power, irreversibility, and returns to scale, respectively.

As noted, this model restricts the scope of the sensitivity of investment to uncertainty, where the overall effects of uncertainty on investment are not the same. After the diagnostic tests and the introduction of economy-wide uncertainty, market power, reversible capital, and decreasing returns to scale, the sign of the investment-uncertainty relationship is positive. As adjustment cost increases over time, the overall effect of those variables on the relationship between investment and firm-specific uncertainty has a negative sign. Corresponding to Hartman (1972), Drakos and Goulas (2006) suggest that as the firm-specific and market-wide uncertainties change, the relationship between uncertainty and investment can be reversed. Moreover, it is argued that irreversibility alone is not enough to affect the relationship of investment-uncertainty. Importantly, the Hartman-Abel effect is documented by Carruth et al. (2000), where if the marginal product of capital is convex in price in a competitive market, an increase in price variance raises the expected return on the marginal product of capital, and thus drives investment. The impact of uncertainty at different levels on investment is worth studying in itself. The subsequent chapters of this thesis examine the impact of uncertainty on different levels of investment.

As mentioned above and in Table 3.2, the behaviour of uncertainty variables has mostly been measured using the GARCH model, which has been shown to effectively process time series data. This model is constructed from the mean equation and the variance equation, removing the disturbance of serial correlation and heterogeneity across the data set (Price, 1995). Unlike the works of Bloom et al. (2007); Bond and Lombardi (2006), this study uses both aggregated and disaggregated data to derive uncertainty variables, such as demand uncertainty, terms of trade uncertainty, and
Chinese GDP growth uncertainty.

Most studies have investigated investment behaviour from two perspectives: the macroeconomic level and the firm level. At the macroeconomic level, variables for demand, tax and terms of trade are included in the empirical model. At the firm level, variables for cash flow, sales and firm features are estimated. The mining industry plays an important role in the Australian economy. Therefore, in this study, introduction of an analysis at the industry level, combined with analyses at other levels, provides a relatively comprehensive picture of Australian investment behaviour.

The study uses a reduced-form model to test investment behaviour. The error correction model (ECM) used by Bond and Lombardi (2006); Bloom et al. (2007), has two advantages. Firstly, assuming investment is partially irreversible, the ECM incorporates short-term and long-term variables in the same equation, allowing for testing the flexible adjustment of targeted variables. Secondly, added control variables interact with targeted variables in the ECM, where the combined effect of those variables can be examined. Therefore, this study uses the ECM to obtain empirical results on the investment behaviour at the macroeconomic, industry and firm levels.

In response to the previous questions in this section, the reviewed papers provide some notable results. Firstly, uncertainty is one of the main concerns in the analysis of investment behaviour. The main sources of uncertainty can be categorised as aggregated (GDP growth uncertainty) and disaggregated (profit uncertainty) uncertainties, which may have different effects on investment at the macroeconomic and firm levels. In addition, different uncertainties may have a correlation (Huizinga, 1993). Policy to create a consistently stable business environment is important to cushion the negative effects of different uncertainties.

Secondly, the negative relationship between uncertainty and investment has been challenged. As surveyed by Carruth et al. (2000), although the negative uncertainty-investment relationship is dominant in most papers, there is a positive relationship
(Hartman-Abel effect) in the theoretical analysis. In a competitive market, if the marginal product of capital is convex in price, an increase in price variance raises the expected return on the marginal product of capital and thus drives investment. In the reviewed empirical papers, other explanations for the positive relationship between uncertainty and investment may be due to data bias (Huizinga, 1993), change in the use of market-wide and firm-specific uncertainties (Drakos and Goulas, 2006), and variation in the analyses at both aggregated and disaggregated levels (Slade, 2013).

Thirdly, the proxies of different uncertainties vary from uncertainty of output growth, inflation rate, and exchange rate at the macro level (Jongwanich and Koh-paiboon, 2008) to uncertainty of demand expectation (Pattillo, 1998), stock returns (Bloom et al., 2007), and economic sentiment indicators (Drakos and Goulas, 2006) at the firm level. The targeted variables for different uncertainties depend on the nature of the economy or individual firm.

In summary, this chapter has presented the development of investment theories: the Classical theory, the Keynesian theory, the Neoclassical theory, the Tobin’s q theory, and the uncertainty theory. The empirical papers at the macroeconomic, industry, and firm levels reviewed as part of this chapter provide important insights into the formation of investment models and the selection of explanatory variables.

The empirical evidence suggests that no attention has been paid to clearly distinguishing between macroeconomic, industry, and firm level investment behaviour. Moreover, there are no consistent methods to examine the impacts of uncertainty on irreversible investment. These issues are the departure points of this thesis and will be addressed in subsequent chapters.
Chapter 4

Research Methodology

4.1 Introduction

This chapter discusses the framework and specification of this study’s empirical model of the investment behaviour of the Australian mining industry. Although the reviewed literature shows that there is no consensus on investment models, several novel characteristics of both the theoretical and empirical models are worth noting. As indicated, the user cost in the Neoclassical theory, the demand variable in the accelerator theory, and uncertainty and irreversibility in the uncertainty theory are some important components of investment models. Notably, these theories have laid the foundation of investment models, including the dynamic adjustments in additional capital stock, demand and investment under uncertainty and irreversibility.

The framework and model specification also provide some detailed explanations for the selected variables, which are tailored to the nature of the Australian mining industry. These offer an effective path for examining the main determinants of Australian mining investment. Section 4.2 sets out the framework of the modelling process. Section 4.3 delivers the model specification to be used for further modelling.
4.2 Analytical Framework

This study attempts to empirically examine the impacts of different types of uncertainty and key factors on Australian mining investment at the macroeconomic, industry, and firm levels. Figure 4.1 presents the flow of investment from the aggregated to the disaggregated level. Along with similar aggregated and disaggregated variables at different levels during the period 1990–2012, this framework ensures consistency and reduces heterogeneity across different levels. Specifically, Figure 4.1 shows that except for the uncertainty variables, Australian mining investment is sensitive to a wide range of factors, including the user cost of capital, aggregate demand, tax, and terms of trade at the aggregated level, and firm features, firm sales and cash flow at the disaggregated level. Based on these factors, this study has implications for minimising the negative effects of different uncertainties, and facilitating sustained development in the mining industry.

Figure 4.1: Research Framework for Australian Mining Investment
This study uses a series of compelling research methodologies. Firstly, the uncertainty theory is fit for empirically analysing the dynamics of Australian mining investment. In particular, examining Australian mining investment at the macroeconomic level requires testing the model for uncertainty of demand, tax, terms of trade, and Chinese GDP growth, as discussed in Chapter 2. Due to its export-oriented nature, the Australian mining industry may be sensitive to uncertainty in terms of trade. At the firm level, both aggregated and disaggregated uncertainties may hinder firms’ investment decisions.

Secondly, the General Autoregressive Conditional Heteroskedasticity (GARCH) model is used to measure uncertainty data for tax, terms of trade, and demand shocks at different levels. The GARCH model has an advantage over other approaches for generating uncertainty data. Specifically, these data can be generated from the conditional variances of the GARCH models, while unconditional variances can be captured by the residuals of the OLS method. In this sense, the GARCH model can be used to examine the extent to which targeted factors at the macroeconomic, industry and firm levels are negatively affected by foreign shocks.

Thirdly, the relationship between different uncertainties and investment derived for this study may have implications for policy makers and investors who wish to minimise the negative impacts of foreign shocks, and to encouraging potential investment over the business cycle. These implications may also suggest a sustainable path for maintaining the Australian mining boom.

4.3 Model Specification

The reduced-form error correction model can be augmented to incorporate a range of variables, such as different uncertainties, demand shocks, terms of trade, and corporate income tax, which are discussed in Chapter 2 and highlighted in Figure 4.1. This study used the augmented error correction model (ECM) in Bloom et al. (2007) and Bond and Lombardi (2006) to empirically examine Australian investment behaviour at different levels.
4.3. MODEL SPECIFICATION

The augmented ECM has several advantages for investigating investment dynamics. Firstly, this is a dynamic model in which the lagged investment process is embedded; this corresponds to theoretical investment theories. Secondly, this model can simultaneously accommodate the long-run and short-run effects of investment and related variables. This suggests that the optimal ratio of investment to capital stock is equivalent to its long-run equilibrium value.

4.3.1 Measuring Investment

The investment model is set up under the assumptions of no friction (no uncertainty, irreversibility, other adjustment costs) of a certain investment, and the optimal capital stock $K_t^*$ in a period $t$ is a proportional function of real output $Y_t$. The function of the optimal capital stock is shown in Equation 4.1.

$$ \log K_t^* = A_t + \log Y_t $$  \hspace{1cm} (4.1)

where $A_t$ is an unobserved time-specific effect defining variation across time in user cost of capital. Assuming this frictionless capital stock, a policy maker can maximise profits with constant returns to scale in a perfectly competitive market.

The actual capital stock $K_t$ may deviate from the path to the frictionless value in the long run. This long term process is expressed in Equation 4.2.

$$ \log K_t = \log K_t^* + e_t $$  \hspace{1cm} (4.2)

where $e_t$ is a stationary error term. An ECM exploiting the relationship between $\log K_t$ and $\log K_t^*$ is derived as shown in Equation 4.3 (Bond and Lombardi, 2006, p.380).

$$ \Delta \log K_t = \alpha \Delta \log Y_t + \theta (\log K_{t-1} - \log Y_{t-1}) + A_t + e_t $$  \hspace{1cm} (4.3)

where $\Delta$ is a difference operator. In eq 4.3, $\Delta \log K_t$ can be approximately replaced by $(\frac{I_t}{K_{t-1}} - \delta_i)$, where $I_t$ is gross investment, $\delta_i$ is the firm-specific depreciation
rate, and $\Delta \log Y_t$ is demand shocks. $\theta > 0$ implies that firms with capital stock below the desired level adjusted the capital stock upwards. To this end, the partial irreversibility model for the investment rate can be rewritten as shown in Equation 4.4 (Bond and Lombardi, 2006).

$$\frac{I_t}{K_{t-1}} = \beta_0 + \beta_1(\Delta \log Y_t) + \beta_2(\log Y_{t-1} - \log K_{t-1}) + \beta_3 Z_t + A_t + B_i + \delta_t + \mu_t \quad (4.4)$$

where $Z_t$ is a set of other control variables that may influence the investment ratio in the short term. In this reduced-form investment model, assuming that investment is partially irreversible, the dependent variable for investment is optimally adjusted by the lagged capital stock. When $\beta_1 > 0$, the capital stock is increased. This increase is driven by a positive demand shock. The error correction term $(\log Y_{t-1} - \log K_{t-1})$ is the logarithm of the ratio of output to capital stock. When the adjustment coefficient $\beta_2 > 0$, the capital stock below the long-term equilibrium level is adjusted upwards, and vice versa.

### 4.3.2 Measuring Uncertainty

To estimate the uncertainty variables at the macroeconomic level, the Autoregressive Conditional Heteroskedasticity (ARCH) or the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models are useful. The ARCH model introduced by Engle (1982) and the GARCH model introduced by Bollerslev (1986) are specifically designed to model the conditional variance of a time series sample. The GARCH model incorporates both the mean and variance equations, allowing for the introduction of serial correlation for the conditional variance. Specifically, the mean equation using stationary data is fitted by the Autoregressive Moving Average (ARMA) model, while non-stationary data is processed by the Autoregressive Integrated Moving Average (ARIMA) model. After carrying out the stationarity tests, the ARIMA $(p, d, q)$ \textsuperscript{13} can be adapted to first-differenced data to derive the mean.

\textsuperscript{13}$p$ is the order of autoregressive terms; $d$ is the order of differencing; $q$ is the order of moving-average process.
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equation. The mean equation \((p, d, q)\) is represented by Equation 4.5:

\[
\Delta y_t = \delta + \beta_1 \Delta y_{t-1} + \ldots + \beta_p \Delta y_{t-p} + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \ldots + \theta_q \epsilon_{t-q} + \epsilon_t \tag{4.5}
\]

where \(y_t\) is the time series variable, and \(\epsilon_t\) has a zero mean and variance of \(\sigma_t^2\).

According to Bollerslev (1986), the conditional heteroskedasticity in the \(\epsilon_t\) of Equation 4.5 leads to an ARCH process in \(y_t\). The GARCH variance equation \((p,q)\) is represented by Equation 4.6:

\[
\sigma_t^2 = \omega + \sum_{j=1}^{p} \alpha_j \epsilon_{t-j}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \tag{4.6}
\]

The GARCH model has two advantages for estimating uncertainty data. Firstly, the coefficient \(\beta\) is a long-memory parameter measuring the long-term effect of exogenous shocks on conditional variance. Secondly, uncertainty data regarding the Australian macroeconomy is effectively estimated from \(\epsilon_{t-j}\) in the variance equation.

To determine the best-fit GARCH model, a two-step empirical procedure is applied. Firstly, logarithms of investment-related data are estimated by the best ARIMA \((p, d, q)\) models and are evaluated by the Box Jenkins method. Secondly, the residuals of the ARIMA methods are verified for the presence of ARCH effects via the Lagrange multiplier (LM) tests. The ARCH LM test uses an auxiliary regression to test for the presence of the ARCH (up to \(p\) order) effect. The ARCH LM test is expressed in Equation 4.7:

\[
\epsilon_t^2 = \beta_0 + \left( \sum_{s=1}^{p} \beta_s \epsilon_{t-s}^2 \right) + v_t, \quad s = 1, \ldots, p \tag{4.7}
\]

\[
BP = n \times R^2 \sim X^2(p)
\]

where \(\epsilon_t\) has a zero mean and variance of \(\sigma_t^2\). If the LM test statistic \(nR^2\) \((R^2\) is the coefficient of determination derived from Equation 4.7) shows that \(nR^2 > \chi^2(p)\), the presence of the ARCH effect is significant.

Similarly, a range of approaches measure panel data uncertainties at the industry
and firm levels, from standard deviations to the GARCH method. The advantages and drawbacks of those models at the disaggregated level are reviewed below.

The first approach to deriving uncertainty data is the standard deviation from a particular variable, which is used by Bloom et al. (2007). To measure the unpredictable component of a variable, the standard deviation is the simplest way and is widely fit for time series, cross-sectional and panel data. Uncertainty data from the standard deviation is unconditional, and is affected by the distortion of serial correlation and other factors.

The second approach is the GARCH model (Huizinga, 1993; Price, 1995). The GARCH model consists of the mean and ARCH equation, which generates conditional uncertainty data. Compared to the ARCH model, the GARCH model can capture the serial correlation for the conditional variance. For panel data on investment at industry and firm levels, the GARCH model can be used to generate uncertainty data for each cross-section unit (Serven, 1998, p.9).

The GARCH model used here is in line with that in the analysis of macro investment. In particular, following the approach of Serven (1998), the two-equation model is separately tested for each industry at the industry level and each mining company at the firm level. As noted, the mean equation is constructed by the ARIMA method. The expression of the GARCH model is given in Equation 4.8:

\[
\Delta y_{it} = \delta_i + \beta_i \Delta y_{i,t-1} + \epsilon_{it} \\
\sigma_{it}^2 = \omega + \sum_{j=1}^{p} \alpha_{i,j} \epsilon_{i,t-j}^2 + \sum_{j=1}^{q} \beta_{i,j} \sigma_{i,t-j}^2
\] (4.8)

where \(y_{it}\) is time series data, and \(\epsilon_{it}\) has a zero mean and variance of \(\sigma_{it}^2\). \(\Delta y_{i,t-1}\), \(\epsilon_{i,t-j}\), \(\sigma_{i,t-j}^2\) are the lagged variables.

### 4.3.3 Macroeconomic-Level Specification

Based on the ECM and the GARCH model, the variables for the investment model at the macroeconomic level need to be specified based on the nature of the Aus-
4.3. MODEL SPECIFICATION

Australian economy and the mining industry. Moreover, the investment model includes the variables of demand shocks, tax costs, exchange rate costs, interest rates, and uncertainties, corresponding to the accelerator theory, the user cost theory and the uncertainty theory (Chapter 3). It is noted that most macroeconomic-level data was collected from ABS (2012). Table 4.1 shows the key variables at the macroeconomic level. The ratio of private investment to private capital stock \( \frac{i_t}{K_{t-1}} \) was chosen as the dependent variable. At the macroeconomic level, private investment and capital stock were represented by annual (quarterly) real private gross investment and capital stock (Bloom et al., 2007; Bond and Lombardi, 2006).

Australian real annual GDP was used to account for the effect of different demand shocks on investment (Bloom et al., 2007; Bond and Lombardi, 2006). In particular, the linear effect of demand shocks on investment was examined using the change in Australian GDP \( (\Delta \log Y_t) \) and the error correction term for the difference between Australian GDP and private capital stock \( (\log Y_{t-1} - \log K_{t-1}) \). Following the works of Bloom et al. (2007); Bond and Lombardi (2006), this study used demand shocks instead of demand to represent the demand accelerator effect. As stated in the accelerator theory, positive demand shocks can stimulate investment in the long run. In addition, the demand variables subsume a quadratic term \((\Delta \log Y_t)^2\) for testing the nonlinear effect of demand shocks on investment. All these demand shocks underpin the structural changes in the Australian macroeconomy and its mining industry.

The changes in annual company income tax \((\Delta \log tax_t)\) and annual terms of trade \((\Delta \log tt_t)\) are key variables for testing the effects of the user cost of capital and changes in foreign trade on investment. Tax expenses are a determinant of national GDP, driving variation in investment. As shown by Ruane (1982), tax expense is one of the critical components in measuring investment response to its user cost. In addition, as suggested in Chapter 2, in Australia, the federal government company income tax is the largest source of tax revenue. Since the beginning of the

\[14\] To remove the effect of tax revenues on the change in company income tax and its uncertainty, company income tax was divided by national revenues.
mining boom, company income tax has been one of the main factors in mining firms’
investment decisions. As company income tax is the largest source of tax revenue,
it is used as a proxy for the user cost of capital (Ruane, 1982). A firm’s profits, and
therefore its investment, is sensitive to company income tax. As shown in Table
4.1, company income tax is expected to have a negative effect on a firm’s profits
and its investment. On the other hand, as discussed in Chapter 2, terms of trade
is sensitive to foreign shocks. Joshua and Marion (1995); Bleaney and Greenaway
(2001) suggest that the terms of trade has an impact on private investment. Thus,
the terms of trade is used to examine the extent to which Australian investment is
negatively affected by foreign shocks.

The construction of uncertainty variables is based on the uncertainty theory
(Dixit and Pindyck, 1994). The GARCH method is used to generate uncertainty
data. The study determines the effects of different uncertainties variables on invest-
ment: company income tax uncertainty ($utax_t$), terms of trade uncertainty ($utt_t$)\(^{15}\),
interest rate uncertainty ($urat_t$), Chinese GDP growth uncertainty ($ucgdp_t$), the ef-
effect of demand uncertainty on the short-run investment response to demand shocks
($ugdp_t \times \Delta \log Y_t$), and demand uncertainty ($ugdp_t$) (Huizinga, 1993). It is worth
stressing that the interest rate in this study is the annual Australian cash rate. To
avoid the issue of endogeneity, interest rate uncertainty was used rather than interest
rates themselves\(^{16}\). Meanwhile, the effect of demand uncertainty on the short-run
investment response to demand shocks is an indirect effect, which interacts with de-
mand shocks. This captures the idea that demand shocks have a reinforced or weak
effect on investment under high uncertainty (Bloom et al., 2007). Data for Chinese
GDP growth was captured from the China Statistical Yearbook (2013). According
to most empirical studies, these uncertainties are expected to have a negative effect

\(^{15}\)The use of uncertainty in the terms of trade instead of uncertainty in the exchange rate is
due to the large amount of missing data for the exchange rate during 1969–1980. In addition, the
effect of uncertainty in the exchange rate on investment may be similar to that of terms of trade
uncertainty. However, if the amount of exchange rate data is sufficient, the work can be extended
by including the effect of exchange rate uncertainty. Notably, in RBA and Department of the
Treasury, the first observation year for the exchange rate is 1980; in BIS, it is 1994; and in IMF,
it is 1995.

\(^{16}\)Interest rates are closely correlated with investment.
Thus, the investment model at the macroeconomic level is expressed in Equation 4.9.

\[
\frac{I_t}{K_{t-1}} = \beta_0 + \beta_1 (\Delta \log Y_t) + \beta_2 (\Delta \log Y_t)^2 + \beta_3 (\log Y_{t-1} - \log K_{t-1}) \\
+ \beta_4 \Delta \log \text{tax}_t + \beta_5 \Delta \log \text{tt}_t + \beta_6 \text{ugdp}_t + \beta_7 \text{utax}_t + \beta_8 \text{utt}_t \\
+ \beta_9 \text{urat}_t + \beta_{10} \text{ucgdp}_t + \beta_{11} \text{ugdp}_t \times \Delta \log Y_t + B_t + \mu_t
\]

where \(\frac{I_t}{K_{t-1}}\) is the ratio of private investment to private capital stock at different times \(t\) and \(t-1\), \(\Delta \log Y_t\) is the demand shocks at time \(t\), \((\log Y_{t-1} - \log K_{t-1})\) is the difference between Australian GDP and private capital stock at time \(t-1\), \((\Delta \log Y_t)^2\) is the squared demand shocks at time \(t\), \(\Delta \log \text{tax}_t\) is the changes in company income tax at time \(t\), \(\Delta \log \text{tt}_t\) is changes in the terms of trade at time \(t\), \(\text{ugdp}_t\) is demand uncertainty at time \(t\), \(\text{ugdp}_t \times \Delta \log Y_t\) is the effect of demand uncertainty on the short-run investment response to demand shocks at time \(t\), \(\text{utax}_t\) is uncertainty of company income tax at time \(t\), \(\text{utt}_t\) is uncertainty of the terms of trade at time \(t\), \(\text{urat}_t\) is uncertainty of the interest rate at time \(t\), \(\text{ucgdp}_t\) is uncertainty of Chinese GDP growth at time \(t\), and \(B_t\) is unobserved time-specific effects.

4.3.4 Industry-Level Specification

The tested variables at the industry level are slightly different from those at the macroeconomic level. At the industry level, panel data was tracked from the ABS (2012), adding more information on Australian investment behaviour. The chosen variables for the ratio of private investment to private capital stock \((\frac{I_{it}}{K_{i,t-1}})\), linear and nonlinear demand shocks \((\Delta \log Y_{it}, (\Delta \log Y_{it})^2)\), the error correction term \((\log Y_{i,t-1} - \log K_{i,t-1})\), changes in company income tax \((\Delta \log \text{tax}_{it})\) \(^{17}\), different demand uncertainties \((\text{ugdp}_{it}, \text{ugdp}_{it} \times \Delta \log Y_{it})\), and company income tax uncertainty \((\text{utax}_{it})\) are similar to those at the macroeconomic level and measured by annual data at the industry level.

\(^{17}\)To remove the effect of tax revenues on the change in company income tax and its uncertainty, company income tax was divided by industrial revenues.
Apart from those variables, due to unavailability of data for the terms of trade at the industry level, the change in export values ($\Delta \log ex_{it}$) is used instead. This represents the negative effect of foreign shocks on investment. Accordingly, terms of trade uncertainty is replaced by uncertainty of export value ($uex_{it}$).

There is no industry-specific interest rate data on uncertainty and Chinese GDP growth. To overcome this issue, the macroeconomic level uncertainties in interest rates and Chinese GDP growth interact with demand uncertainty at the industry level ($ugdp_{it} \ast urat_{t}$ and $ugdp_{it} \ast ucgdp_{it}$). These variables suggest that uncertainty in interest rates and Chinese GDP growth have an indirect effect through demand uncertainty on investment. The interaction terms were used as in Yoon and Ratti (2011), where the interactions of energy price uncertainty and leverage uncertainty with demand uncertainty were used to obtain the indirect negative effect on firm investment.

According to the above discussion, the investment model at the industry level is given in Equation 4.10:

$$\frac{I_{it}}{K_{i,t-1}} = \beta_0 + \beta_1(\Delta \log Y_{it}) + \beta_2(\Delta \log Y_{it})^2 + \beta_3(\log Y_{i,t-1} - \log K_{i,t-1})$$

$$+ \beta_4(\Delta \log tax_{i,t}) + \beta_5(\Delta \log ex_{it}) + \beta_6(utax_{it}) + \beta_7(uex_{it})$$

$$+ \beta_8(ugdp_{it} \ast urat_{t}) + \beta_9(ugdp_{it} \ast ucgdp_{it}) + \beta_{10}(ugdp_{it})$$

$$+ \beta_{11}(ugdp_{it} \ast \Delta \log Y_{it}) + B_i + C_t + \mu_{it} \tag{4.10}$$

where $\frac{I_{it}}{K_{i,t-1}}$ is the ratio of private investment to private capital stock for industry $i$ at different times $t$ and $t - 1$, $\Delta \log Y_{i,t}$ is the industrial demand shocks at time $t$, $(\Delta \log Y_{i,t})^2$ is the squared demand shocks at time $t$, $(\log Y_{i,t-1} - \log K_{i,t-1})$ is the difference between industry GDP and private capital stock at time $t - 1$, $\Delta \log tax_{i,t}$ is changes in industrial company income tax at time $t$, $\Delta \log ex_{i,t}$ is the changes in industrial export values at time $t$, $ugdp_{i,t}$ is industrial demand uncertainty at time $t$, $ugdp_{i,t} \ast \Delta \log Y_{i,t}$ is the interaction between demand shocks and demand uncertainty at time $t$, $utax_{i,t}$ is industrial uncertainty of company income tax at time $t$. 
time $t$, $uex_{i,t}$ is industrial uncertainty of export values at time $t$, $ugdp_{i,t} \ast urat_t$ is interacted uncertainty between demand and interest rate at time $t$, $ugdp_{i,t} \ast ucgdp_t$ is interacted uncertainty between demand and Chinese GDP growth at time $t$, $B_t$ and $C_t$ are unobserved industry-specific and time-specific effects.

4.3.5 Firm-Level Specification

The variables presented at the firm level are modified from those at the macroeconomic and industry levels. At the firm level, substantial observations about mining firms’ annual operations were given as panel data. These data were collected from annual reports and DatAnalysis (2012). At the firm level, most explanatory variables are the same as those at the macroeconomic and industry levels, but the definitions are different. In particular, private investment and capital stock are defined by expenditure for the purchase of property, plant, and equipment, and gross total equity in the firm’s financial statements. In addition, as documented by Bloom et al. (2007), the firm’s cash flow is another control variable for analysing firm investment. They used cash flow to measure financial constraints and profitability. In this study, the firm’s cash flow adjusted by the lagged capital stock ($\frac{C_{i,t-1}}{K_{i,t-1}}$) was introduced into the mining investment model at the firm level.

Change in firm sales was used to account for the positive effects of different demand shocks on mining investment at the firm level. The setting of demand variables follows that of Bloom et al. (2007); Yoon and Ratti (2011); Ghosal and Loungani (1996) using the linear and nonlinear demand shocks ($\Delta logsal_{i,t}, (\Delta logsal_{i,t})^2$) and the error correction term ($logsal_{i,t-1} - logK_{i,t-1}$).

Similarly, variation in tax expenses ($\Delta logtax_{i,t}$) and changes in exchange rate costs ($\Delta loger_{i,t}$) were used to incorporate the negative impacts of tax and exports on mining investment at the firm level. In contrast to Serven (1998); Guimarães and Unteroberdoerster (2006), changes in taxes and exchange rates are not directly

\footnote{The fluctuation of exchange rates results in extra costs for a firm’s exports. To remove the effects of tax revenues and revenues on exchange rate changes on their costs and uncertainties, company income tax and exchange rate costs were divided by firm revenues.}
observed at the firm level. However, changes in a firm’s tax expenses and exchange rates indirectly represent the effects of changes in taxes and exchange rates. Moreover, due to the capital intensity and export-oriented nature of the mining industry, mining investment is vulnerable to variation in taxes and exports.

According to the vast empirical literature, the uncertainty variables at the firm level were modified and expected to have negative effects on investment. These uncertainty variables include demand uncertainty \( \Delta usal_{it}, usal_{it} \ast \Delta logsal_{it} \), firm tax uncertainty \( utax_{it} \), exchange rate cost uncertainty \( uer_{it} \), and interactions between uncertainties in the interest rate, Chinese GDP growth, and demand \( usal_{it} \ast urat_{t} \) and \( usal_{it} \ast ucgdp_{t} \).

In response to firm features emphasised in the description of the Australian mining industry, a series of variables were introduced into the investment model at the firm level. Pattillo (1998) examined the investment responses to firm features using the number of employees to represent firm size, along with firm age and foreign ownership. As demonstrated by Baker and Wurgler (2002), market capitalisation can be used to compute and reflect the market value of a company, which is closely related to capital structure. In addition, during the mining boom, Chinese investors have had a large influence on the Australian mining industry. Therefore, the use of number of employees \( emp_{it} \), firm age in 2012 \( ages_{it} \), market capitalisation \( mkt_{it} \) and Chinese ownership \( ocn_{it} \) in this study is designed to investigate whether mining firms with features, such as large firm size, long history, large market value and Chinese ownership, undertake more investment.

\[19^\text{In this study, if there is foreign ownership in the mining firm, the share of ownership varies between 20\% and 49.9\%. In Aitken and Harrison (1999, p.609), Venezuelan firms are classified by degree of foreign ownership into three types: domestic firms, with less than 20\% foreign ownership; foreign-funded firms, with 20\%-49.9\% foreign ownership; and foreign firms, with over 50\% foreign ownership.}\]
The investment model at the firm level is shown in Equation 4.11.

\[
\frac{I_{it}}{K_{i,t-1}} = \gamma_0 + \gamma_1(\Delta \text{logsal}_{it}) + \gamma_2(\Delta \text{logsal}_{it})^2 + \gamma_3(\text{logsal}_{i,t-1} - \log K_{i,t-1}) \\
+ \gamma_4\left(\frac{C_{it}}{K_{i,t-1}}\right) + \gamma_5(\Delta \text{logtax}_{i,t}) \\
+ \gamma_6(\Delta \text{loger}_{it}) + \gamma_7(\text{utax}_{it}) + \gamma_8(\text{uer}_{it}) + \gamma_9(\text{usal}_{it} \ast \text{urat}_t) \\
+ \gamma_{10}(\text{usal}_{it} \ast \text{ucgdp}_t) + \gamma_{11}(\Delta \text{usal}_{it}) \\
+ \gamma_{12}(\text{usal}_{it} \ast \Delta \text{logsal}_{it}) + \gamma_{13}(\text{logemp}_{it}) + \gamma_{14}(\text{age}_{it}) \\
+ \gamma_{15}(\text{logmkt}_{it}) + \gamma_{16}(\text{ocn}_{it}) + D_i + E_t + \mu_{it}
\] (4.11)

where \(\frac{I_{it}}{K_{i,t-1}}\) is the ratio of private investment to private capital stock for firm \(i\) at different times \(t\) and \(t - 1\), \(\Delta \text{logsal}_{i,t}\) is firm demand shocks at time \(t\), \((\Delta \text{logsal}_{i,t})^2\) is squared demand shocks at time \(t\), \((\text{logsal}_{i,t-1} - \log K_{i,t-1})\) is the difference between firm sales and private capital stock at time \(t - 1\), \(\Delta \text{logtax}_{i,t}\) is the change in firm tax expenses at time \(t\), \(\Delta \text{loger}_{i,t}\) is the change in exchange rate at time \(t\), \(\text{usal}_{i,t}\) is firm-level demand uncertainty at time \(t\), \(\text{usal}_{i,t} \ast \Delta \text{logsal}_{i,t}\) is the interaction between demand shocks and demand uncertainty at time \(t\), \(\text{utax}_{i,t}\) is firm uncertainty of tax expense at time \(t\), \(\text{uer}_{i,t}\) is firm uncertainty of costs in exchange rates at time \(t\), \(\text{usal}_{i,t} \ast \text{urat}_t\) is uncertainty interaction between demand and the interest rate at time \(t\), \(\text{usal}_{i,t} \ast \text{ucgdp}_t\) is interacted uncertainty between demand and Chinese GDP growth at time \(t\), \(\text{logemp}_{it}\) is firm size, \(\text{age}_{it}\) is firm age in 2012, \(\text{logmkt}_{it}\) is market capitalisation, \(\text{ocn}_{it}\) is a dummy variable of Chinese ownership, and \(D_i, E_t\) are unobserved firm-specific and time-specific effects.

In summary, this chapter has shed light on the framework, model construction, and relevant variables for estimating Australian mining investment behaviour. Table 4.1 summarises the definitions of variables at the macroeconomic, industry and firm levels. The next chapters describe the data and present the empirical investment models at the macroeconomic, industry and firm levels.
### Table 4.1: Definitions of Variables

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Acronym</th>
<th>Source</th>
<th>Expected sign</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macro level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate investment</td>
<td>$I_t$</td>
<td>ABS</td>
<td></td>
<td>Annual and quarterly real private gross investment (Million AU$)</td>
</tr>
<tr>
<td>Aggregate capital stock</td>
<td>$K_t$</td>
<td>ABS</td>
<td></td>
<td>Annual real private gross capital stock (Million AU$)</td>
</tr>
<tr>
<td>Aggregate demand shocks</td>
<td>$\Delta \log Y_t$</td>
<td>ABS</td>
<td></td>
<td>Difference in real national expenditure (Australian GDP) (Million AU$)</td>
</tr>
<tr>
<td>Aggregate squared demand shocks</td>
<td>$(\Delta \log Y_t)^2$</td>
<td>ABS</td>
<td></td>
<td>Squared difference in real national expenditure (Australian GDP) (Million AU$)</td>
</tr>
<tr>
<td>Aggregate error correction term</td>
<td>$\log Y_{t-1} - \log K_{t-1}$</td>
<td>RBA</td>
<td></td>
<td>Difference between lagged demand and lagged capital stock (Million AU$)</td>
</tr>
<tr>
<td>Changes in aggregate tax</td>
<td>$\Delta \log tax_t$</td>
<td>RBA</td>
<td></td>
<td>Difference in company income tax (Million AU$)</td>
</tr>
<tr>
<td>Changes in macro exports</td>
<td>$\Delta \log ex_t$</td>
<td>RBA</td>
<td></td>
<td>Difference in export values (Million AU$)</td>
</tr>
<tr>
<td>Relevant uncertainties</td>
<td>$u_{tax_t}$, $u_{tt_t}$, $u_{rat_t}$, $u_{cgp_t}$</td>
<td>RBA</td>
<td></td>
<td>Conditional variance of GARCH model</td>
</tr>
<tr>
<td><strong>Industry level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry investment</td>
<td>$I_d$</td>
<td>ABS</td>
<td></td>
<td>Annual real private gross investment (Million AU$)</td>
</tr>
<tr>
<td>Industry capital stock</td>
<td>$K_d$</td>
<td>ABS</td>
<td></td>
<td>Annual real private gross capital stock (Million AU$)</td>
</tr>
<tr>
<td>Industry demand shocks</td>
<td>$\Delta \log Y_d$</td>
<td>ABS</td>
<td></td>
<td>Difference in real national expenditure (Australian GDP) (Million AU$)</td>
</tr>
<tr>
<td>Industry squared demand shocks</td>
<td>$(\Delta \log Y_d)^2$</td>
<td>ABS</td>
<td></td>
<td>Squared difference in real national expenditure (Australian GDP) (Million AU$)</td>
</tr>
<tr>
<td>Industry error correction term</td>
<td>$\log Y_{d,t-1} - \log K_{d,t-1}$</td>
<td>RBA</td>
<td></td>
<td>Difference between lagged demand and lagged capital stock (Million AU$)</td>
</tr>
<tr>
<td>Changes in industry tax</td>
<td>$\Delta \log tax_d$</td>
<td>RBA</td>
<td></td>
<td>Difference in company income tax (Million AU$)</td>
</tr>
<tr>
<td>Changes in industry exports</td>
<td>$\Delta \log ex_d$</td>
<td>RBA</td>
<td></td>
<td>Difference in export values (Million AU$)</td>
</tr>
<tr>
<td>Relevant uncertainties</td>
<td>$u_{tax_d}$, $u_{ex_d}$, $u_{cgp_d}$</td>
<td>RBA</td>
<td></td>
<td>Conditional variance of GARCH model</td>
</tr>
<tr>
<td><strong>Firm level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm investment</td>
<td>$I_e$</td>
<td>DatAnalysis</td>
<td></td>
<td>Expenditure for the purchase of property, plant, and equipment (AU$)</td>
</tr>
<tr>
<td>Firm capital stock</td>
<td>$K_e$</td>
<td>DatAnalysis</td>
<td></td>
<td>Gross total equity (AU$)</td>
</tr>
<tr>
<td>Adjusted cash flow</td>
<td>$\frac{\Delta \log sal}{\log K_{i,t-1}}$</td>
<td>DatAnalysis</td>
<td>+</td>
<td>Ratio of firm cash flow to lagged capital stock</td>
</tr>
<tr>
<td>Micro demand shocks</td>
<td>$\Delta \log sal_d$</td>
<td>DatAnalysis</td>
<td>+</td>
<td>Difference in firm sales (AU$)</td>
</tr>
<tr>
<td>Micro squared demand shocks</td>
<td>$(\Delta \log sal_{d,t-1})^2$</td>
<td>DatAnalysis</td>
<td>+</td>
<td>Squared difference in firm sales (AU$)</td>
</tr>
<tr>
<td>Micro error correction term</td>
<td>$\log sal_{d,t-1} - \log K_{d,t-1}$</td>
<td>RBA</td>
<td>+</td>
<td>Difference between lagged demand and lagged capital stock at the firm level (AU$)</td>
</tr>
<tr>
<td>Changes in firm tax expenses</td>
<td>$\Delta \log tax_{e,t}$</td>
<td>Annual report</td>
<td>-</td>
<td>Difference in firm tax expenses (AU$)</td>
</tr>
<tr>
<td>Changes in firm exchange rate costs</td>
<td>$\Delta \log er_{e,t}$</td>
<td>Annual report</td>
<td>-</td>
<td>Difference in exchange rate costs (AU$)</td>
</tr>
<tr>
<td>Firm size</td>
<td>$\log emp$</td>
<td>Annual report</td>
<td>+</td>
<td>Number of firm employees</td>
</tr>
<tr>
<td>Firm age</td>
<td>$age$</td>
<td>Annual report</td>
<td>+</td>
<td>Firm age in 2012 (1990=1)</td>
</tr>
<tr>
<td>Market capitalisation</td>
<td>$\log mkt$</td>
<td>DatAnalysis</td>
<td>+</td>
<td>Market capitalisation adjusted by GDP deflator (AU$)</td>
</tr>
<tr>
<td>Chinese ownership</td>
<td>$ocn$</td>
<td>Annual report</td>
<td>+</td>
<td>Dummy variable (1 stands for Chinese ownership, 0, otherwise)</td>
</tr>
<tr>
<td>Relevant uncertainties</td>
<td>$u_{tax_e}$, $u_{er_e}$, $u_{sal_e}$</td>
<td>RBA</td>
<td></td>
<td>Conditional variance of GARCH model</td>
</tr>
</tbody>
</table>

Source: ABS (2012), RBA (2012), DatAnalysis (2012), and Author’s calculations using the data from firms’ annual reports.
Chapter 5

Determinants of Macro Investment

5.1 Introduction

Since 2003 the Australian economy and mining industry have experienced a marked increase in investment, primarily driven by fast growth in Chinese demand. The increase in investment has been accompanied by structural changes in exports, exchange rates, taxes, production, and revenues. This chapter empirically explores how these changes are interrelated with Australian private investment at the macroeconomic level. As elaborated in Chapter 4, the empirical model in Bloom et al. (2007) is useful for understanding the implications of the mining boom on Australian private investment and the economy as a whole. Other contributions and challenges to which investment models have been applied are also discussed in detail below.

Section 5.2 sets up an estimation framework of investment behaviour at the macro level. Section 5.3 describes the nature of macroeconomic investment data. Section 5.4 presents the results of the stationarity tests. Section 5.5 generates uncertainty variables for the Australian economy. Section 5.6 assesses the empirical models along with the estimations and analyses.
5.2 Macro Investment Estimation Framework

An empirical model to estimate the dynamics of Australian macro investment is presented below. The estimation is carried out using unit root tests, the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model, and the ECM model. These methods are based on the reviewed models and equations in Chapter 3, and on the research methodology described in Chapter 4.

The stationarity test is first used to examine whether investment-related variables are stationary or not. If the relevant variables are non-stationary, the results of the empirical test may be spurious and biased. Moreover, the non-stationary variables can be processed by an ARIMA method. Except for the general variables, the uncertainty variables are generated by the GARCH models. To be precise, the GARCH model generates conditional data (uncertainty data). An OLS method is first estimated to inspect the preliminary relationship between Australian macro investment and explanatory variables. Due to the possibility of endogeneity, the GMM method is also adopted. The testing process for these two models is driven by Bloom et al. (2007), but differs in choices of variables. Specifically, the variables used in this chapter are time series data, while Bloom et al. (2007) use panel data.

5.3 Data Description at the Macroeconomic Level

This chapter provides a rough description of time series data for Australian private investment at the macroeconomic level from the Australian Bureau of Statistics data for the years 1969–2012\textsuperscript{20}. Forty-three observations were available for modelling investment behaviour. This description focuses on the annual value of the investment ratio, GDP, company income tax, and terms of trade. As shown in Table 5.1, the mean investment ratio is 1.073, while the median investment ratio is 1.072. For aggregate demand, company income tax, and terms of trade, the means are slightly higher than the medians. Figure 5.1 shows the description of key variables at the

\textsuperscript{20}From 1960 to 1969, some observations are missing in the data set. Thus, the complete and consistent time series sample is established from 1969 to 2012.
5.4. STATIONARITY TESTS AT THE MACROECONOMIC LEVEL

macroeconomic level. At the macroeconomic level company income tax and terms of trade experienced stable growth during the period 1990–2012, while the private investment ratio and aggregate demand showed large volatility in the period 1969–2012. Notably, 1992 marked the lowest point for the investment ratio.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>P25</th>
<th>P50</th>
<th>P75</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{I_t}{K_{t-1}}$</td>
<td>1.073</td>
<td>1.064</td>
<td>1.072</td>
<td>1.081</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>198270.1</td>
<td>126513.5</td>
<td>179530.0</td>
<td>263822.5</td>
</tr>
<tr>
<td>$tax_t$</td>
<td>1045.617</td>
<td>112.357</td>
<td>562.549</td>
<td>1480.821</td>
</tr>
<tr>
<td>$tt_t$</td>
<td>62.779</td>
<td>54.806</td>
<td>56.834</td>
<td>64.147</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using ABS (2012)

Notes: $P_i$ is the $i$th percentile. $Y_t$ is the real value of GDP in 2012 (AU$Million). $\frac{I_t}{K_{t-1}}$ stands for the ratio of the investment at time $t$ to the capital stock at time $t - 1$. $tax_t$ is the real company income tax (relative to GDP deflator in 2012). $tt_t$ is the real terms of trade (relative to GDP deflator in 2012).

5.4 Stationarity Tests at the Macroeconomic Level

Examining whether certain variables concerning Australian private investment are stationary or non-stationary is of great importance to better interpreting investment performance. In the absence of stationarity tests, there is a risk of obtaining spurious results from non-stationary variables. The non-stationary series are associated with the infinite and time-dependent mean and variance of data series. Thus, non-stationary variables affected by random shocks have permanent effects in the long run.

To avoid some misleading observations and inferences, Dickey and Fuller (1979)
proposed the unit root test to examine whether a variable follows a random walk. Among different types of unit root tests, the augmented Dickey Fuller (ADF) test considers a variable having a unit root as the null hypothesis, while the alternative hypothesis assumes that there is no unit root in the given data. Moreover, due to the possibility of deterministic variation, this test is extended to include a constant term and time trend (Dickey and Fuller, 1979), as expressed in Equation 5.1:

$$\Delta \pi_t = \alpha + \lambda t + \gamma \pi_{t-1} + \sum_{s=1}^{m} \alpha_s \Delta \pi_{t-s} + v_t$$  \hspace{1cm} (5.1)$$

where $\Delta \pi_t$ is the difference of time series data, $\alpha$ is the constant term, $v_t$ is a white noise with a zero mean and constant variance, $t$ is the time trend, and $\pi_{t-1}$ is the lagged variable. The ADF test is estimated by the ordinary least squares (OLS) regression. However, the accuracy of ADF test results is reduced due to the possibility of serial correlation.

To overcome the issue of serial correlation, Phillips and Perron (1988) introduced the Newey-West heteroskedasticity and autocorrelation-consistent covariance matrix.

**Figure 5.1:** Key Variables at the Macro Level, 1969–2012
5.4. STATIONARITY TESTS AT THE MACROECONOMIC LEVEL

estimator. While the test equation is the same as Equation 5.1. The Phillips-Perron test (PP) remains biased towards the non-rejection of the null hypothesis that (that the data has a unit root) if the time series data is subject to structural breaks over time.

To account for the effect of structural breaks, Zivot and Andrews (2002) devised the conventional unit root test to allow a structural break in the deterministic trend. This test, expressed in Equation 5.2, detects a single trend or intercept break with an unknown date.

\[ y_t = \mu + \beta_a t + \theta_a D\mu_t(T_B) + \gamma_a D\tau(T_B) + \alpha a y_{t-1} + \mu_t \] (5.2)

where \( y_t \) is time series data, \( T_B \) is the date of break, and \( D\mu_t \) and \( D\tau \) are 0 when there is no break in the intercept or trend; otherwise they are marked as 1. This test demonstrates that the stochastic break has no prominent impacts on the deterministic trend or intercept in the long run. Vogelsang and Perron (1998) then reproduced the ADF test by allowing for one significant structural break in the trend or intercept to examine the stationarity of data. Vogelsang and Perron’s (1998) model performs well in panel data with an unknown break date. The specification of the model is similar to that of Zivot and Andrews (2002).

Consequently, before proceeding to the estimation of Australian private investment, it is important to verify whether the employed data is stationary or non-stationary. Stationarity tests are carried out using the ADF test, the PP test, the Zivot and Andrews test, and the Vogelsang and Perron test. Table 5.2 shows the results for stationarity at the macroeconomic level. Due to skewed distributions of variables, the logarithmic transformations of those variables were used. As indicated, except for Chinese GDP growth, these tests fail to reject the null hypothesis that the given series is non-stationary at the 1% level of significance. This suggests that only data for Chinese GDP growth is stationary in all tests, while other data are non-stationary in one or more tests. After the first differences, those variables are stationary. The stationarity of Chinese GDP growth in Table 5.2 shows that the
### Table 5.2: Unit Root Tests at the Macro Level

<table>
<thead>
<tr>
<th>Macroeconomic variables</th>
<th>ADF test</th>
<th>PP test</th>
<th>Zivot &amp; Andrews test</th>
<th>Vogelsang &amp; Perron test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_0$: Unit root</td>
<td>$H_0$: Unit root</td>
<td>$H_0$: Unit root</td>
<td>$H_0$: Unit root</td>
</tr>
<tr>
<td></td>
<td>$H_1$: Stationary with one unknown break</td>
<td>$H_1$: Stationary with one unknown break</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>I(0)/I(1)</th>
<th>I(0)/I(1)</th>
<th>I(0)/Unit root</th>
<th>Break date ($T_B$)</th>
<th>I(0)/Unit root</th>
<th>Break date ($T_B$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private investment/Private capital stock*</td>
<td>I(0)</td>
<td>I(0)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
<tr>
<td>Chinese GDP growth*</td>
<td>I(0)</td>
<td>I(0)</td>
<td>I(0)</td>
<td>1982</td>
<td>I(0)</td>
<td>1974</td>
</tr>
<tr>
<td>Australian real GDP</td>
<td>I(1)</td>
<td>I(1)</td>
<td>I(0)</td>
<td>2005</td>
<td>I(0)</td>
<td>2006</td>
</tr>
<tr>
<td>Commodity prices</td>
<td>I(1)</td>
<td>I(1)</td>
<td>I(0)</td>
<td>1999</td>
<td>I(0)</td>
<td>2009</td>
</tr>
<tr>
<td>Real terms of trade</td>
<td>I(0)</td>
<td>I(0)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
<tr>
<td>Real unit labour cost</td>
<td>I(0)</td>
<td>I(0)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
<tr>
<td>Real unemployment</td>
<td>I(0)</td>
<td>I(1)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
<tr>
<td>Cash rates</td>
<td>I(1)</td>
<td>I(1)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
<tr>
<td>CPI</td>
<td>I(1)</td>
<td>I(1)</td>
<td>I(0)</td>
<td>2002</td>
<td>I(0)</td>
<td>2008</td>
</tr>
<tr>
<td>Company income tax</td>
<td>I(1)</td>
<td>I(1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Real effective exchange rates*</td>
<td>I(0)</td>
<td>I(1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Net foreign debt</td>
<td>I(1)</td>
<td>I(1)</td>
<td>Unit root</td>
<td>-</td>
<td>Unit root</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: All variables except for variables* were tested in logarithm form. These data were tested in levels. If data exhibited a unit root in levels, first differences of the data were examined to ensure stationarity. I(0) indicates that it does not contain a unit root. I(1) indicates that its first-differenced series is stationary.
Chinese economy is less affected by permanent shocks.

Given the consideration of the structural break, the results of the ADF and the PP tests are different from those of the Zivot and Andrews and the Vogelsang and Perron tests for private investment and Australian real GDP. Due to the possible permanent shocks embodied in these variables, the hypothesis of stationarity of given data cannot be tested directly. Notably, the impacts of the structural breaks on private investment and Australian real GDP need to be confirmed.

Conversely, price variables (for example, the real terms of trade) confirm the non-rejection of the null hypothesis under the ADF and the PP tests, while it is rejected under the Zivot and Andrews and the Vogelsang and Perron tests. In this regard, the break dates in each price variable range from 1999 to around 2008. These findings suggest that the financial crises in 1999 and 2008 had distinct effects on the relevant price variables.

The ADF and the PP tests seem to be biased due to structural breaks in the data set resulting from policy changes or economic shocks. These large changes in the trend or intercept can be captured by the Zivot and Andrews and the Vogelsang and Perron tests. Therefore, these two tests are appropriate for subsequent estimation.

5.5 Uncertainty Data at the Macroeconomic Level

To estimate the uncertainty variables of the Australian macroeconomy, the Autoregressive Conditional Heteroskedasticity (ARCH) and the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models are used. As discussed in Chapter 4, the GARCH model has several advantages for estimating uncertainty data. Firstly, the coefficient $\beta$ is a long-memory parameter measuring the long-term effect of exogenous shocks on conditional variance. Secondly, uncertainty data regarding the Australian macroeconomy is directly obtained from $\epsilon_{t-j}$ for the conditional variance. In terms of this conditional variance, it is possible to calculate forward expected data. Thirdly, compared to the ARCH model, the GARCH model can capture the serial correlation for conditional variance.
This study follows the works of Bloom et al. (2007); Bond and Lombardi (2006), in which aggregated data are transformed to derive uncertainty variables. Therefore, based on aggregate data, the GARCH model can approximate uncertainty data from the conditional variance.

The results of the GARCH models for Australian macroeconomic uncertainty data are summarised in Table 5.3 and shown in Figure 5.2. The chosen autoregressive terms are inspected by the criterion of Akaike Information Criterion. Other than Chinese GDP growth, uncertainty data are characterised by a significant ARCH effect. This effect confirms the usefulness of the GARCH model to obtain uncertainty data. In addition, these results show that the ARCH effect is more likely observed in high-frequency data than other data.

<table>
<thead>
<tr>
<th>Macroeconomic Uncertainty Variables</th>
<th>ARMA(p,q) / ARIMA(p,d,q)</th>
<th>ARCH(p) / GARCH(p,q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese GDP growth (yearly)</td>
<td>(2,1)</td>
<td>-</td>
</tr>
<tr>
<td>Australian GDP (quarterly)</td>
<td>(8,1,8)</td>
<td>(3,1)</td>
</tr>
<tr>
<td>Terms of trade (quarterly)</td>
<td>(5,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Unit labour cost (quarterly)</td>
<td>(2,1,1)</td>
<td>(6,1)</td>
</tr>
<tr>
<td>Net foreign debt (quarterly)</td>
<td>(1,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Company income tax (monthly)</td>
<td>(5,1,8)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Real effective exchange rate (monthly)</td>
<td>(1,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Real unemployment (monthly)</td>
<td>(12,1,12)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Commodity prices (monthly)</td>
<td>(12,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Trimmed mean CPI (monthly)</td>
<td>(12,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Cash rate (monthly)</td>
<td>(1,1,1)</td>
<td>(1,1)</td>
</tr>
</tbody>
</table>

Notes: All variables were tested in logarithms. These quarterly/monthly variances were averaged to obtain annual variances. To remove the effect of tax revenues on the change in company income tax and its uncertainty, company income tax was divided by national revenues. The ratio of company income tax to company income can highlight the effect of the changes in tax rates, in contrast to the changes in revenues, on investment behaviour.
5.5. **UNCERTAINTY DATA AT THE MACROECONOMIC LEVEL**

Compared to other uncertainty data, that for Australian GDP displayed a steady decline from 1960 to 2010. This performance was in line with the fact that Australian GDP experienced stable growth without large disruptions from 1960 to 2010.

There are two salient spikes in the terms of trade. The first spike, in 1973/1974, was linked with the first oil crisis, which resulted in sharp increases in global oil prices. In response to high demand for imported oil, Australian terms of trade were volatile in that period. The second spike, in 2009/2010, was provoked by the global
5.5. **UNCERTAINTY DATA AT THE MACROECONOMIC LEVEL**

financial crisis. This crisis severely influenced Australian exports and imports, and therefore the terms of trade.


Similar to real exchange rates, capital cost also displayed large volatility. Firstly, company income tax showed high spikes in the years 1970, 1973, 1990 and 2000. Spikes in the terms of trade in 1970 and 1973 were attributable to the first global oil crisis. The 1990 spike was triggered by the Gulf war in Iraq, raised concerns about economic development and the volatility of commodity prices. In 2000, the Australian government introduced its goods and services tax to replace sales taxes.

Secondly, a notable spike was observed in the interest rate in 1983/1984, in line with the change in foreign exchange policy. The floating exchange rate resulted in a sharp decrease in exchange rates, and correspondingly the domestic cash rate. The 2008 global financial crisis had a far larger impact on CPI than the various shocks in the 1970s and 1980s.

Table 5.4 shows the frequency of low and high levels of different uncertainties; this suggests that low levels of Australian macro uncertainty are more likely. Table 5.5 presents macroeconomic investment preference over low and high levels of uncertainty. As shown, the Australian macroeconomy is more likely to encounter low levels of uncertainty for a number of factors, such as different categories of demand, tax revenues, foreign trade, interest rates and Chinese GDP growth. In contrast, as suggested by the differences of means tests, investors at the macroeconomic level have an incentive to invest more under the significant effect of high demand uncertainty on the short-run investment response to demand shocks, high levels of uncertainties in demand, terms of trade and Chinese GDP growth. Together with the distributions of different uncertainties (Figure 5.2), the frequency results indicate
that investors facing some types of high uncertainty have been prone to investing more than under low uncertainty at the macroeconomic level. This is in line with the nature of the mining industry (Chapter 2). Most capital-intensive projects in the mining industry take a long time to reach completion. Consequently, mining production has a lagged response to high and positive demand shocks. To reduce the response time of production, mining investors are more interested in initiating investment in periods of high uncertainty. Therefore, at the macroeconomic level, Australian investment behaviour is influenced by the mining industry.

Table 5.4: Macroeconomic Data Frequency under Low and High Uncertainties

<table>
<thead>
<tr>
<th></th>
<th>( u_{gdp_t} )</th>
<th>( u_{gdp_t} \times \Delta \log Y_t )</th>
<th>( utax_t )</th>
<th>( utt_t )</th>
<th>( urat_t )</th>
<th>( ucgdp_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>0.00020</td>
<td>0.00001</td>
<td>0.88</td>
<td>0.001</td>
<td>0.0021</td>
<td>0.1361</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>0.00018</td>
<td>8.54e-6</td>
<td>0.80</td>
<td>0.0006</td>
<td>0.0012</td>
<td>0.0231</td>
</tr>
<tr>
<td><strong>Skewness</strong></td>
<td>0.464</td>
<td>1.78</td>
<td>1.167</td>
<td>1.544</td>
<td>3.86</td>
<td>4.473</td>
</tr>
</tbody>
</table>

Notes: \( u_{gdp_t} \) is GDP uncertainty, \( u_{gdp_t} \times \Delta \log Y_t \) is the interaction between GDP uncertainty and GDP growth, \( utax_t \) is uncertainty in company income tax, \( urat_t \) is uncertainty in the cash rate, \( ucgdp_t \) is uncertainty in Chinese GDP growth. If the mean is larger (smaller) than the median, the distribution of uncertainty data is right (left) skewed. This indicates that most values of uncertainty data are lower (higher) than the average value.

5.6 Models of Macroeconomic Investment

As discussed in the literature review in Chapter 3, the accelerator theory argues that aggregate demand is an important multiplier of macro investment. The user cost has a similar effect on investment. These investment theories also suggest that an endogeneity problem occurs, if some variables are not exogenously determined. Therefore, this study uses the Generalised Method of Moments (GMM) to address the issue of under-identification, due to the presence of endogeneity and unobserved firm-specific effects (Arellano and Bond, 1991). This approach allows the results of
### Table 5.5: Macroeconomic Mean Investment under Low and High Uncertainties

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low</th>
<th>High</th>
<th>Difference of Means Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ugdp_t$</td>
<td>0.064</td>
<td>0.077</td>
<td>S</td>
</tr>
<tr>
<td>$ugdp_t , \Delta \log Y_t$</td>
<td>0.066</td>
<td>0.075</td>
<td>S</td>
</tr>
<tr>
<td>$utax_t$</td>
<td>0.070</td>
<td>0.071</td>
<td>N</td>
</tr>
<tr>
<td>$urat_t$</td>
<td>0.067</td>
<td>0.074</td>
<td>S</td>
</tr>
<tr>
<td>$ucgdp_t$</td>
<td>0.072</td>
<td>0.069</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
<td>0.072</td>
<td>S</td>
</tr>
</tbody>
</table>

Notes: $ugdp_t$ is GDP uncertainty, $ugdp_t \, \Delta \log Y_t$ is the interaction between GDP uncertainty and GDP growth, and $utax_t$ is uncertainty in company income tax. (To remove the effect of tax revenues on the change in company income tax and its uncertainty, the company income tax was divided by national revenues.

The ratio of company income tax to company income can be used to examine the effect of changes in tax rates rather than changes in revenues on the investment behaviours.

$urat_t$ is uncertainty in the cash rate, $ucgdp_t$ is uncertainty in Chinese GDP growth, and Low (High) refers to the frequency of the observations for which measured uncertainty is lower (higher) than the sample median. Figures in bold indicates that investment under high uncertainty is significantly greater than under low uncertainty. The difference of means tests is used to determine whether the differences in average investment under high and low uncertainty are statistically significant. S indicates significance at 10%, N indicates non-significance at 10%.
the empirical findings to be compared with the reviewed literature. Section 5.6.1 uses the Ordinary Least Squares (OLS) method to examine the relationship between different variables and investment. Section 5.6.2 presents the GMM results for Australian private investment at the macroeconomic level (1969–2012 and 1990–2012) using annual and quarterly data. Section 5.7 concludes and compares the results with those of other studies.

The empirical specification uses the GMM method which refers to Baum (2006) and Wooldridge (2002). The GMM estimator is typically used to correct for bias caused by endogenous explanatory variables. Wooldridge (2002) used a GMM estimator to simultaneously estimate lagged variables and endogenous variables in a regression with unobserved effects. Specifically, the estimator in the regression ensures no serial correlation between the error terms and explanatory variables and eliminates the unobserved fixed effects in the regression. The instrumental variables are corrected and expressed by the lagged endogenous variables. This transformation is valid if there is no rejection of the null hypothesis using the Hansen over-identification test. More importantly, when the number of instrumental variables is greater than the number of unobserved (endogenous) variables, the issue of over-identification occurs. This study follows Arellano and Bover (1995) and Blundell and Bond (1998) in using the lagged differences of the endogenous variables as instruments to ensure no correlation between the error terms and explanatory variables.

5.6.1 OLS Method

The first equation is estimated using the OLS method. This method shows the preliminary result of the determinants of Australian private investment at the macroeconomic level. The OLS method (from 1969 to 2012) for annual data is given in
5.6. MODELS OF MACROECONOMIC INVESTMENT

Equation 5.3:

\[
\frac{I_t}{K_{t-1}} = 0.093 + 0.045(\Delta \log Y_t) - 1.357(\Delta \log Y_t)^2
\]

\[
+ 0.006(\log Y_{t-1} - \log K_{t-1}) + 0.0001 \Delta \log tax_t
\]

\[
+ 5.8ugdp_t + 3.556ugdp_t \ast \Delta \log Y_t - 0.002utax_t
\]

\[
- 1.766utt_t - 0.735urat_t + 0.005ugdpt_t
\]

\[(5.3)\]

*** indicates significance at 1%, ** significance at 5%, * significance at 10%. The figures in parentheses are the standard errors of the estimates.

where \( \frac{I_t}{K_{t-1}} \) is the ratio of private investment to private capital stock at times \( t \) and \( t - 1 \), \( \Delta \log Y_t \) is demand shocks at time \( t \), \( (\log Y_{t-1} - \log K_{t-1}) \) is the difference between Australian GDP and private capital stock at time \( t - 1 \), \( (\Delta \log Y_t)^2 \) is squared demand shocks at time \( t \), \( \Delta \log tax_t \) is the change in company income tax at time \( t \), \( ugdp_t \) is demand uncertainty at time \( t \), \( ugdpt_t \ast \Delta \log Y_t \) is the effect of demand uncertainty on the short-run investment response to demand shocks at time \( t \), \( utax_t \) is uncertainty in company income tax at time \( t \), \( utt_t \) is uncertainty in terms of trade at time \( t \), \( urat_t \) is uncertainty in the interest rate at time \( t \), and \( ugdpt_t \) is uncertainty in Chinese GDP growth at time \( t \).

As shown by the OLS method in Table 5.6, several effects are dominant in the macroeconomic investment model. The relationship between demand shocks and investment expressed by the variable \( \Delta \log Y_t \) and \( (\Delta \log Y_t)^2 \) is negative and insignificant, while the long-term error correction term given by \( (\log Y_{t-1} - \log K_{t-1}) \) is significant and positive. This shows that the effect of long-term demand shocks on private investment is dominant in the OLS method. This confirms the accelerator theory in which demand shocks are important multipliers of investment (Clark, 1917).

\[21\] Due to the difference between the sign of the terms of trade and the expected sign in Table 4.1, the terms of trade variable is dropped.
For the change in company income tax ($\Delta \log\text{tax}_t$), a positive and significant coefficient is observed, confirming the importance of the user cost of capital. The positive sign confirms the income and transfer effects described in Chapter 2. The Australian mining boom has also led to a boom in revenue, with an increase in income taxes.

In particular, the significant and positive uncertainty coefficients in this model are demand uncertainty ($u_{gdp_t}$) and uncertainty of Chinese GDP growth ($u_{gdp_t}$). The positive coefficients suggest that demand shocks from Chinese economic growth have a positive effect on Australian investment under high uncertainty.

When the examined period is shortened to 1990–2012, different results for the OLS in Table 5.7 are shown. The coefficient for Chinese GDP growth uncertainty is shown to be negative and insignificant, while that for terms of trade uncertainty ($u_{tt_t}$) is negative and significant at −4.122. The coefficients of changes in company income tax and terms of trade remain nearly unchanged at 0.011 and 0.036, respectively.

These different uncertainty results for two periods may be due to the feature of the export-oriented Australian economy. Simultaneously, these ambiguous results raise concerns about endogeneity in this regression. To avoid endogeneity and over-identification, the GMM method is considered.

5.6.2 GMM Method

Tables 5.6, 5.7 and 5.8 reported the preferred specification in the GMM estimation. Through the Hansen over-identification test, the estimation results except for GMM column (1) of Table 5.6 are valid for assessment and explanation. Using the first-differenced explanatory variables can give more precise results against the serial correlation and the fixed effects in the regression.

This study uses the GMM method to address the issue of under-identification, due to the presence of endogeneity and unobserved firm-specific effects (Arellano

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22 This period is consistent with the analyses at the industry and firm levels.
The GMM method does not asymptotically perform worse than the 2SLS model (Wooldridge, 2002). Based on this advantage, the determinants of Australian private investment at the macroeconomic level are examined using the GMM method. The variables in the GMM method (from 1969 to 2012) are the same as those in the OLS method. Hence, the results of the GMM method for annual data are presented in Table 5.6. Although GMM columns (4) and (5) in Table 5.6 analyse the main results, the results for GMM columns (1), (2) and (3) indicate whether there are large variations in the signs and significances of the main variables.

Column (1) of Table 5.6 shows the results for a basic linear investment model, along with the additional effects of company income tax and terms of trade. Although a negative and insignificant coefficient for $\Delta \log Y_t$ is observed, the positive-signed coefficient for the error correction term ($\log Y_{t-1} - \log K_{t-1}$) is significant at 0.011. This suggests that long-run demand shocks have a positive impact on investment, and that the capital stock adjusts towards a level proportional to demand changes. This finding is in line with those of Bloom et al. (2007) and Bond and Lombardi (2006), stressing that firms with capital stock below the long-run equilibrium level adjust capital stock upwards. Surprisingly, the significant coefficient on the changes in company income tax ($\Delta \log \text{tax}_t$) is positively signed at 0.005, which is different from the expected signs in Table 4.1. According to the facts in Chapter 2, due to the mining boom, significant increases in Australian tax revenue were observed from 2003 to 2010. For this period, Australian company income tax and the terms of trade performed cyclically with private investment (Convey, 2012). Therefore, this model captures the positive and significant coefficients of the changes in company income tax and terms of trade. However, in terms of the rejection of the null hypothesis of the Hansen over-identification test, the statistical explanatory power of the model in column (1) is limited.

Column (2) of Table 5.6 introduces a term for the squared demand changes ($\left((\Delta \log Y_t)^2\right)$) to investigate whether the linear accelerator effect or the nonlinear ef-

23Discussions for columns (1), (2) and (3) help to understand whether the addition of demand uncertainty and other uncertainties has a large impact on model estimation.
fect on investment dominates over time. To interpret the effects of different demand shocks on macroeconomic investment shown in column (2), the marginal effects of demand shocks during 1969–2012 were quantified at \(-3.312\). The combined effects of demand shocks are large, negative, and significantly different from zero, implying that investment has a concave response to demand shocks over time. According to Figure 5.1, Australian macroeconomic investment experienced a downward trend after 1969. Thus, the turning point for the concave relationship between demand shocks and investment was prior to 1969 and macroeconomic investment data clustered at the right side of the turning point. This is opposite to the sign of the quadratic demand term in Bloom et al. (2007), this is, partly because the tested economy is different. Simultaneously, investors under high uncertainty after 1969 may have been more cautious about macro investment. Notably, the signs and sizes of the significant coefficient for \(\Delta \log tax_t\) are fairly the same as those in column (1) and under the OLS method. A simple goodness of fit statistic also suggests that this model has reasonable explanatory power at the macroeconomic level.

Column (3) of Table 5.6 includes the effects of uncertainty variables; specifically, the effect of demand uncertainty on the short-run investment response to demand shocks, uncertainties in demand, company income tax and terms of trade, interest rate and Chinese GDP growth. The coefficients of the changes in company income tax and the terms of trade are very similar to those in column (2). Also similar to column (2), the marginal effects of demand shocks are observed at \(-1.566\). For uncertainty of the interest rate and Chinese GDP growth, significant coefficients are derived with negative and positive signs, respectively. The only positive uncertainty variable is Chinese GDP growth uncertainty, which is in contrast to the negative uncertainty effect in Dixit and Pindyck (1994). This confirms the finding that investment is more likely to happen in periods of high uncertainty of Chinese GDP growth. The positive relationship between Chinese GDP growth uncertainty and investment helps in reducing the response time of production to meet expected

\[\frac{\partial \Delta \log Y_t}{\partial \Delta \log Y_t} + \frac{\partial \Delta \log Y_t}{\partial (\Delta \log Y_{t-1})^2} + \frac{\partial \Delta \log Y_t}{\partial (\Delta \log Y_{t-1} - \Delta \log K_{t-1})} = -3.312\]
rising Chinese demand. In addition, as suggested by Slade (2013), the uncertainty-investment relationship may not be negative; instead, it may be caused by variation in the analyses at the aggregated and disaggregated levels. The other possibility is the Hartman-Abel effect; in a competitive market, if the marginal product of capital is convex in price, an increase in price variance raises the expected return on the marginal product of capital and thus drives investment (Carruth et al., 2000).

Column (4) of Table 5.6 reports the full variable set where the nonlinear effect of demand changes is tested. The increase in the statistics of the goodness-of-fit tests suggests that this model has reasonable explanatory power. Firstly, the significant result of $ugdp_t$ shows that the long-run effect of demand uncertainty is identified with the coefficient at 4.492. A positive coefficient is also found for Chinese GDP growth uncertainty at 0.008. As suggested above, high uncertainty is an incentive for investment due to the Hartman-Abel effect.

Secondly, during 1969–2012, although the coefficient for short-term demand shocks is insignificant, the marginal effects of different demand shocks on investment are derived at $-2.747^{25}$. Thus, the turning point for the concave relationship between demand shocks and investment is prior to 1969 and macro investment data clustered at the right side of the turning point. This confirms the findings in columns (2) and (3) that the concave relationship between demand shocks and investment is evident under uncertainty. This behaviour corresponds to the nature of the Australian economy and its mining industry, where investment projects are characterised by capital intensity, especially in their early stages.

Thirdly, the effect of the changes in company income tax on investment is similar to that shown in column (3) and is persistent. Given the range of uncertainty variables, the effects of tax uncertainty and uncertainty of Chinese demand growth are the same, while the effect of uncertainty in terms of trade is opposite to that of column (3).

Column (5) of Table 5.6 omits demand uncertainty ($ugdp_t$) to individually test

\[ \frac{\partial \frac{I}{K}}{\partial (\Delta \log Y)}^2 + \frac{\partial \frac{I}{K}}{\partial (\log Y_{t-1} - \log K_{t-1})} = -2.747^{25} \]
its effect on the short-run investment response to demand shocks \((ugdp_t \ast \Delta \log Y_t)\). The omission of demand uncertainty has no impacts on the explanatory power. In contrast to column (4), under uncertainty the concave effect of demand changes on investment is significantly observed at \(-2.076\). The coefficients of the changes in company income tax and terms of trade and other uncertainties are the same as those in column (4). It is worth stressing that the results of columns (2) (3) (4) and (5) are supported by the Hansen over-identification tests.

To obtain the GMM results (Table 5.7), the investment model for the short period 1990–2012 was tested to maintain consistency with those at the industry and firm levels \(^{26}\). The main differences are centred in the relationship between demand shocks and investment, and that between uncertainty and investment. From columns (1) to (5) of Table 5.7, the coefficients for the error correction term transform to be positive and insignificant. Only in the full set of column (4), the coefficient for nonlinear demand shocks becomes positive and significant at 3.731. The coefficients of Chinese GDP growth uncertainty in columns (3), (4), and (5) are significantly negative, while the coefficients of demand uncertainty and the effect of demand uncertainty on the short-run investment response to demand shocks are insignificant. Apart from these changes in Table 5.7, the investment responses to changes in company income tax and terms of trade, and changes in terms of trade uncertainty remain unchanged.

The reversed GMM results for 1990–2012 suggest that for that period, the convex relationship between demand shocks and macroeconomic investment under different uncertainties is not statistically confirmed. More specifically, over 1990–2012, in GMM column (4) the only significantly marginal effects of different demand shocks on investment were observed at 6.981 \(^{27}\). Although the coefficients for the linear and squared terms imply a U-shaped relationship, the coefficients for demand uncertainty and the effect of demand uncertainty on the short-run investment response

\(^{26}\)Due to the limited number of observations in Table 5.7, the model’s power of explanation may be affected.

\(^{27}\)According to the coefficients in column (4) of Table 5.7, the marginal effects of demand shocks are calculated as

\[
\frac{\partial I_t}{\partial \Delta \log Y_t} + \frac{\partial I_t}{\partial (\Delta \log Y_t)^2} = 6.981
\]
to demand shocks are insignificant. Hence, the relationship between demand shocks and investment under demand uncertainty is not clear. As shown in Figure 5.1, the lowest point of Australian macroeconomic investment was 1992. Thus, the turning point for the convex relationship between demand shocks and investment was 1992, at which point macroeconomic investment data clustered at the right side of the turning point. This is in line with the findings of Bloom et al. (2007) who argued that in periods subsequent to times of high-level uncertainty, investors may wait for more information.

Similarly, during 1990–2012, Chinese GDP growth uncertainty had a negative effect on macroeconomic investment, implying that stable Chinese economic growth has been increasingly important to the Australian economy. As discussed in Chapter 2, at the aggregated level, foreign trade with China led to a boom in mining exports, government income, tax revenues, and investment. At the disaggregated level, Chinese investment provided large and sustainable earnings for Australian mining firms over the long run. The results for 1969–2012 and 1990–2012 characterise the Australian economy as capital-intensive and export-oriented. Furthermore, similar to those in Table 5.6, the statistics for the goodness-of-fit tests in Table 5.7 suggest that the model for 1990–2012 has reasonable explanatory power.

To examine the impact of quarterly data on the results of Australian macroeconomic investment, the model for quarterly data (from 1992 to 2012) is presented in
the following equation and shown in column (4) of Table 5.8.

\[
\Delta \log I_t = 0.038 - 0.155(\Delta \log Y_t) + 3.478(\Delta \log Y_t)^2 \\
- 0.165(\Delta \log I_{t-1}) - 0.0001 \Delta \log tax_t \\
+ 11.992ugdp_t + 5.885ugdp_t \ast \Delta \log Y_t \\
- 0.007utax_t + 0.765utt_t - 5.109urat_t - 0.003ucgdp_t
\]

(5.4)

*** indicates significance at 1%, ** significance at 5%, * significance at 10%. The figures in parentheses are the standard errors of the estimates.

where \( \Delta \log I_t \) is private investment at time \( t \), \( \Delta \log Y_t \) is the change in Australian GDP at time \( t \), \( (\Delta \log Y_t)^2 \) is squared Australian demand shocks at time \( t \), \( \Delta \log I_{t-1} \) is lagged private investment at time \( t - 1 \), \( \Delta \log tax_t \) is the change in the company income tax at time \( t \), \( ugdpt \) is the change in uncertainty of Australian GDP at time \( t \), \( ugdpt \ast \Delta \log Y_t \) is the interaction of uncertainty of Australian GDP and the change in Australian GDP at time \( t \), \( utax_t \) is uncertainty of company income tax at time \( t \), \( utt_t \) is uncertainty of the terms of trade at time \( t \), \( urat_t \) is uncertainty of the cash rate at time \( t \), and \( ucgdp_t \) is uncertainty of Chinese GDP growth at time \( t \).

Due to the unavailability of quarterly data for capital stock at the macro level, the investment ratio was replaced by the change in quarterly investment and its lagged variable. Other tested variables in the quarterly model estimated by the GMM are the same as in the annual model. In addition, due to the lack of long historical data (1969–2012) on Chinese GDP growth, the quarterly data on Chinese GDP growth (1992–2012) was tested using the GARCH model, which can generate the uncertainty of Chinese GDP growth.

In Table 5.8, most signs of the coefficients in the quarterly model are aligned with those of the annual model. However, the positive and insignificant coefficients of

\[28\] Due to the difference between the sign of the terms of trade and the expected sign in Table 4.1, the terms of trade variable is dropped.
the squared demand shocks and demand uncertainty are in contrast to the negative coefficients in the annual model, indicating that the relationship between demand shocks and investment in the quarterly model is ambiguous. A significantly negative coefficient is observed in column (4) of Table 5.8 for uncertainty in the interest rate, and is bigger than that found using the annual model; this implies that uncertainty in the interest rate has a significant effect on quarterly data.

For the quarterly data test in Table 5.8, although the Hansen over-identification supports the goodness-of-fit model, most results seem to have weak explanatory power for Australian macroeconomic investment behaviour. This may suggest that more frequent data cannot explain investment. In addition, the multiple effects of different variables may counteract each other, causing the weak estimation. Notably, the reason for the differences in the results for Tables 5.7 and 5.8 can be determined from Figure 5.3, which shows that the dependent variable in the quarterly test is more volatile than in the yearly test.

Overall, the findings for the macroeconomic investment estimation are inconsistent with those of Bloom et al. (2007) and Bond and Lombardi (2006). Firstly, a significant demand uncertainty in the long run is evident against the ambiguous effect of uncertainty that these researchers assert. Secondly, under uncertainty the concave and convex relationships between demand changes and investment are explored, supporting that the short-term effects of demand changes are not aligned with the long-run effects.

5.7 Conclusion

The GMM techniques for analysing annual and quarterly data are helpful to shed light on the determinants of Australian private investment at the macroeconomic level. Based on the results in Table 5.6, aggregate demand shocks, changes in tax, uncertainty in company income tax, uncertainty in the terms of trade, uncertainty in the interest rate, and uncertainty in Chinese GDP growth are significant variables. Therefore, although the sign of the aggregate demand shocks is not consistent with
### Table 5.6: OLS and GMM Estimation Results for Annual Macroeconomic Data (1969–2012)

<table>
<thead>
<tr>
<th>Dependent variable: ((I_t/K_{t-1}))</th>
<th>OLS</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \log Y_t)</td>
<td>0.045</td>
<td>-0.009</td>
<td>0.166</td>
<td>0.128</td>
<td>0.078</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>(0.094)</td>
<td>(0.046)</td>
<td>(0.090)*</td>
<td>(0.073)*</td>
<td>(0.051)</td>
<td>(0.080)</td>
</tr>
<tr>
<td>((\log Y_{t-1} - \log K_{t-1}))</td>
<td>0.006</td>
<td>0.010</td>
<td>0.012</td>
<td>0.011</td>
<td>0.015</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.004)**</td>
<td>(0.002)***</td>
<td>(0.001)***</td>
<td>(0.002)***</td>
<td>(0.007)***</td>
<td>(0.004)</td>
</tr>
<tr>
<td>(\Delta \log \text{tax}_t)</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.0001)*</td>
<td>(0.0001)**</td>
<td>(0.0001)***</td>
<td>(0.0001)*</td>
<td>(0.0001)***</td>
<td>(0.0001)***</td>
</tr>
<tr>
<td>((\Delta \log Y_t)^2)</td>
<td>-1.357</td>
<td>-1.745</td>
<td>-1.683</td>
<td>-1.381</td>
<td>-2.076</td>
<td>-2.076</td>
</tr>
<tr>
<td></td>
<td>(0.982)</td>
<td>(0.701)**</td>
<td>(0.592)***</td>
<td>(0.605)**</td>
<td>(0.698)**</td>
<td></td>
</tr>
<tr>
<td>(utax_t)</td>
<td>-0.002</td>
<td>-0.001</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(utt_t)</td>
<td>-1.766</td>
<td>-0.734</td>
<td>-3.232</td>
<td>-1.823</td>
<td>-1.823</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.455)</td>
<td>(0.523)</td>
<td>(1.461)***</td>
<td>(1.102)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(urat_t)</td>
<td>-0.735</td>
<td>-0.678</td>
<td>-0.993</td>
<td>-0.63</td>
<td>-0.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.403)*</td>
<td>(0.312)**</td>
<td>(0.325)***</td>
<td>(0.262)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ucgdp_t)</td>
<td>0.005</td>
<td>0.006</td>
<td>0.008</td>
<td>0.007</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)*</td>
<td>(0.001)***</td>
<td>(0.002)***</td>
<td>(0.002)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_t)</td>
<td>5.800</td>
<td>4.992</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(2.70)*</td>
<td>(1.029)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_t \times \Delta \log Y_t)</td>
<td>3.556</td>
<td>3.800</td>
<td>4.278</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.835)</td>
<td>(1.718)</td>
<td>(1.372)***</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The tests of endogeneity are applied to \((\log Y_{t-1} - \log K_{t-1})\) for (1) and (2), and to both \((\log Y_{t-1} - \log K_{t-1})\) and \(ut\) for (3) (4) (5). The goodness-of-fit measuring \(\text{corr}(\hat{I}_t/K_t, \hat{I}_t/K_t)^2\) is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression. Due to the difference between the sign of the terms of trade and the expected sign in Table 4.1, the terms of trade variable is dropped.
### Table 5.7: OLS and GMM Estimation Results for Annual Macroeconomic Data (1990–2012)

<table>
<thead>
<tr>
<th>Dependent variable: ((I_t/K_{t-1}))</th>
<th>OLS</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \log Y_t)</td>
<td>-0.355</td>
<td>-0.002</td>
<td>-0.263</td>
<td>-0.426</td>
<td>-0.481</td>
<td>-0.623</td>
</tr>
<tr>
<td></td>
<td>(0.233)</td>
<td>(0.047)</td>
<td>(0.273)</td>
<td>(0.314)</td>
<td>(0.332)*</td>
<td>(0.275)*</td>
</tr>
<tr>
<td>(((\log Y_{t-1} - \log K_{t-1})))</td>
<td>0.009</td>
<td>0.003</td>
<td>0.002</td>
<td>0.009</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.001)**</td>
<td>(0.008)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>(\Delta \log tax_t)</td>
<td>0.0001</td>
<td>0.0005</td>
<td>0.0008</td>
<td>0.0067</td>
<td>0.0009</td>
<td>0.0008</td>
</tr>
<tr>
<td></td>
<td>(0.0001)**</td>
<td>(0.0002)***</td>
<td>(0.0001)**</td>
<td>(0.0001)***</td>
<td>(0.0001)***</td>
<td>(0.0001)***</td>
</tr>
<tr>
<td>((\Delta \log Y_t)^2)</td>
<td>2.264</td>
<td>1.212</td>
<td>3.443</td>
<td>3.731</td>
<td>5.375</td>
<td></td>
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<tr>
<td></td>
<td>(1.218)*</td>
<td>(2.198)</td>
<td>(2.192)</td>
<td>(2.866)*</td>
<td>(1.935)</td>
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</tr>
<tr>
<td>(utax_t)</td>
<td>0.004</td>
<td>0.001</td>
<td>0.002</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(utt_t)</td>
<td>-4.122</td>
<td>-4.601</td>
<td>-4.085</td>
<td>-4.057</td>
<td>-4.367</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.071)***</td>
<td>(0.612)***</td>
<td>(0.556)***</td>
<td>(0.656)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(urat_t)</td>
<td>1.589</td>
<td>1.079</td>
<td>1.065</td>
<td>0.677</td>
<td></td>
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<tr>
<td></td>
<td>(0.940)</td>
<td>(1.148)</td>
<td>(1.163)</td>
<td>(1.069)</td>
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</tr>
<tr>
<td>(ucgdp_t)</td>
<td>0.006</td>
<td>-0.022</td>
<td>-0.010</td>
<td>-0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(0.006)***</td>
<td>(0.017)***</td>
<td>(0.006)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_t)</td>
<td>-4.978</td>
<td></td>
<td>-7.117</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(1.306)</td>
<td></td>
<td>(1.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_t \times \Delta \log Y_t)</td>
<td>8.836</td>
<td>9.829</td>
<td>7.720</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.432)</td>
<td>(1.162)</td>
<td>(1.532)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. Observations: 22
Hansen’s over-identification test: 5.513 5.719 10.235 15.034 13.004
Goodness of fit: 0.701 0.108 0.381 0.726 0.436
F-test statistic: 6.62*** 44.58*** 48.66*** 50.64*** 52.23***

Notes: *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to \((\log Y_{t-1} - \log K_{t-1})\) for (1) and (2) and to both \((\log Y_{t-1} - \log K_{t-1})\) and \(utt_t\) for (3) (4) (5). The goodness-of-fit measuring \(\text{corr}(I_t/K_t, \hat{I}_t/K_t)^2\) is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression. Due to the difference between the sign of the terms of trade and the expected sign in Table 4.1, the terms of trade variable is dropped.
### Table 5.8: OLS and GMM Estimation Results for Quarterly Macro Data (1992–2012)

<table>
<thead>
<tr>
<th>Dependent variable: $(\Delta \log I_t)$</th>
<th>OLS</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log Y_t$</td>
<td>-0.155</td>
<td>-0.027</td>
<td>-0.002</td>
<td>0.054</td>
<td>-0.032</td>
<td>-0.021</td>
</tr>
<tr>
<td></td>
<td>(0.409)</td>
<td>(0.099)</td>
<td>(0.088)</td>
<td>(0.066)</td>
<td>(0.055)</td>
<td>(0.134)</td>
</tr>
<tr>
<td>$\Delta \log I_{t-1}$</td>
<td>-0.165</td>
<td>-0.172</td>
<td>-0.213</td>
<td>-0.165</td>
<td>-0.185</td>
<td>-0.019</td>
</tr>
<tr>
<td></td>
<td>(0.121)</td>
<td>(0.140)</td>
<td>(0.125)*</td>
<td>(0.122)</td>
<td>(0.102)**</td>
<td>(0.100)</td>
</tr>
<tr>
<td>$\Delta \log \text{tax}_t$</td>
<td>-0.0001</td>
<td>-0.0001</td>
<td>-0.0003</td>
<td>-0.0003</td>
<td>0.0002</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0003)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0005)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>$(\Delta \log Y_t)^2$</td>
<td>3.478</td>
<td>2.408</td>
<td>2.968</td>
<td>2.451</td>
<td>3.124</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.199)</td>
<td>(1.567)</td>
<td>(1.630)*</td>
<td>(1.343)</td>
<td>(1.023)</td>
<td></td>
</tr>
<tr>
<td>$\Delta \log \text{tax}_t$</td>
<td>-0.007</td>
<td>-0.005</td>
<td>-0.004</td>
<td>-0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{ut}_t$</td>
<td>0.765</td>
<td>1.224</td>
<td>2.030</td>
<td>3.455</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.660)</td>
<td>(3.747)</td>
<td>(1.678)</td>
<td>(1.122)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{uat}_t$</td>
<td>-5.109</td>
<td>-5.328</td>
<td>-5.384</td>
<td>-5.111</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.205)</td>
<td>(3.642)</td>
<td>(3.254)*</td>
<td>(2.404)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{ucgdp}_t$</td>
<td>-0.003</td>
<td>-0.043</td>
<td>0.001</td>
<td>-0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.418)</td>
<td>(0.269)</td>
<td>(0.254)</td>
<td>(0.376)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{ugdp}_t$</td>
<td>11.922</td>
<td>7.324</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.337)</td>
<td>(1.263)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \text{ugdp}_t \times \Delta \log Y_t$</td>
<td>5.585</td>
<td>8.606</td>
<td>9.677</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.548)</td>
<td>(0.363)</td>
<td>(1.215)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Notes: *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to $\Delta \log Y_t$ for (1) and (2) and to $\Delta \text{ut}_t$ for (3) (4) (5). The goodness-of-fit measuring $\text{corr}(I/K, \hat{I}/\hat{K})^2$ is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression. Due to the difference between the sign of the terms of trade and the expected sign in Table 4.1, the terms of trade variable is dropped. |
the linear accelerator theory, the negative sign of terms of trade uncertainty seems to conform with the conventional uncertainty theory. In addition, this implies that aggregate demand shocks, changes in tax, uncertainty in company income tax, uncertainty in the terms of trade, uncertainty in interest rates, and uncertainty in Chinese economic growth are the main determinants of the dynamics of Australian private investment.

Beyond that, for the short period 1990–2012, macroeconomic investment had a convex response to demand shocks, while over the long run of 1969–2012, the concave relationship was dominant for demand shocks and investment. Likewise, for the period of 1990–2012, the coefficient for demand uncertainty was not significant. When the period was extended to 1969–2012, the effects of demand uncertainty on the short-run investment response to demand shocks and demand uncertainty were characterised by significantly positive and negative coefficients. However, during 1969–2012 and 1990–2012, the changes in company income tax had long-lasting and significantly positive effects on investment. Concurrently, during 1990–2012, the coefficient for Chinese GDP growth uncertainty was significant and negative, while during 1969–2012, the relationship between Chinese GDP growth uncertainty and macroeconomic investment was significantly positive.
Chapter 6

Determinants of Industry Investment

6.1 Introduction

This chapter retests the investment model to examine the effects of different key variables on Australian private investment at the industry level. The analysis in Chapter 5 has shown that macroeconomic investment has different responses to demand shocks, the user cost of capital, foreign trade, and different uncertainties. The industry analysis endeavours to investigate whether these key variables at the industry level have the same effects on investment. In addition, panel data used in this chapter adds more information on the dynamics of investment across different industries. Therefore, the model in this chapter examines the issue of heterogeneity across different industries.

Section 6.2 sets up the estimation framework for investment behaviour at the industry level. Section 6.3 describes the nature of panel data. Section 6.4 presents the results of the stationarity tests. Section 6.5 selects various useful variables related to the estimation of Australian investment. Section 6.6 assesses the empirical models and provides robust estimations and analyses.
6.2 Industry Investment Estimation Framework

The empirical estimation in this chapter identifies the pattern of the dynamics of Australian private investment at the industry level. A series of tests are used in this estimation, such as stationarity tests and uncertainty tests, along with a range of empirical models. These tests are in line with discussion in the literature review and the research methodology.

To observe the distribution and dynamics of industry investment, the data description at the industry level is pursued. After a preliminary description, stationarity tests are used. As indicated in the analysis of macroeconomic investment, the stationarity tests help in identifying the stationarity of the series for the estimation of an unbiased empirical model. The GARCH method is also fit for panel data to capture conditional uncertainty data. It is worth stressing that in contrast to the direct effects of uncertainty in interest rates and Chinese GDP growth uncertainty on Australian macroeconomic investment, the effects of these uncertainty variables on industry investment are indirect, and are calculated because of data unavailability at the industry level. These uncertainty variables at the industry level are interacted with demand uncertainty. The empirical models applied to industry level data are the Random Effects (RE) method, the Fixed Effects (FE) method, and the generalised method of moments (GMM).

6.3 Data Description at the Industry Level

This chapter collects panel data for Australian investment at the industry level from the Australian Bureau of Statistics for the years 1960–2012. The panel data set contains 20 industries indexed by the ABSID, ranging from agriculture, forestry and fishing to ownership of dwellings. Table 6.1 compares a range of variables across all these industries, such as the mean ratio of investment to capital stock, mean value of GDP, mean tax on company income and mean value of exports. Of all industries, the mining industry from 1960 to 2012 had the highest value for the mean ratio of
investment to capital stock and the mean value of exports, as well as a high ranking for the mean value of GDP.

Table 6.2 presents distributions of the key variables of investment at the industry level. Figures 6.1, 6.2, 6.3 and 6.4 describe key variables in all industries. The performances of the variables suggest that key variables for Australian industries grew rapidly after the 2000s. Notably, except for company income tax, the mean values of key variables in the mining industry are higher than those in all industries. Figures 6.1, 6.2, 6.3 and 6.4 show that after the 2000s there was high and sustained growth in Australian mining investment, mining demand, mining company income tax and export value. However, between the 1970s and the 2000s, the mean investment ratio in the mining industry experienced large volatility. As shown in Table 6.2, the mining industry plays an important role in the Australian economy.

6.4 Stationarity Tests at the Industry Level

As in the analysis of macro investment, the analysis of industry investment applies stationarity tests to panel data. Those at the industry level minimise the risk of spurious estimation, where the mean and variance of non-stationary data are not constant.

Choi (2001) redesigned the augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test and proposed the Fisher-type test for panel data to judge whether the data has a unit root. In this respect, the null hypothesis in the Fisher-type test for panel unit roots is that all panels contain a unit root, while the alternative hypothesis shows that at least one panel is stationary. The test equation for stationarity is specified in Equation 7.1:

$$\Delta y_{it} = \phi_i y_{i,t-1} + z_{it}' \gamma_i + \epsilon_{it}$$

(6.1)

where $i = 1, ..., N$ indexes panels; $t = 1, ..., T_i$ indexes time; $y_{it}$ is the variable being tested; and $\epsilon_{it}$ is a stationary error term. The $z_{it}$ term can represent panel-specific
Table 6.1: Data Description at the Industry Level

<table>
<thead>
<tr>
<th>ABSID</th>
<th>Industries</th>
<th>$\frac{I_i,t}{K_i,t-1}$</th>
<th>$Y_{i,t}$</th>
<th>$\text{tax}_{i,t}$</th>
<th>$\text{ex}_{i,t}$</th>
<th>No. of Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3348008R</td>
<td>Agriculture, Forestry and Fishing</td>
<td>0.11</td>
<td>21968.77</td>
<td>10.58</td>
<td>220.63</td>
<td>146</td>
</tr>
<tr>
<td>A3348050V</td>
<td>Mining</td>
<td>0.16</td>
<td>71660.74</td>
<td>35.27</td>
<td>409.37</td>
<td>146</td>
</tr>
<tr>
<td>A3346520R</td>
<td>Manufacturing</td>
<td>0.12</td>
<td>86065.21</td>
<td>102.71</td>
<td>155.56</td>
<td>146</td>
</tr>
<tr>
<td>A3346600J</td>
<td>Electricity, Gas, Water and Waste Services</td>
<td>0.06</td>
<td>27722.54</td>
<td>13.64</td>
<td>409.37</td>
<td>146</td>
</tr>
<tr>
<td>A3346560J</td>
<td>Construction</td>
<td>0.11</td>
<td>56816.62</td>
<td>60.42</td>
<td>0.63</td>
<td>126</td>
</tr>
<tr>
<td>A3346640J</td>
<td>Wholesale Trade</td>
<td>0.06</td>
<td>37427.87</td>
<td>53.71</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A3347906R</td>
<td>Retail Trade</td>
<td>0.06</td>
<td>38944.23</td>
<td>50.74</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A3347846J</td>
<td>Accommodation and Food Services</td>
<td>0.07</td>
<td>22661.90</td>
<td>22.46</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A3347866A</td>
<td>Transport, Postal and Warehousing</td>
<td>0.08</td>
<td>40091.44</td>
<td>48.43</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A334651R</td>
<td>Information Media and Telecommunications</td>
<td>0.10</td>
<td>20642.15</td>
<td>26.73</td>
<td>24.34</td>
<td>126</td>
</tr>
<tr>
<td>A3347363R</td>
<td>Financial and Insurance Services</td>
<td>0.04</td>
<td>57345.59</td>
<td>92.15</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A3347403W</td>
<td>Rental, Hiring and Real Estate Services</td>
<td>0.07</td>
<td>23689.54</td>
<td>19.40</td>
<td>146</td>
<td>104</td>
</tr>
<tr>
<td>A334743R</td>
<td>Professional, Scientific and Technical Services</td>
<td>0.12</td>
<td>40281.38</td>
<td>97.88</td>
<td>5.57</td>
<td>146</td>
</tr>
<tr>
<td>A3347639T</td>
<td>Administrative and Support Services</td>
<td>0.08</td>
<td>26025.87</td>
<td>54.13</td>
<td>126</td>
<td>146</td>
</tr>
<tr>
<td>A334769K</td>
<td>Public Administration and Safety</td>
<td>0.06</td>
<td>50564.87</td>
<td>130.05</td>
<td>126</td>
<td>120</td>
</tr>
<tr>
<td>A3347719T</td>
<td>Education and Training</td>
<td>0.05</td>
<td>45221.05</td>
<td>37.57</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>A3347760V</td>
<td>Health Care and Social Assistance</td>
<td>0.06</td>
<td>47644.54</td>
<td>76.24</td>
<td>0.10</td>
<td>120</td>
</tr>
<tr>
<td>A3347499A</td>
<td>Arts and Recreation Services</td>
<td>0.07</td>
<td>6835.33</td>
<td>8.67</td>
<td>6.34</td>
<td>126</td>
</tr>
<tr>
<td>A3347540T</td>
<td>Other Services</td>
<td>0.12</td>
<td>18775.90</td>
<td>25.88</td>
<td>176.83</td>
<td>120</td>
</tr>
<tr>
<td>A2423051K</td>
<td>Ownership of Dwellings</td>
<td>0.06</td>
<td>78481.49</td>
<td>8.04</td>
<td>146</td>
<td>104</td>
</tr>
</tbody>
</table>

Source: ABS (2012). ABSID is the code of the Australian Bureau of Statistics’ industrial coding system.

Notes: All original values are recorded in AU$Million. $\frac{I_i,t}{K_i,t-1}$ stands for the mean ratio of the investment at time $t$ to the capital stock at time $t-1$. $Y_{i,t}$ is the mean value of industry GDP. $\text{tax}_{i,t}$ is the mean company income tax (relative to GDP deflator in 2012). $\text{ex}_{i,t}$ is the mean export value of each industry (relative to GDP deflator in 2012). Some missing data are found in $\text{ex}_{i,t}$ for unbalanced data.
Figure 6.1: Description of Investment Ratio in All Industries
Figure 6.2: Description of Industry Demand in All Industries
There are some missing values in company income tax in all industries. The unbalanced panel data can be tested by the GMM method.
Figure 6.4: Description of Export Value in All Industries
### Table 6.2: Distributions of Key Variables at the Industry Level

<table>
<thead>
<tr>
<th></th>
<th>All Industries</th>
<th>Mining Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\frac{I_{i,t}}{K_{i,t-1}}$</td>
<td>$Y_{i,t}$</td>
</tr>
<tr>
<td>Mean</td>
<td>0.08</td>
<td>41282.85</td>
</tr>
<tr>
<td>P25</td>
<td>0.05</td>
<td>21413.5</td>
</tr>
<tr>
<td>P50</td>
<td>0.08</td>
<td>33491.5</td>
</tr>
<tr>
<td>P75</td>
<td>0.10</td>
<td>56059.5</td>
</tr>
<tr>
<td>No.of Obs.</td>
<td>1060</td>
<td>780</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using ABS (2012)

Notes:
- $P_i$ is the $i$th percentile. $Y_{i,t}$ the real value of GDP in 2012 (AU$Million).
- $\frac{I_{i,t}}{K_{i,t-1}}$ stands for the ratio of investment at time $t$ to capital stock at time $t-1$.
- $tax_{i,t}$ is the real company income tax (relative to the GDP deflator in 2012), and $ex_{i,t}$ is the real export value of each industry (relative to the GDP deflator in 2012).

means, panel-specific means and a time trend, or nothing, depending on the features of the data. This equation originates from the ADF test and the PP test, and is fit for panel data. This panel unit root test is used to test the null hypothesis $H_0 : \phi_i = 0$ for all $i$ versus the alternative $H_\alpha : \phi_i < 0$.

The size of the panel is an important criterion for selecting the most appropriate test of stationarity. In a panel dataset, if each cross-section unit contains the same number of observations per time period, it is balanced; otherwise, it is unbalanced. Addressing unbalanced panel data is one of the advantages of the Fisher-type test. Hence, investment for unbalanced panel data at the Australian industry level is also fit for the Fisher-type test.

Table 6.3 displays the results of the Fisher-type test for panel data at the industry level. Due to the skewed distributions of variables, logarithmic transformations of these variables are used. Apart from company income tax, these tests reject the null hypothesis that all the given data has a unit root at the 1% significance level. This indicates that panel data in the long-run is less affected by permanent shocks.
6.5. **UNCERTAINTY DATA AT THE INDUSTRY LEVEL**

Therefore, panel data at the industry level used by the empirical models would not lead to a biased estimation.

**Table 6.3:** Fisher Unit Root Tests at the Industry Level

<table>
<thead>
<tr>
<th>Industry variables</th>
<th>ADF test</th>
<th>PP test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_0$: Unit root</td>
<td>$H_0$: Unit root</td>
</tr>
<tr>
<td><strong>I(0)/I(1)</strong></td>
<td><strong>I(0)/I(1)</strong></td>
<td></td>
</tr>
<tr>
<td>Private investment/Private capital stock</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
<tr>
<td>Australian real GDP</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
<tr>
<td>Company income tax</td>
<td>I(0)</td>
<td>I(1)</td>
</tr>
<tr>
<td>Value of exports</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
</tbody>
</table>

Notes: All variables were tested in logarithms and in levels. If data exhibited a unit root in levels, first differences of the data were examined to ensure stationarity. I(0) indicates that the data doesn’t contain a unit root. I(1) indicates that the data’s first-differenced series is stationary. To remove the effect of revenues on the changes in company income tax and exports and their uncertainties, company income tax and export value were divided by national revenues.

**6.5 Uncertainty Data at the Industry Level**

Prior to modelling the effect of key variables on Australian private investment at the industry level, it is worth examining the selection of different estimated variables. All the variables are tested in logarithm form. All nominal variables are divided by the GDP deflator. The uncertainty variables at the industry level are defined as follows.
6.5. UNCERTAINTY DATA AT THE INDUSTRY LEVEL

6.5.1 Uncertainty Variables

The results at the industry level are summarised in Table 6.4. With significant ARCH effects, the best-fit GARCH models at the industry level are verified by the Akaike Information Criterion. The dynamics of uncertainty data are also illustrated in Figures 6.5, 6.6 and 6.7.

Table 6.4: Overview of Uncertainty Measures at the Industry Level

<table>
<thead>
<tr>
<th>Industry Uncertainty Variables</th>
<th>ARIMA(p,d,q)</th>
<th>GARCH(p,q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Industry GDP (yearly)</td>
<td>(1,0,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Company Income Tax (yearly)</td>
<td>(1,1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Value of Exports (yearly)</td>
<td>(1,0,1)</td>
<td>(1,1)</td>
</tr>
</tbody>
</table>

Notes: All variables are tested in logarithm.

Figure 6.5 shows that there were no big shocks or volatility for industry GDP in the majority of industries from 1960 to 2012. Only one striking fluctuation was found in manufacturing, information technology, and arts and recreation around 1976. This fluctuation was far greater than the period of flat data and was due to the aftermath of the oil crisis in 1974, which caused high resource prices and worldwide economic turmoil. Thus, volatility of industry GDP was low in most Australian industries from 1960 to 2012.

Figure 6.6 shows that volatility in company income tax was observed in the mining, information media and telecommunications, and real estate industries from 2001 to 2012. This volatility suggests that during 2001–2012, these Australian industries had widespread uncertain expectations on taxation, corresponding to the mining boom and the global financial crisis. Hence, high volatility of company income tax at the industry level was evident in some capital intensive industries (such as mining) from 2001 to 2012.

Figure 6.7 shows that a notable spike in the industrial value of exports in the 1970s (Figure 6.7). This spike was linked to the global oil crisis in the 1970s. However, the construction and health care services industries experienced a large spike around
Figure 6.5: Industry Uncertainty Data for GDP (Conditional Variances)
Figure 6.6: Industry Uncertainty Data for Company Income Tax (Conditional Variances)
2000. This exports shock was caused by the Asian economic crisis in 1997. Therefore, the industrial volatility of export value was not uniform across all industries and time periods.

![Industry Uncertainty Data for Export Values (Conditional Variances)](image)

**Figure 6.7:** Industry Uncertainty Data for Export Values (Conditional Variances)

According to the conventional theory on investment, if the coefficients of industry uncertainty for GDP, tax, and export values are statistically significant and negative, the timing of investment is delayed. Simultaneously, the expected positive association between demand shocks and investment is dampened. Apart from un-
6.5. **UNCERTAINTY DATA AT THE INDUSTRY LEVEL**

Certainties in GDP, tax, and export values, uncertainty in interest rates and Chinese GDP growth at the industry level also affect industry investment.

As discussed in Chapter 4, the effects of uncertainties in interest rates and Chinese GDP growth on investment are examined by the interaction term with uncertainty on industry GDP ($ugdp_{it} \times urat_t$, $ugdp_{it} \times ucgdp_t$). In the industry investment model, interest rate uncertainty and Chinese GDP growth uncertainty can influence industry investment by either reinforcing or alleviating the impact of uncertainty of industry GDP on industry investment. The significantly negative coefficients of interacted interest rate uncertainty and Chinese GDP growth uncertainty imply that under interacted uncertainty, industry investment responds positively and slowly to growth of industry demand. This slow response supports the view in the theoretical analysis that uncertainty raises the trigger value of industry investment.

To capture the features of the uncertainty data, Table 6.5 and 6.6 provide some descriptive statistics. As argued by Bloom et al. (2007), the effect of demand uncertainty on the short-run investment response to demand shocks is defined by the interaction between demand uncertainty and demand shocks ($ugdp_{it} \times \Delta \log Y_{it}$), while demand uncertainty is simplified as $ugdp_{it}$. These proxies are indicated in Tables 6.5 and 6.6.

Table 6.5 demonstrates that for all industries, the occurrence of relatively high uncertainty on company income tax is more frequent than that of low uncertainty. The probabilities of the effect of high demand uncertainty on the short-run investment response to demand shocks, high uncertainty of demand, export value, interest rates and Chinese GDP growth are more likely to be relatively low. This uncertainty pattern coincides with that at the macroeconomic level.

Table 6.6 records mean investment across all industries, showing that it varies with different uncertainties. Most statistics support the perspective that investment under low uncertainty is greater than under high uncertainty. However, this perspective is not consistent with the estimations for mining and ownership of dwellings, where there is more investment under relatively high uncertainty. Except for demand
<table>
<thead>
<tr>
<th>Industries</th>
<th>ugdp&lt;sub&gt;i&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;i&lt;/sub&gt; * ∆logY&lt;sub&gt;i&lt;/sub&gt;</th>
<th>utax&lt;sub&gt;i&lt;/sub&gt;</th>
<th>uex&lt;sub&gt;i&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;i&lt;/sub&gt; * ucgdp&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;i&lt;/sub&gt; * urat&lt;sub&gt;i&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>MD</td>
<td>SK</td>
<td>M</td>
<td>MD</td>
<td>SK</td>
</tr>
<tr>
<td>Agriculture, Forestry and Fishing</td>
<td>0.06</td>
<td>0.05</td>
<td>6.02</td>
<td>0.003</td>
<td>0.001</td>
<td>1.93</td>
</tr>
<tr>
<td>Mining</td>
<td>0.03</td>
<td>0.01</td>
<td>6.48</td>
<td>0.001</td>
<td>0.002</td>
<td>-3.3</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.11</td>
<td>0.01</td>
<td>6.92</td>
<td>-0.001</td>
<td>0.001</td>
<td>-4.98</td>
</tr>
<tr>
<td>Electricity, Gas, Water and Waste</td>
<td>0.02</td>
<td>0.01</td>
<td>4.19</td>
<td>0.001</td>
<td>0.0001</td>
<td>4.92</td>
</tr>
<tr>
<td>Services</td>
<td>0.04</td>
<td>0.02</td>
<td>6.09</td>
<td>0.002</td>
<td>0.001</td>
<td>4.96</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>0.02</td>
<td>0.01</td>
<td>1.33</td>
<td>0.001</td>
<td>0.0001</td>
<td>1.02</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>0.02</td>
<td>0.02</td>
<td>0.82</td>
<td>0.001</td>
<td>0.0001</td>
<td>1.13</td>
</tr>
<tr>
<td>Accommodation and Food Services</td>
<td>0.02</td>
<td>0.01</td>
<td>5.7</td>
<td>-0.001</td>
<td>0.001</td>
<td>-5.5</td>
</tr>
<tr>
<td>Transport, Postal and Warehousing</td>
<td>0.02</td>
<td>0.01</td>
<td>0.68</td>
<td>0.001</td>
<td>0.0001</td>
<td>4.95</td>
</tr>
<tr>
<td>Information Media and Telecommunications</td>
<td>0.13</td>
<td>0.01</td>
<td>6.93</td>
<td>-0.001</td>
<td>0.001</td>
<td>-5.76</td>
</tr>
<tr>
<td>Financial and Insurance Services</td>
<td>0.02</td>
<td>0.01</td>
<td>0.81</td>
<td>0.001</td>
<td>0.0001</td>
<td>4.14</td>
</tr>
<tr>
<td>Rental, Hiring and Real Estate Services</td>
<td>0.04</td>
<td>0.01</td>
<td>6.78</td>
<td>-0.001</td>
<td>0.001</td>
<td>-5.76</td>
</tr>
<tr>
<td>Professional, Scientific and Technical</td>
<td>0.02</td>
<td>0.01</td>
<td>0.72</td>
<td>0.001</td>
<td>0.0001</td>
<td>1.52</td>
</tr>
<tr>
<td>Services</td>
<td>0.04</td>
<td>0.01</td>
<td>6.79</td>
<td>-0.001</td>
<td>0.001</td>
<td>-5.44</td>
</tr>
<tr>
<td>Public Administration and Safety</td>
<td>0.03</td>
<td>0.01</td>
<td>6.31</td>
<td>0.001</td>
<td>0.0001</td>
<td>5.91</td>
</tr>
<tr>
<td>Education and Training</td>
<td>0.02</td>
<td>0.01</td>
<td>0.78</td>
<td>0.001</td>
<td>0.0001</td>
<td>5.46</td>
</tr>
<tr>
<td>Health Care and Social Assistance</td>
<td>0.02</td>
<td>0.01</td>
<td>0.88</td>
<td>0.001</td>
<td>0.0001</td>
<td>3.64</td>
</tr>
<tr>
<td>Arts and Recreation Services</td>
<td>0.22</td>
<td>0.01</td>
<td>6.87</td>
<td>0.001</td>
<td>0.0001</td>
<td>5.88</td>
</tr>
<tr>
<td>Other Services</td>
<td>0.03</td>
<td>0.01</td>
<td>6.49</td>
<td>0.001</td>
<td>0.0001</td>
<td>5.75</td>
</tr>
<tr>
<td>Ownership of Dwellings</td>
<td>0.04</td>
<td>0.01</td>
<td>6.89</td>
<td>0.001</td>
<td>0.0001</td>
<td>5.78</td>
</tr>
</tbody>
</table>

Notes: ugdp<sub>i</sub> is the uncertainty on industry GDP, ugdp<sub>i</sub> * ∆logY<sub>i</sub> is the interaction between the uncertainty on industry GDP and the differenced industry GDP. utax<sub>i</sub> is the uncertainty on company income tax. uex<sub>i</sub> is the uncertainty on export values and ugdp<sub>i</sub> * ucgdp<sub>t</sub> is the uncertainty on Chinese GDP growth. ugdp<sub>i</sub> * urat<sub>i</sub> is the uncertainty on target rates. SK indicates skewness. M indicates mean, while MD indicates median. The missing data in company income tax and exchange rate cost may cause large changes in frequency values. If the mean is larger (smaller) than the median, distribution of uncertainty data is right (left) skewed. This indicates that most values of uncertainty data are lower (higher) than the average value.
uncertainty, mining investors are keen to invest during periods of high uncertainty. Across all Australian industries, most other investors are cautious about investing under high uncertainty. To some extent, this finding is in line with the highlights in Chapter 2, which showed that not all industries have benefited from the mining boom. It is evident that some industries are sensitive to increases in related product prices and terms of trade.

Overall, except for uncertainty of company income taxes, relatively low uncertainty is prevalent across all industries. Furthermore, under high uncertainty, the mining and the ownership of dwellings industries are likely to observe more investment than under low uncertainty.

6.6 Models of Industry Investment

This section examines the determinants of Australian private investment behaviour (1960–2012) at the industry level. The model in this section originates from the error correction model (ECM) of capital stock adjustment in Bloom et al. (2007), which also assumes that investment is partially irreversible under uncertainty.

A panel dataset can be estimated by using a random effects model or a fixed effects model (Wooldridge, 2002). The random effects (RE) model assumes that the individual specific effects are uncorrelated with the independent variables. RE models can be estimated using the Generalised Least Squares (GLS) method. The fixed effects (FE) model assumes that the individual specific effect is correlated with the independent variables. Both the RE and FE methods were used to do the preliminary tests.

Due to suspicion of heteroscedasticity across different industries, the Random Effects (GLS) method was first put forward to empirically test the effect of uncertainty variables, demand variables, and variables of the user cost of capital on investment. Due to possible heterogeneity across different industries, the fixed ef-

\[ \text{Bloom et al. (2007) chose adjusted capital stock and investment as the dependent variable, in which investment is partially irreversible and capital stock can be adjusted in the long-run.} \]
Table 6.6: Mean Investment under Low and High Uncertainties

<table>
<thead>
<tr>
<th>Industries</th>
<th>ugdp&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;t&lt;/sub&gt; * ∆ logY&lt;sub&gt;t&lt;/sub&gt;</th>
<th>utax&lt;sub&gt;t&lt;/sub&gt;</th>
<th>wx&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;t&lt;/sub&gt; * ucgdp&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ugdp&lt;sub&gt;t&lt;/sub&gt; * urat&lt;sub&gt;t&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>Agriculture, Forestry and Fishing</td>
<td>-2.201</td>
<td>-2.178</td>
<td>N</td>
<td>-2.221</td>
<td>-2.167</td>
<td>N</td>
</tr>
<tr>
<td>Mining</td>
<td>-2.019</td>
<td>-1.868</td>
<td>N</td>
<td>-2.138</td>
<td>-1.867</td>
<td>N</td>
</tr>
</tbody>
</table>

Notes: ugdp<sub>t</sub> is the uncertainty in industry GDP, ugdp<sub>t</sub> * ∆ logY<sub>t</sub> is the interaction between the uncertainty in industry GDP and the differenced industry GDP. utax<sub>t</sub> is uncertainty in company income tax. wx<sub>t</sub> is the uncertainty in export values. ugdp<sub>t</sub> * ucgdp<sub>t</sub> is the uncertainty in Chinese GDP growth. ugdp<sub>t</sub> * urat<sub>t</sub> is the uncertainty in target rates. L (H) denotes the subsample mean investment ratio, when the measured subsample uncertainty is lower (higher) than the sample median. The missing data in company income tax also causes missing data in utax<sub>t</sub>. Figures in bold indicate investment under high uncertainty that is significantly greater than under low uncertainty. Bold S indicates for difference of means tests to determine whether the differences in average investment under high and low uncertainty are statistically significant. Value of S indicates significance at 10%, and N indicates insignificance at 10%.
6.6. MODELS OF INDUSTRY INVESTMENT

Effects (FE) method was also adopted. In addition, endogeneity in the regression may contribute to a biased result. To correct for endogeneity and over-identification, the GMM method was applied and provided reliable results.

Time and fixed effects were eliminated using forward-mean differences and time differences for those variables in logarithm. Section 6.6.1 sets up the RE and FE methods for the preliminary testing of Australian private investment (1960–2012) at the industry level. In Section 6.6.2 the estimation is carried out using the GMM method. Section 6.7 concludes and summarises the results of the different empirical models.

6.6.1 RE and FE Methods

RE (GLS method) is applied to panel data at the industry level to derive the results for investment. The RE (GLS method) (from 1960 to 2012) for panel data is given by:

$$
\frac{I_{i,t}}{K_{i,t-1}} = - \frac{2.336}{(0.110)***} + \frac{0.33(\Delta \log Y_{i,t})}{(0.485)} - \frac{1.41(\Delta \log Y_{i,t})^2}{(3.321)}
$$

$$
+ \frac{0.041(\log Y_{i,t-1} - \log K_{i,t-1})}{(0.087)} + \frac{0.022 \Delta \log tax_{i,t}}{(0.331)} - \frac{0.022 \Delta \log ex_{i,t}}{0.037}
$$

$$
- \frac{5.76 ugdp_{i,t}}{(2.435)***} + \frac{0.121 ugdp_{i,t} * \Delta \log Y_{i,t}}{(0.110)} + \frac{1.35 utax_{i,t}}{(2.667)}
$$

$$
+ \frac{0.018 uex_{i,t} + 1.350 ugdp_{i,t} * urat_{t} + 3.020 ugdp_{i,t} * ucgdp_{t}}{(0.034)}
$$

$$
= \frac{1.350 ugdp_{i,t} * urat_{t} + 3.020 ugdp_{i,t} * ucgdp_{t}}{(1.162)***}
$$

*** indicates significance at 1%, ** significance at 5% and * significant at 10%. The figures in parentheses are the standard errors of the estimates.

where $\frac{I_{i,t}}{K_{i,t-1}}$ is the ratio of private investment to private capital stock for industry $i$ at times $t$ and $t-1$, $\Delta \log Y_{i,t}$ is industry demand shocks at time $t$, $(\Delta \log Y_{i,t})^2$ is squared demand shocks at time $t$, $(\log Y_{i,t-1} - \log K_{i,t-1})$ is the difference between industry GDP and private capital stock at time $t-1$, $\Delta \log tax_{i,t}$ is changes in industrial company income tax at time $t$, $\Delta \log ex_{i,t}$ is changes in industrial export
values at time \( t \), \( u_{gdpi,t} \) is industrial demand uncertainty at time \( t \), \( u_{gdpi,t} \Delta \log Y_{it} \)
is the effect of industrial demand uncertainty on the short-run investment response
to demand shocks at time \( t \), \( u_{taxi,t} \) is industrial uncertainty of company income tax
at time \( t \), \( u_{exi,t} \) is industrial uncertainty of export values at time \( t \), \( u_{gdpi,t} \Delta urat_{t} \) is
interacted uncertainty between demand and the interest rate at time \( t \), and \( u_{gdpi,t} \Delta ucgdp_{t} \) is interacted uncertainty between demand and Chinese GDP growth at time \( t \).

Results for the RE estimation were determined using Equation 6.2 and were
reported in Table 6.7. As shown, all demand-related variables have positive coeffi-
cients, including linear demand changes (\( \Delta \log Y_{it} \)), squared demand changes (\( (\Delta \log Y_{it})^2 \)),
and the error correction term (\( \log Y_{i,t-1} - \log K_{i,t-1} \)). These results are consistent
with the accelerator theory. In addition, a positive coefficient is observed for changes
in company income tax (\( \Delta \log tax_{it} \)), while a negative coefficient on changes is ob-
erved for export values (\( \Delta \log ex_{it} \)). The effect of changes in company income tax
is the same as that in the analysis of macroeconomic investment. In a variety of
uncertainty terms, apart from the negative coefficients of the interaction terms of
demand uncertainty (\( u_{gdpi,t} \Delta \log Y_{it} \)) and interest rate uncertainty (\( u_{gdpi,t} \Delta urat_{t} \)),
other variables have positive coefficients. These mixed signs are not aligned with
the conventional effect of uncertainty on investment. Remarkably, these variables
under RE estimation are insignificant, raising concerns about heterogeneity and
endogeneity in this panel set.

To improve the efficiency of model estimation, the fixed effects (FE) model for
the same specification in Equation 6.2 was undertaken, and the results reported in
Table 6.7. The FE method has an advantage over the RE method for correcting
for heterogeneity across panel data. In contrast to the RE model, the signs on the
coefficients of the squared demand changes (\( (\Delta \log Y_{it})^2 \)) and the error correction
term (\( \log Y_{i,t-1} - \log K_{i,t-1} \)) are negative. The sizes and standard deviations in these
variables are different from those in the RE model. However, all variables in the RE
and FE methods are insignificant, implying that the estimations are not consistent.
6.6. MODELS OF INDUSTRY INVESTMENT

6.6.2 GMM Method

To address the issues of endogeneity and over-identification, the model is estimated using the GMM method to derive more robust and unbiased results. Following the specification under the RE and FE methods, this section uses the GMM estimation for Australian investment at the industry level. In response to the issues of endogeneity and over-identification, the appropriate instrumental variables are chosen in the GMM method. Hence, the GMM method seems to be an effective method to examine the effect of long-term demand, short-term demand, the user cost of capital and uncertainty terms on Australian industry investment. The GMM method (from 1960 to 2012) for panel data is given by:

\[
\frac{I_{i,t}}{K_{i,t-1}} = -2.256^{(0.048)***} - 0.157(\Delta \log Y_{i,t}) + 0.918(\Delta \log Y_{i,t})^2^{(3.263)}
\]

\[
+ 0.132(\log Y_{i,t-1} - \log K_{i,t-1})^{(0.030)***} + 0.759 \Delta \log t a x_{i,t}^{(0.663)} - 0.018 \Delta \log e x_{i,t}^{(0.059)}
\]

\[
- 0.046 u g d p_{i,t}^{(0.030)} + 0.132 u g d p_{i,t} \ast \Delta \log Y_{i,t}^{(1.01)} + 9.684 u t a x_{i,t}^{(4.472)***}
\]

\[
- 0.087 u c x_{i,t}^{(0.069)} + 3.092 u g d p_{i,t} \ast w r a t_{i}^{(0.521)**} + 2.119 u g d p_{i,t} \ast u c g d p_{t}^{(0.667)}
\]

(6.3)

*** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates.

where \( \frac{I_{i,t}}{K_{i,t-1}} \) is the ratio of private investment to private capital stock for industry \( i \) at times \( t \) and \( t - 1 \), \( \Delta \log Y_{i,t} \) is industrial demand shocks at time \( t \), \( (\Delta \log Y_{i,t})^2 \) is squared demand shocks at time \( t \), \( (\log Y_{i,t-1} - \log K_{i,t-1}) \) is the difference between industry GDP and private capital stock at time \( t - 1 \), \( \Delta \log t a x_{i,t} \) is the change in industrial company income tax at time \( t \), \( \Delta \log e x_{i,t} \) is the change in industrial export values at time \( t \), \( u g d p_{i,t} \) is industrial demand uncertainty at time \( t \), \( u g d p_{i,t} \ast \Delta \log Y_{i,t} \) is the effect of industrial demand uncertainty on the short-run investment response to demand shocks at time \( t \), \( u t a x_{i,t} \) is the industrial uncertainty of company income.

\(^{30}\) The level equation is instrumented by the lagged level of those variables, while the difference equation is instrumented by the lagged first differences of those variables.
tax at time \( t \), \( uex_{i,t} \) is the industrial uncertainty of export values at time \( t \), \( ugdpi,t * urat \) is the interacted uncertainty between demand and interest rate at time \( t \), and \( ugdpi,t * ucgdp_t \) is the interacted uncertainty between demand and Chinese GDP growth at time \( t \).

Table 6.7 reports the results for the GMM methods. GMM column (1) displays the baseline model, including linear demand changes, the error correction term, the user cost of capital, and changes in export values. Unlike the results for the RE and FE methods, the coefficient for changes in company income tax is positively related to investment but is insignificant. Apart from that, the remaining signs on other coefficients (demand changes, tax changes) are consistent with those found using the RE method. Notably, the positive coefficient on the error correction term is positive and significant at 0.114, suggesting that demand shocks in the long-run are positively connected with investment. This positive relationship is also highlighted by Bond and Lombardi (2006).

GMM column (2) investigates whether the squared demand changes have an additional impact on investment in the long run. The results on the coefficients of linear demand changes, the error correction term, the changes in company income tax, and the changes in export values are insignificant, which is similar to the results in column (1). Conversely, the significant positive coefficients on this quadratic term and error correction term lead to the marginal effects of demand shocks on investment at 6.718 \(^{31}\). This suggests that in the long run, investment under uncertainty has a convex response to demand shocks. This convex relationship between long-term demand shocks and investment is supported by Bloom et al. (2007). However, this relationship is not supported by the coefficients in columns (3), (4) and (5).

GMM column (3) adds four types of uncertainty variables: uncertainties in company income tax, export value, the interaction terms of the interest rate and Chinese GDP growth. In this model, the positive signs prevail in the coefficients of the error correction term at 0.134, and the changes in tax, export values and nonlinear

---

\(^{31}\) According to column(2) of Table 6.7, the marginal effects of demand shocks are calculated as:

\[
\frac{\partial \hat{I}_t}{\partial (\log Y_{i,t-1} - \log K_{i,t-1})} + \frac{\partial \hat{I}_t}{\partial (\Delta \log Y_t)^2} = 6.718
\]
demand. For the uncertainty variables, only the coefficient for the uncertainty of export values is negative, but it is not significant. In addition, significant coefficients are observed by the error correction term, uncertainties in company income tax and interacted interest rates. This fact suggests that tax uncertainty and interest rate uncertainty under this circumstance have positive impacts on investment. This is not in line with the results at the macroeconomic level. This may be due to the variation in the analyses at aggregated and disaggregated levels (Slade, 2013), data bias (Huizinga, 1993) and the unavailability of interest rates at the industry level.

GMM column (4) tests the model with all the variables. The results for demand changes, the error correction term, the changes in tax, and the uncertainty terms in the column (4) are similar to those in column (3), where long-run demand shocks to investment are positively dominant at 0.132. Notably, contrary to the macroeconomic estimation, company income tax uncertainty has a significantly positive effect on investment. This corresponds to the results for Table 6.6. The differences in results may be caused by the estimations at different levels. At the industry level, resource tax (from the mining industry) is reallocated to other industries, increasing the incentive to invest (Slade, 2013). However, the coefficient for interacted interest rate uncertainty is significantly positive at 3.092, while the result of the test for investment preference under the interacted interest rate uncertainty in Table 6.6 does not support the positive effect of interest rate uncertainty. This may be caused by data bias (Huizinga, 1993) and unavailability of interest rates at the industry level. Furthermore, the coefficients of the effect of demand uncertainty on the short-run investment response to demand shocks and demand uncertainty are insignificant and have different signs (0.132 and –0.046). These results are in contrast to those in Bloom et al. (2007), due to the different variables and economy examined. It is worth stressing that in Australia, although the mining industry is one of the main drivers of economic growth, the integrated effect on investment across all industries appears to be less driven by foreign demand. A simple goodness-of-fit statistic and an F-test statistic also suggest that this model has reasonable explanatory power at
6.7. CONCLUSION

the industry level.

GMM column (5) skips demand uncertainty \((ugdp_{it})\) and re-estimates the model in column (4). Compared to the results for column (4), the coefficient for the effect of demand uncertainty on the short-run investment response to demand shocks \((ugdp_{it} \times \Delta logY_{it})\) is insignificant. The goodness-of-fit and F-test statistics in column (5) are 0.114 and 57.86, respectively, which are smaller than the values of 0.128 and 59.48 in column (4). This suggests that although the signs on the coefficients are similar, the model in column (5) has a weaker explanation for investment behavior than that in column (4). In addition, the statistics of overall diagnostic tests (Hansen’s over-identification tests), goodness-of-fit tests, and F-tests support the results of the GMM estimation.

To have consistent and comparable results with those in Chapter 5, Table 6.8 provides the RE, FE and GMM results for 1990–2012. As indicated, the only changes are found in column (4). The coefficient for interest rate uncertainty has slightly increased to 3.141. The unchanged results from 1960–2012 to 1990–2012 suggest that industry investment behaviour is steady. As discussed in Chapter 2, the transfer effect in the mining boom is dominant.

6.7 Conclusion

In summary, examining the impact of demand changes, tax changes, and uncertainty in industry investment provides a deep understanding of the pattern of Australian private investment in both the short and long-term. In light of the GMM results, statistically significant effects are found in the error correction term, uncertainty in company income tax, and interacted uncertainty in interest rates. More specifically, the error correction term, uncertainty in company income tax, and interacted uncertainty in interest rate are positively related to (that is, motivates) investment. However, the coefficients of the effect of demand uncertainty on the short-run investment response to demand shocks and demand uncertainty are insignificant. These results for demand uncertainty are different from Bloom et al. (2007), who found
### Table 6.7: RE, FE and GMM Estimation Results for Annual Industry Data (1960–2012)

<table>
<thead>
<tr>
<th>Dependent variable: $(I_i/K_{i,t-1})$</th>
<th>RE</th>
<th>FE</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log Y_{i,t}$</td>
<td>0.330</td>
<td>0.292</td>
<td>0.064</td>
<td>0.271</td>
<td>-0.154</td>
<td>-0.157</td>
<td>-0.026</td>
</tr>
<tr>
<td></td>
<td>(0.485)</td>
<td>(0.401)</td>
<td>(0.468)</td>
<td>(0.349)</td>
<td>(0.408)</td>
<td>(0.646)</td>
<td>(0.666)</td>
</tr>
<tr>
<td>$(\log Y_{i,t-1} - \log K_{i,t-1})$</td>
<td>0.041</td>
<td>-0.114</td>
<td>0.114</td>
<td>0.118</td>
<td>0.134</td>
<td>0.132</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.354)</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.029)*****</td>
</tr>
<tr>
<td>$\Delta \log t_{ax_{i,t}}$</td>
<td>0.002</td>
<td>0.0001</td>
<td>0.036</td>
<td>0.025</td>
<td>0.030</td>
<td>0.041</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0000)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\Delta \log e_{x_{i,t}}$</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.001</td>
<td>-0.002</td>
<td>0.003</td>
<td>-0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$(\Delta \log Y_{i,t})^2$</td>
<td>-1.410</td>
<td>-1.786</td>
<td>3.300</td>
<td>1.148</td>
<td>0.918</td>
<td>1.244</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.321)</td>
<td>(2.557)</td>
<td>(1.522)**</td>
<td>(1.576)</td>
<td>(3.263)</td>
<td>(3.566)</td>
<td></td>
</tr>
<tr>
<td>$\Delta t_{ax_{i,t}}$</td>
<td>1.350</td>
<td>1.228</td>
<td>8.978</td>
<td>9.684</td>
<td>9.179</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta e_{x_{i,t}}$</td>
<td>0.018</td>
<td>0.019</td>
<td>-0.096</td>
<td>-0.087</td>
<td>-0.102</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.020)</td>
<td>(0.070)</td>
<td>(0.069)</td>
<td>(0.073)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ugdp_{i,t} \times urat_{t}$</td>
<td>1.350</td>
<td>11.729</td>
<td>1.302</td>
<td>3.092</td>
<td>6.640</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.667)</td>
<td>(1.029)</td>
<td>(0.014)*</td>
<td>(0.521)**</td>
<td>(2.075)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ugdp_{i,t} \times ucgdp_{t}$</td>
<td>3.020</td>
<td>3.013</td>
<td>0.532</td>
<td>2.119</td>
<td>-0.218</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.162)**</td>
<td>(1.519)*</td>
<td>(0.013)</td>
<td>(0.667)</td>
<td>(0.799)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ugdp_{i,t}$</td>
<td>-0.058</td>
<td>-0.057</td>
<td>-0.046</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.024)**</td>
<td>(0.034)</td>
<td>(0.030)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ugdp_{i,t} \Delta \log Y_{i,t}$</td>
<td>0.121</td>
<td>0.020</td>
<td>0.132</td>
<td>0.021</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.110)</td>
<td>(0.001)</td>
<td>(0.101)</td>
<td>(0.041)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. Observations</td>
<td>154</td>
<td>154</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Hansen’s over-identification test</td>
<td>4.109</td>
<td>5.526</td>
<td>10.275</td>
<td>8.828</td>
<td>10.421</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodness of fit</td>
<td>0.025</td>
<td>0.095</td>
<td>0.099</td>
<td>0.100</td>
<td>0.123</td>
<td>0.128</td>
<td>0.114</td>
</tr>
<tr>
<td>F-test statistic</td>
<td>11.35</td>
<td>46.23***</td>
<td>25.04***</td>
<td>26.72***</td>
<td>42.68***</td>
<td>59.48***</td>
<td>57.86***</td>
</tr>
</tbody>
</table>

Notes: *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to $(\log Y_{i,t-1} - \log K_{i,t-1})$ for (1) and (2), to both $(\log Y_{i,t-1} - \log K_{i,t-1})$ and $ugdp_{i,t} \times ucgdp_{t}$ for (3) and (5), and to $(\log Y_{i,t-1} - \log K_{i,t-1})$, $ugdp_{i,t} \times ucgdp_{t}$ and $ugdp_{i,t}$ for (4). The goodness-of-fit measuring $\text{corr}(\hat{I}/K, I/K)^2$ is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression.
### Table 6.8: RE, FE and GMM Estimation Results for Annual Industry Data (1990–2012)

<table>
<thead>
<tr>
<th>Dependent variable: ((I_i,t/K_{i,t-1}))</th>
<th>RE</th>
<th>FE</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \log Y_{i,t})</td>
<td>0.330</td>
<td>0.292</td>
<td>0.064</td>
<td>0.271</td>
<td>-0.154</td>
<td>-0.157</td>
<td>-0.026</td>
</tr>
<tr>
<td></td>
<td>(0.485)</td>
<td>(0.401)</td>
<td>(0.468)</td>
<td>(0.349)</td>
<td>(0.408)</td>
<td>(0.646)</td>
<td>(0.666)</td>
</tr>
<tr>
<td>((\log Y_{i,t-1} - \log K_{i,t-1}))</td>
<td>0.041</td>
<td>-0.114</td>
<td>0.114</td>
<td>0.118</td>
<td>0.134</td>
<td>0.132</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.354)</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.030)**</td>
<td>(0.029)**</td>
</tr>
<tr>
<td>(\Delta \log tax_{i,t})</td>
<td>0.002</td>
<td>0.0001</td>
<td>0.036</td>
<td>0.025</td>
<td>0.030</td>
<td>0.041</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0000)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>(\Delta \log ex_{i,t})</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.001</td>
<td>-0.002</td>
<td>0.003</td>
<td>-0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>((\Delta \log Y_{i,t})^2)</td>
<td>-1.410</td>
<td>-1.786</td>
<td>3.300</td>
<td>1.148</td>
<td>0.918</td>
<td>1.244</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.321)</td>
<td>(2.557)</td>
<td>(1.522)**</td>
<td>(1.576)</td>
<td>(3.263)</td>
<td>(3.566)</td>
<td></td>
</tr>
<tr>
<td>(utax_{i,t})</td>
<td>1.350</td>
<td>1.228</td>
<td>8.978</td>
<td>9.684</td>
<td>9.179</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(uex_{i,t})</td>
<td>0.018</td>
<td>0.019</td>
<td>-0.096</td>
<td>-0.087</td>
<td>-0.102</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.020)</td>
<td>(0.070)</td>
<td>(0.069)</td>
<td>(0.073)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_{i,t} * urat_{t})</td>
<td>1.350</td>
<td>11.729</td>
<td>1.302</td>
<td>3.141</td>
<td>6.640</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.667)</td>
<td>(1.029)</td>
<td>(0.014)*</td>
<td>(0.521)**</td>
<td>(2.075)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_{i,t} * ucgdp_{t})</td>
<td>3.020</td>
<td>3.013</td>
<td>0.532</td>
<td>2.119</td>
<td>-0.218</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.162)**</td>
<td>(1.519)*</td>
<td>(0.013)</td>
<td>(0.667)</td>
<td>(0.799)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_{i,t} * \Delta \log Y_{i,t})</td>
<td>-0.058</td>
<td>-0.057</td>
<td>-0.046</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.024)**</td>
<td>(0.034)</td>
<td>(0.030)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ugdp_{i,t} * \Delta \log Y_{i,t})</td>
<td>0.121</td>
<td>0.020</td>
<td>0.132</td>
<td>0.021</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.110)</td>
<td>(0.001)</td>
<td>(0.101)</td>
<td>(0.041)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: ** indicates significance at 1%, *** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to \((\log Y_{i,t-1} - \log K_{i,t-1})\) for (1) and (2), to both \((\log Y_{i,t-1} - \log K_{i,t-1})\) and \(ugdp_{i,t} * ucgdp_{t}\) for (3) and (5), and to \((\log Y_{i,t-1} - \log K_{i,t-1})\), \(ugdp_{i,t} * ucgdp_{t}\) and \(ugdp_{i,t}\) for (4). The goodness-of-fit measuring \(\text{corr}(I/K, \hat{I}/\hat{K})^2\) is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression.
that the coefficient for uncertainty is significant, and that investment has a negative response to uncertainty.

Compared to the results at the macroeconomic level for the period 1990–2012, although the signs remain the same, the coefficients of the squared demand shocks, the change in company income tax, the change in export value, and Chinese GDP growth uncertainty are all insignificant. These variables indicate the nature of the Australian economy: the nonlinear effect of demand shocks, capital intensity, and its export-oriented nature, suggesting that across different industries nature is less dominant. Accordingly, apart from the opposite effects of interacted and demand uncertainty, the significant effects of tax uncertainty and interest rate uncertainty are different from those at the macroeconomic level. This also implies that the impact of the Australian economy on investment across all industries is diminished. To clarify this understanding of investment behaviour, the estimation of Australian private investment at the firm level is pursued in Chapter 7.
Chapter 7

Determinants of Firm Investment

7.1 Introduction

Although the previous chapter laid out factors determining investment, such as demand shocks, the user cost of capital, foreign trade, and demand uncertainty, attention was focused primarily on the macroeconomic and industry levels. To that extent, this thesis’s discussion on investment is fairly broad, as is much of the relevant literature. This chapter focuses on investment at the firm level that has arisen parallel to the discussions described in Chapters 5 and 6. In particular, four variables were added to the investment analysis at the firm level: number of employees, firm age in 2012, market capitalisation, and Chinese ownership. These variables correspond to firm size, long duration of operation, capital intensity, and Chinese demand, which are discussed in Chapters 2 and 4.

Section 7.2 sets up the estimation framework for investment behaviour at the firm level. Section 7.3 describes the nature of the panel data. Section 7.4 presents the results of the stationarity tests. Section 7.5 discusses uncertainty variables related to the estimation of Australian investment. Section 7.6 assesses the empirical models.
7.2 Firm Level Investment Estimation Framework

This chapter empirically assesses the behaviour of Australian mining investment at the firm level. The estimation approach follows that in Chapter 6, comprising stationarity tests, uncertainty tests, and a number of empirical models. These tests are closely linked with investment analyses at the macroeconomic and industry levels, providing sufficient evidence to better understand the dynamics of Australian mining investment.

The estimation in this chapter starts with the data description, followed by stationarity tests. These preliminary tests present the features of investment-related data to ensure that estimation variables are unbiased. Corresponding to the previous chapters, the uncertainty variables are generated using the GARCH model. As mentioned in Chapter 6, due to data unavailability at the firm level, the impact of interest rate uncertainty and Chinese GDP growth uncertainty on investment is measured by interacted terms with demand uncertainty. Moreover, the error correction process of cash flow and firm sales, as well as the specific firm features of firm size \((emp_{it})\), firm age \((age_{it})\), market capitalisation \((mkt_{it})\), and Chinese ownership \((ocn_{it})\) are included in the estimation models. To examine the extent to which investment at the firm level is affected by these related factors, the random effects (RE), the fixed effects (FE) methods and the generalised method of moments (GMM) are used.

7.3 Data Description at the Firm Level

The scope of the mining industry includes all operations associated with the extraction of minerals or hydrocarbons (oil and gas), exploration for minerals or hydrocarbons and provision of a variety of processing services (Finch, 2014). This chapter gathers panel data for Australian mining investment at the firm level from firms’ annual reports for the years 1990–2012. The chosen years cover a period of major economic events, such as the Asian economic crisis, the mining boom and the global
financial crisis, which affected Australian economic conditions and investment behaviour. Payment for the purchase of property, plant and equipment is chosen because it is the most relevant variable for mining investment at the firm level.

Investment behaviour at the firm level is examined using data from over 1,012 publicly listed Australian mining firms between 1990 and 2012. As discussed in Chapter 4, this data also includes total equity as capital stock, cash flows, operating sales, the number of employees for firm size, market capitalisation for the market value, expenses from exchange rate variations, firm age (in 2012), tax expenses, different ownership, and mining production. All these data are available from the firms’ annual reports and DatAnalysis (2012). The value of relevant data was deflated by the Australian GDP deflator. In addition, due to the increasing importance of Chinese investors, a dummy variable for Chinese ownership was created; if a firm is funded by Chinese investors, the dummy variable equals one; otherwise, it is zero.

As shown in Table 7.1, this firm level sample is characterised by firm size, market capitalisation, age in 2012, foreign ownership, and mining production. Using these features, the firms are grouped, with most grouped as being of micro and small size (≤ 30 employees), young firm age (≤ 5 years), and low market capitalisation (≤ AU$50,000,000). This suggests that small listed firms associated with young firm ages are the main components of the Australian mining industry. Furthermore, most mining firms are owned by British, American, and Chinese investors who primarily invest in gold and oil mines.

In contrast, Table 7.2 clarifies large firm size, large market capitalisation, and older firm age as the main drivers of mean investment across firms in the Australian mining industry. Although many mining firms are characterised by micro size (< 5 employees), small market capitalisation (≤ 50,000,000) and young firm age (≤ 5 years), large firms (≥ 100 employees) with large market capitalisation

\[ \text{Purchase of property, plant and equipment is recorded at cost less accumulated depreciation, cost on leased equipment and impairment charges, but includes the purchase of second hand equipment. According to the accounting standard, it may not be easy to find any better alternative for firm investment than purchase of property, plant and equipment. (Appendix A provides a more detailed explanation.)} \]
Table 7.1: Sample Characteristics of Australian Mining Firms (percent)

<table>
<thead>
<tr>
<th>Size</th>
<th>Market Capitalisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro (&lt; 5 employees)</td>
<td>≤ 50,000,000</td>
</tr>
<tr>
<td>Small (6–29 employees)</td>
<td>50,000,000–250,000,000</td>
</tr>
<tr>
<td>Medium (30–99 employees)</td>
<td>250,000,000–2,000,000,000</td>
</tr>
<tr>
<td>Large (≥ 100 employees)</td>
<td>≥ 2,000,000,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age in 2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5 years</td>
<td>39.32</td>
</tr>
<tr>
<td>6–10 years</td>
<td>27.94</td>
</tr>
<tr>
<td>11–19 years</td>
<td>25.77</td>
</tr>
<tr>
<td>≥ 20 years</td>
<td>6.97</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign Ownership</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>Coal</td>
</tr>
<tr>
<td>United States</td>
<td>Iron Ore</td>
</tr>
<tr>
<td>China</td>
<td>Bauxite</td>
</tr>
<tr>
<td>Japan</td>
<td>Copper</td>
</tr>
<tr>
<td>Oceania</td>
<td>Gold</td>
</tr>
<tr>
<td>Europe</td>
<td>Oil</td>
</tr>
<tr>
<td>Asia</td>
<td>Gas</td>
</tr>
<tr>
<td>Americas</td>
<td>Other</td>
</tr>
<tr>
<td>Africa</td>
<td>Other</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using data from firms’ annual reports.
7.3. DATA DESCRIPTION AT THE FIRM LEVEL

(≥ 2,000,000,000) and older firm age (≥ 20 years) gain more investment. Simultaneously, most investment is from the United Kingdom, United States, China, Japan and other Asian countries. Iron ore, bauxite and copper production receive the most investment. Most production in coal, iron ore, bauxite and copper comes from large firms (≥ 100 employees).

Table 7.2: Mean Investment by Firm Feature of Australian Mining Firms (AU$)

<table>
<thead>
<tr>
<th>Size</th>
<th>Market Capitalisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro (&lt; 5 employees)</td>
<td>1,646,979</td>
</tr>
<tr>
<td>Small (6–29 employees)</td>
<td>5,730,735</td>
</tr>
<tr>
<td>Medium (30–99 employees)</td>
<td>2.23e+07</td>
</tr>
<tr>
<td>Large (≥ 100 employees)</td>
<td>8.15e+08</td>
</tr>
</tbody>
</table>

Age in 2012

<table>
<thead>
<tr>
<th>Age in 2012</th>
<th>Investment (AU$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5 years</td>
<td>4,260,083</td>
</tr>
<tr>
<td>6–10 years</td>
<td>7,557,409</td>
</tr>
<tr>
<td>11–19 years</td>
<td>9,236,336</td>
</tr>
<tr>
<td>≥ 20 years</td>
<td>1.61e+08</td>
</tr>
</tbody>
</table>

Foreign Ownership

<table>
<thead>
<tr>
<th>Foreign Ownership</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>1.13e+08</td>
</tr>
<tr>
<td>United States</td>
<td>2.01e+08</td>
</tr>
<tr>
<td>China</td>
<td>6.39e+07</td>
</tr>
<tr>
<td>Japan</td>
<td>4.56e+07</td>
</tr>
<tr>
<td>Oceania</td>
<td>8.68e+07</td>
</tr>
<tr>
<td>Europe</td>
<td>3.59e+07</td>
</tr>
<tr>
<td>Asia</td>
<td>2.22e+08</td>
</tr>
<tr>
<td>Americas</td>
<td>2.72e+07</td>
</tr>
<tr>
<td>Africa</td>
<td>3.43e+07</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using data from firms’ annual reports
For production, mining firms with large size (≥ 100) account for 56.86% of firms mining coal, 74.13% of those mining iron ore, 100% of those mining bauxite, 66.67% of those mining copper, 35.37% of those mining gold, 29.7% of those mining oil and 34.73% of those mining other commodities.

Figure 7.1 shows the proportion of Australian mining firms undertaking investment from 1990 to 2012. Notably, the proportion increased from less than 1% in 1990 to over 10% in 2012. The increase from 2003 to 2012 was steeper than that from 1990 to 2002, corresponding to the period of the mining boom in Australia.
The only decline in the proportion of those firms investing was in 2009. Overall, the years 2003 and 2009 were important for behavioural changes in Australian mining investment. Table 7.3 compares the proportion of investing firms between 2003 and 2009.

Table 7.3 characterises the change in the proportion of observed firms investing between 2003 and 2009 using a different classification. For micro firms ( < 5 employees), the proportion of observed firms investing decreased sharply from 34.38% in 2003 to 28.16% in 2009, while for large firms ( ≥ 100 employees), the proportion increased by 3% between the two periods. Conversely, the group of firms aged less than 5 years experienced approximately a 20% increase in the proportion of observed firms investing between 2003 and 2009, while a 10% decline was seen in the group of firms older than 20 years. Meanwhile, the proportion of observed firms investing with different market capitalisation remained steady during that period. For Chinese ownership, the proportion more than doubled from 5% to 13.16%, while no large changes were seen among the various mining products.

Table 7.4 compares the means of key variables at the firm level with the medians,
## Table 7.3: Firm Level Mining Investment Variables

<table>
<thead>
<tr>
<th>By firm size</th>
<th>Proportion of observed firms investing in 2003</th>
<th>Proportion of observed firms investing in 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro (&lt; 5 employees)</td>
<td>34.38</td>
<td>28.16</td>
</tr>
<tr>
<td>Small (6–29 employees)</td>
<td>35.16</td>
<td>35.92</td>
</tr>
<tr>
<td>Medium (30–99 employees)</td>
<td>9.38</td>
<td>11.65</td>
</tr>
<tr>
<td>Large (≥ 100 employees)</td>
<td>21.09</td>
<td>24.27</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By age in 2012</th>
<th>Proportion of observed firms investing in 2003</th>
<th>Proportion of observed firms investing in 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5 years</td>
<td>14.86</td>
<td>32.32</td>
</tr>
<tr>
<td>6–10 years</td>
<td>18.58</td>
<td>24.39</td>
</tr>
<tr>
<td>11–19 years</td>
<td>31.08</td>
<td>17.03</td>
</tr>
<tr>
<td>≥ 20 years</td>
<td>35.47</td>
<td>26.26</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By market capitalisation</th>
<th>Proportion of observed firms investing in 2003</th>
<th>Proportion of observed firms investing in 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 50,000,000</td>
<td>83.51</td>
<td>75.83</td>
</tr>
<tr>
<td>50,000,000–250,000,000</td>
<td>9.12</td>
<td>15.20</td>
</tr>
<tr>
<td>250,000,000–2,000,000,000</td>
<td>4.21</td>
<td>6.08</td>
</tr>
<tr>
<td>≥ 2,000,000,000</td>
<td>3.16</td>
<td>2.89</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By Chinese ownership</th>
<th>Proportion of observed firms investing in 2003</th>
<th>Proportion of observed firms investing in 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Production</td>
<td>Proportion of observed firms investing in 2003</td>
<td>Proportion of observed firms investing in 2009</td>
</tr>
<tr>
<td>Coal</td>
<td>3.20</td>
<td>4.33</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>2.40</td>
<td>3.72</td>
</tr>
<tr>
<td>Bauxite</td>
<td>1.20</td>
<td>1.55</td>
</tr>
<tr>
<td>Copper</td>
<td>1.20</td>
<td>1.55</td>
</tr>
<tr>
<td>Gold</td>
<td>15.60</td>
<td>18.27</td>
</tr>
<tr>
<td>Oil</td>
<td>20.40</td>
<td>22.29</td>
</tr>
<tr>
<td>Gas</td>
<td>0.40</td>
<td>0.62</td>
</tr>
<tr>
<td>Other</td>
<td>55.60</td>
<td>47.68</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using data from firms’ annual reports.

Notes: The percentage for Chinese ownership is the ratio of the number of observed investing firms funded by Chinese investors to the number of observed investing firms funded by all foreign investors.
suggesting that except for exchange rate costs, the distributions of those variables are highly asymmetric. Specifically, the medians for investment ratio, sales ratio, cash flow ratio, market capitalisation, and tax expenses are far lower than their means.

As an example, the distributions of key variables for four major players (BHP Billiton, Rio Tinto, Xstrata and FMG) in the Australian mining industry were plotted in Figures 7.2, 7.3, 7.4 and 7.5. In the period 1990-2012, the four companies showed large volatility in most variables, while after the 2000s there was a sustained increase in most variables. In particular, BHP Billiton and Rio Tinto, the two biggest mining companies in Australia showed similar dynamics for investment ratio, sales ratio, cash flow ratio, market capitalisation and exchange rate costs over 1990–2012. Only in tax expenses, they were different. Except for investment ratio, FMG showed rapid growth in most variables after the 2000s, while Xstrata showed large volatility in most variables over 1990–2012.

![Figure 7.2: Variable Description for BHP Billiton](image)

Fluctuation in exchange rates results in extra costs for firms’ exports.
### 7.3. DATA DESCRIPTION AT THE FIRM LEVEL

#### Table 7.4: Distributions of Key Variables at the Firm Level

<table>
<thead>
<tr>
<th></th>
<th>$\frac{I_{it}}{K_{i,t-1}}$</th>
<th>$\frac{sal_{it}}{K_{it}}$</th>
<th>$\frac{C_{it}}{K_{i,t-1}}$</th>
<th>$mkt_{it}$</th>
<th>$er_{it}$</th>
<th>$tax_{it}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.281</td>
<td>2.209</td>
<td>3.542</td>
<td>12.102</td>
<td>6.670</td>
<td>7.324</td>
</tr>
<tr>
<td>P25</td>
<td>0.030</td>
<td>0.092</td>
<td>0.067</td>
<td>10.850</td>
<td>4.811</td>
<td>6.091</td>
</tr>
<tr>
<td>P50</td>
<td>0.144</td>
<td>0.442</td>
<td>0.165</td>
<td>11.731</td>
<td>6.803</td>
<td>7.144</td>
</tr>
<tr>
<td>P75</td>
<td>0.350</td>
<td>1.180</td>
<td>0.395</td>
<td>12.913</td>
<td>8.618</td>
<td>8.339</td>
</tr>
<tr>
<td>No. of Obs.</td>
<td>8096</td>
<td>3345</td>
<td>7843</td>
<td>9089</td>
<td>2696</td>
<td>9008</td>
</tr>
</tbody>
</table>

Source: Author’s calculations using data from firms’ annual reports

Notes: $P_i$ is the $i$th percentile. $er_{it}$ is exchange rate costs (AU$Million). $mkt_{it}$ is market capitalisation (AU$Million). $tax_{it}$ is tax expenses (AU$Million). $\frac{I_{it}}{K_{i,t-1}}$ is the ratio of the investment at time $t$ to the capital stock at time $t-1$. $\frac{sal_{it}}{K_{it}}$ is the ratio of the firm sales at time $t$ to the capital stock at time $t$. $\frac{C_{it}}{K_{i,t-1}}$ is the ratio of the cash flow at time $t$ to the capital stock at time $t-1$.

#### Figure 7.3: Variable Description for Rio Tinto
7.3. DATA DESCRIPTION AT THE FIRM LEVEL

![Graphs showing variable descriptions for Xstrata and FMG](image)

**Figure 7.4:** Variable Description for Xstrata

**Figure 7.5:** Variable Description for FMG
7.4  Stationarity Tests at the Firm Level

In testing stationarity in the analysis of industry investment, the Fisher-type augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test are designed to test panel data. As the panel dataset contains a large number of observed firms and time spans, the mean and variance of the sample are constant. However, some key data at the firm level need to be confirmed for stationarity by the Fisher-type ADF and PP tests.

As conveyed in Chapter 6, the Fisher-type stationarity method tests the null hypothesis that all panels contain a unit root, while the alternative hypothesis is that at least one panel is stationary. In addition, one of the benefits of adopting the Fisher-type stationarity test is its fitness of application to unbalanced panel data, which means that it is fit for data at the firm level. The equation of the Fisher-type test is specified by:

\[ \Delta y_{it} = \phi_i y_{i,t-1} + z_{it}^{'} \gamma_i + \epsilon_{it} \]  

(7.1)

where \( i = 1, ..., N \) indexes panels; \( t = 1, ..., T_i \) indexes time; \( y_{it} \) is the variable being tested; and \( \epsilon_{it} \) is a stationary error term. The \( z_{it} \) term can represent panel-specific means and a time trend, or no trend depending on the features of the data. This equation originates from the ADF test and the PP test, and is suited to panel data. Moreover, this panel unit root test is used to test the null hypothesis \( H_0 : \phi_i = 0 \) for all \( i \) versus the alternative \( H_a : \phi_i < 0 \).

Table 7.5 shows the results of the Fisher-type tests for panel data at the firm level. Due to skewed distributions of variables, the logarithmic transformations of variables were used. Not surprisingly, these tests reject the null hypothesis that all given data have a unit root at the 1% significance level, indicating that these panel data in the long-run are less affected by permanent shocks. Hence, panel data at the firm level is stationary.
### Table 7.5: Fisher Unit Root Tests at the Firm Level

<table>
<thead>
<tr>
<th>Firm level variables</th>
<th>ADF test</th>
<th>PP test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_0$: Unit root</td>
<td>$H_0$: Unit root</td>
</tr>
<tr>
<td></td>
<td>I(0)/I(1)</td>
<td>I(0)/I(1)</td>
</tr>
<tr>
<td>Mining investment/Capital stock</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
<tr>
<td>Firm sales</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
<tr>
<td>Tax expenses</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
<tr>
<td>Exchange rate costs</td>
<td>I(0)</td>
<td>I(0)</td>
</tr>
</tbody>
</table>

Notes: All variables are tested in logarithms. I(0) indicates that the data does not contain a unit root. I(1) indicates that its first-differenced series is stationary. To remove the effects of revenues on tax and exchange rate costs and their uncertainties, the company income tax and exchange rate costs were divided by firm revenues.
7.5 Uncertainty Data at the Firm Level

To empirically examine the primary determinants of Australian mining investment at the firm level, the relevant uncertainty variables are chosen and estimated. These uncertainty variables are related to uncertainty theory (the real options theory). Due to data limitations, choosing desirable uncertainty variables is not straightforward. Instead, the uncertainty variables are generated by the GARCH models, which are described below.

7.5.1 Uncertainty Variables

As discussed in Chapter 4, the GARCH model offers advantages for estimating uncertainty variables. Firstly, it avoids the disturbance of serial correlation and heterogeneity across panel data. Secondly, it provides a basis for deriving the conditional variance, because, unlike the ARCH model, it can capture the serial correlation for the conditional variance. In this sense, the GARCH model is appropriate for obtaining the uncertainty variables at the firm level.

Table 7.6 reports the best-fit GARCH models for uncertainty variables at the firm level. These results are verified by the Akaike Information Criterion. Figures 7.6, 7.7, and 7.8 plot conditional uncertainty data from four mining firms that are major players in the Australian mining industry: BHP Billiton, Rio Tinto, Xstrata and FMG; the data is processed using the GARCH models.

<table>
<thead>
<tr>
<th>Firm Level Uncertainty Variables</th>
<th>ARMA(p,q)</th>
<th>GARCH(p,q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm Sales (yearly)</td>
<td>(1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Tax Expenses (yearly)</td>
<td>(1,1)</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Exchange Rate Costs (yearly)</td>
<td>(1,1)</td>
<td>(1,1)</td>
</tr>
</tbody>
</table>

Notes: All variables are tested in logarithms.
7.5. **UNCERTAINTY DATA AT THE FIRM LEVEL**

Figure 7.6 shows that the impact of economic shocks on firm sales in the four selected firms diverged between 1990 and 2012. A salient shock to the sales of BHP Billiton and Rio Tinto was revealed in 1991, which was in response to the burst of the Japanese asset price bubble. Due to its proximity to the Asian market, exports and sales to the Japanese market were important for international mining firms such as BHP Billiton and Rio Tinto. In contrast, large variability was seen for Xstrata in 1997, corresponding to the Asian financial crisis, while for FMG, a large disturbance to firm sales was found in 2009, which was related to the global financial crisis.

![Figure 7.6: Firm Level Uncertainty in Firm Sales (Conditional Variances)](image)

Figure 7.7 shows that the volatility of the four firms for tax expense was similar to that of firm sales from 1990 to 2012. During that period, the burst of the Japanese asset price bubble caused a radical change in the tax expenses of BHP Billiton and Rio Tinto. Similarly, the 2008 global financial crisis led to a distinct move in the tax expenses of Xstrata and FMG. The amounts of tax expenses depend on the condition of firm sales; this relationship contributes to volatility in both factors.

Figure 7.8 shows a different behaviour for exchange rate costs from that for firm
sales and tax expenses from 1990 to 2012. Exchange rate costs for BHP Billiton were subject to the big shock resulting from the 1994 Mexico debt crisis. Consequently, the revenues of mining firms were disturbed by changes in exchange rates and fell by a large margin. Shocks resulting in changes in exchange rate costs were obvious for Rio Tinto in 1994 (the Mexico debt crisis), 1997 (the Asian financial crisis), and 2009 (the global financial crisis). For Xstrata and FMG, the notable shock to exchange rate costs was in 2009 (the global financial crisis).

To statistically characterise this uncertainty data, Tables 7.7 and 7.8 present the frequency of low and high uncertainties. As demonstrated in Chapter 6, the interaction terms representing Chinese GDP growth, interest rate, and short-term demand shocks were added as proxies for uncertainties faced by firms.

As shown in Table 7.7, mining firms, independent of size, tend to display low uncertainty. The exceptions are the high frequency of high uncertainty in exchange rate costs for micro and small firms and that for demand uncertainty for medium firms. This suggests that small firms are more likely to encounter high uncertainty.
in exchange rate costs, while medium-sized firms are more likely to face high levels of demand uncertainty. The high uncertainty in exchange rate costs may confirm the export-oriented nature of the mining industry in Australia. In 2012, only the mining firms aged over 10 years were subject to high uncertainty in firm sales, while other firms were influenced by low uncertainty. All the mining firms tended to face more low uncertainty than high uncertainties in market capitalisation and Chinese ownership. For the various products, high demand uncertainty was common in coal mining, iron ore mining, copper mining, gold mining, and gas mining.

Table 7.8 reports firms’ mean investment under low and high uncertainties. For demand uncertainty, mining firms that have been established for a long time and those with medium to large firm size are prone to investment under high uncertainty, implying that under high demand uncertainty, large mining firms have more resources (capital) to commit to investment. However, for other uncertainties, especially for small mining firms, more investment is undertaken under low uncertainty than high uncertainty.
### Table 7.7: Firm Level Data Frequency under Low and High Uncertainties (Conditional Variances)

<table>
<thead>
<tr>
<th>Classification</th>
<th>$usal_{it}$</th>
<th>$ucf_{it}$</th>
<th>$ucr_{it}$</th>
<th>$utax_{it}$</th>
<th>$usal_{it}$ * $ucgdp_{t}$</th>
<th>$usal_{it}$ * $urat_{t}$</th>
<th>$usal_{it}$ * $\Delta logsal_{it}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>MD</td>
<td>SK</td>
<td>M</td>
<td>MD</td>
<td>SK</td>
<td>M</td>
</tr>
<tr>
<td>By firm size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro (&lt; 5 employees)</td>
<td>1.65</td>
<td>0.4</td>
<td>6.64</td>
<td>0.97</td>
<td>0.58</td>
<td>2.15</td>
<td>0.65</td>
</tr>
<tr>
<td>Small (6-29 employees)</td>
<td>5.73</td>
<td>1.53</td>
<td>13.5</td>
<td>0.65</td>
<td>0.43</td>
<td>1.94</td>
<td>0.56</td>
</tr>
<tr>
<td>Medium (30-99 employees)</td>
<td>22.3</td>
<td>5.22</td>
<td>32.9</td>
<td>0.35</td>
<td>0.23</td>
<td>0.99</td>
<td>0.61</td>
</tr>
<tr>
<td>Large (≥ 100 employees)</td>
<td>815</td>
<td>61.7</td>
<td>227</td>
<td>0.38</td>
<td>0.22</td>
<td>1.67</td>
<td>0.65</td>
</tr>
<tr>
<td>By firm age in 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 5 years</td>
<td>3.32</td>
<td>0.54</td>
<td>7.5</td>
<td>0.62</td>
<td>0.42</td>
<td>1.22</td>
<td>0.65</td>
</tr>
<tr>
<td>6-10 years</td>
<td>3.23</td>
<td>0.43</td>
<td>3.7</td>
<td>0.82</td>
<td>0.74</td>
<td>2.23</td>
<td>1.27</td>
</tr>
<tr>
<td>11-19 years</td>
<td>28.3</td>
<td>29.3</td>
<td>-3.5</td>
<td>1.21</td>
<td>0.94</td>
<td>2.02</td>
<td>0.65</td>
</tr>
<tr>
<td>≥ 20 years</td>
<td>42.1</td>
<td>60.7</td>
<td>-0.5</td>
<td>0.68</td>
<td>0.23</td>
<td>2.14</td>
<td>1.78</td>
</tr>
<tr>
<td>By market capitalisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 50,000,000</td>
<td>9.83</td>
<td>3.31</td>
<td>6.5</td>
<td>0.62</td>
<td>0.42</td>
<td>0.94</td>
<td>0.78</td>
</tr>
<tr>
<td>50,000,000-250,000,000</td>
<td>10.81</td>
<td>6.34</td>
<td>5.8</td>
<td>0.67</td>
<td>0.49</td>
<td>0.78</td>
<td>0.65</td>
</tr>
<tr>
<td>250,000,000-2,000,000,000</td>
<td>15.22</td>
<td>7.23</td>
<td>10.2</td>
<td>0.86</td>
<td>0.65</td>
<td>0.87</td>
<td>0.29</td>
</tr>
<tr>
<td>≥ 2,000,000,000</td>
<td>21.23</td>
<td>9.83</td>
<td>8.8</td>
<td>0.97</td>
<td>0.643</td>
<td>1.25</td>
<td>0.45</td>
</tr>
<tr>
<td>Chinese Ownership</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>5.22</td>
<td>6.29</td>
<td>-1.34</td>
<td>0.62</td>
<td>0.53</td>
<td>0.94</td>
<td>0.23</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>5.45</td>
<td>6.65</td>
<td>-2.04</td>
<td>0.68</td>
<td>0.67</td>
<td>1.04</td>
<td>0.78</td>
</tr>
<tr>
<td>Bauxite</td>
<td>8.23</td>
<td>4.28</td>
<td>1.43</td>
<td>1.65</td>
<td>0.93</td>
<td>2.94</td>
<td>1.24</td>
</tr>
<tr>
<td>Copper</td>
<td>5.23</td>
<td>7.76</td>
<td>-1.53</td>
<td>0.65</td>
<td>0.65</td>
<td>0</td>
<td>2.32</td>
</tr>
<tr>
<td>Gold</td>
<td>2.34</td>
<td>9.84</td>
<td>4.34</td>
<td>0.87</td>
<td>0.76</td>
<td>0.23</td>
<td>0.78</td>
</tr>
<tr>
<td>Oil</td>
<td>8.23</td>
<td>4.23</td>
<td>3.40</td>
<td>0.65</td>
<td>0.76</td>
<td>0.71</td>
<td>0.23</td>
</tr>
<tr>
<td>Gas</td>
<td>1.34</td>
<td>4.97</td>
<td>-5.23</td>
<td>2.46</td>
<td>0.43</td>
<td>0.35</td>
<td>0.72</td>
</tr>
<tr>
<td>Other</td>
<td>7.87</td>
<td>6.67</td>
<td>2.02</td>
<td>0.75</td>
<td>0.63</td>
<td>0.22</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Notes: $usal_{it}$ is uncertainty on firm sales. $ucf_{it}$ is uncertainty on cash flow. $usal_{it}$ * $\Delta logsal_{it}$ is the interaction between uncertainty on firm sale and differences in firm sales. $utax_{it}$ is uncertainty on tax expenses. $ucr_{it}$ is uncertainty on exchange rate costs. $ural_{t}$ is uncertainty on exchange rate costs. $usal_{it}$ * $ucgdp_{t}$ is uncertainty on Chinese GDP growth. $usal_{it}$ * $urat_{t}$ is uncertainty on cash rates.

SK indicates skewness. M indicates mean, while MD indicates median. If the mean is larger (smaller) than the median, distribution of uncertainty data is right (left) skewed.

This indicates that most values of uncertainty data are lower (higher) than the average value.
As shown in Table 7.7, Australian mining investment is frequently impeded by high uncertainty in exchange rate costs. Only under high demand uncertainty, older firms of medium size shift more resources to investment. This may confirm the capital-intensive and export-oriented nature of the Australian mining industry.

### 7.6 Models of Firm Investment

At the firm level, the data limitations require explicit explanations, which are provided in Appendix A. More specifically, the number of observations in GMM estimation with firm features is substantially smaller than the number of observations given in Table 7.4. As presented in Tables 7.9 and 7.10, Australian private investment behaviour (1990–2012) at the firm level is empirically estimated. As elaborated in Chapter 6, the error correction model (ECM) in Bloom et al. (2007) is fit for constructing the investment model. The advantages of the ECM are twofold: it simultaneously captures the performances of short-term and long-run variables (for example, differenced and error correction term of firm sales); and, apart from capital and sales variables, it can include and test additional control variables. In the current study, the additional control variables at the firm level consist of cash flow, uncertainty, firm size, firm age in 2012, and market capitalisation. Under the framework of the ECM, the random effects (RE) and the fixed effects (FE) methods were first adopted to approximate the preliminary results of firm investment. Due to suspicions of endogeneity and over-identification in the panel regression, the GMM method was also used.

In particular, the model of mining investment at the firm level, along with changes in firm sales, the error correction term, tax changes and uncertainty terms, is estimated by the following empirical approach. Time and fixed effects are eliminated by using forward-mean differences and time differences to those variables in logarithm form. This empirical estimation is separated into two parts. One is the model without firm characteristics, such as firm size, firm age in 2012, market capitalisation, and Chinese ownership, to align with the model in previous chapters. The
Table 7.8: Firm Level Mean Investment under Low and High Uncertainties

<table>
<thead>
<tr>
<th>Classification</th>
<th>usal₁</th>
<th>ucf₁</th>
<th>uer₁</th>
<th>utax₁</th>
<th>usal₁ * ucgdp₁</th>
<th>usal₁ * urat₁</th>
<th>usal₁ * ∆logsal₁</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>H</td>
<td>S</td>
<td>L</td>
<td>H</td>
<td>S</td>
<td>L</td>
</tr>
<tr>
<td>By firm size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro (≤ 5 employees)</td>
<td>0.211</td>
<td>0.482</td>
<td>N 0.487</td>
<td>0.300</td>
<td>N 0.501 0.283</td>
<td>N 0.234 0.589</td>
<td>N 0.250 0.554  N 0.291 0.508</td>
</tr>
<tr>
<td>Small (6-29 employees)</td>
<td>0.484</td>
<td>0.402</td>
<td>N 0.373</td>
<td>0.493</td>
<td>N 0.434 0.428</td>
<td>N 0.405 0.458</td>
<td>S 0.393 0.471  N 0.418 0.444</td>
</tr>
<tr>
<td>Medium (30-99 employees)</td>
<td>0.478</td>
<td>1.003</td>
<td>S 0.846</td>
<td>0.597</td>
<td>N 0.884 0.563</td>
<td>N 0.851 0.392</td>
<td>N 0.633 0.980  S 0.526 0.941</td>
</tr>
<tr>
<td>Large (≥ 100 employees)</td>
<td>0.235</td>
<td>0.439</td>
<td>S 0.350</td>
<td>0.320</td>
<td>N 0.360 0.310</td>
<td>N 0.355 0.314</td>
<td>N 0.325 0.386  N 0.240 0.433</td>
</tr>
<tr>
<td>By firm age in 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 5 years</td>
<td>1.305</td>
<td>0.494</td>
<td>S 0.321</td>
<td>0.825</td>
<td>S 0.430 0.823</td>
<td>S 0.553 0.782</td>
<td>N 0.503 0.794  N 0.699 0.607</td>
</tr>
<tr>
<td>6-10 years</td>
<td>0.538</td>
<td>5.439</td>
<td>S 0.528</td>
<td>6.579</td>
<td>S 0.656 0.489</td>
<td>S 0.513 6.595</td>
<td>S 0.498 0.575  N 0.634 0.454</td>
</tr>
<tr>
<td>11-19 years</td>
<td>0.382</td>
<td>0.611</td>
<td>S 0.516</td>
<td>0.469</td>
<td>N 0.488 0.497</td>
<td>N 0.363 0.625</td>
<td>N 0.438 0.636  N 0.397 0.589</td>
</tr>
<tr>
<td>≥ 20 years</td>
<td>0.363</td>
<td>0.549</td>
<td>S 0.327</td>
<td>0.587</td>
<td>S 0.534 0.365</td>
<td>S 0.437 0.475</td>
<td>N 0.423 0.560  S 0.378 0.535</td>
</tr>
<tr>
<td>By market capitalisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 50,000,000</td>
<td>0.491</td>
<td>2.235</td>
<td>S 0.370</td>
<td>2.700</td>
<td>S 2.388 0.523</td>
<td>N 0.359 2.713</td>
<td>S 2.381 0.527  N 2.432 0.552</td>
</tr>
<tr>
<td>50,000,000-250,000,000</td>
<td>0.598</td>
<td>0.881</td>
<td>N 0.549</td>
<td>0.956</td>
<td>N 0.623 0.860</td>
<td>N 0.482 1.023</td>
<td>N 0.589 0.911  N 0.672 0.827</td>
</tr>
<tr>
<td>250,000,000-2,000,000,000</td>
<td>0.349</td>
<td>1.115</td>
<td>S 0.925</td>
<td>0.524</td>
<td>N 0.905 0.560</td>
<td>N 0.950 0.498</td>
<td>N 0.875 0.577  N 0.358 1.106</td>
</tr>
<tr>
<td>≥ 2,000,000,000</td>
<td>0.243</td>
<td>0.252</td>
<td>S 0.230</td>
<td>0.266</td>
<td>N 0.257 0.238</td>
<td>N 0.245 0.251</td>
<td>N 0.225 0.271  N 0.248 0.247</td>
</tr>
<tr>
<td>Chinese Ownership</td>
<td>0.565</td>
<td>0.484</td>
<td>N 0.342</td>
<td>0.693</td>
<td>N 0.657 0.409</td>
<td>N 0.358 0.682</td>
<td>N 0.522 0.506  N 0.707 0.300</td>
</tr>
<tr>
<td>By Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.365</td>
<td>0.546</td>
<td>N 0.539</td>
<td>0.347</td>
<td>N 0.453 0.432</td>
<td>N 0.530 0.345</td>
<td>N 0.296 0.615  N 0.227 0.715</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>0.295</td>
<td>0.378</td>
<td>N 0.338</td>
<td>0.332</td>
<td>N 0.309 0.360</td>
<td>N 0.314 0.358</td>
<td>N 0.244 0.432  N 0.322 0.349</td>
</tr>
<tr>
<td>Bauxite</td>
<td>0.168</td>
<td>0.156</td>
<td>N 0.184</td>
<td>0.143</td>
<td>N 0.144 0.178</td>
<td>N 0.174 0.152</td>
<td>N 0.164 0.160</td>
</tr>
<tr>
<td>Copper</td>
<td>0.396</td>
<td>0.246</td>
<td>N 0.380</td>
<td>0.272</td>
<td>N 0.400 0.259</td>
<td>N 0.228 0.454</td>
<td>N 0.348 0.310</td>
</tr>
<tr>
<td>Gold</td>
<td>0.307</td>
<td>0.436</td>
<td>N 0.317</td>
<td>0.456</td>
<td>N 0.347 0.406</td>
<td>N 0.302 0.477</td>
<td>N 0.298 0.461</td>
</tr>
<tr>
<td>Oil</td>
<td>0.427</td>
<td>0.590</td>
<td>N 0.412</td>
<td>0.607</td>
<td>N 0.528 0.481</td>
<td>N 0.478 0.533</td>
<td>N 0.385 0.638</td>
</tr>
<tr>
<td>Gas</td>
<td>1.018</td>
<td>0.252</td>
<td>N 0.285</td>
<td>0.819</td>
<td>N 0.881 0.119</td>
<td>N 0.164 0.926</td>
<td>N 0.874 0.295</td>
</tr>
<tr>
<td>Other</td>
<td>0.327</td>
<td>0.590</td>
<td>N 0.515</td>
<td>0.406</td>
<td>N 0.636 0.329</td>
<td>N 0.481 0.445</td>
<td>N 0.488 0.441</td>
</tr>
</tbody>
</table>

Notes: usal₁ is uncertainty on firm sales, ucf₁ is uncertainty on cash flow, usal₁ * ucgdp₁ is the interaction between uncertainty on firm sale and Chinese GDP growth. uer₁ is uncertainty on tax expenses. uer₁ is uncertainty on exchange rate costs. usal₁ * urat₁ is uncertainty on Chinese GDP growth. usal₁ * urat₁ is uncertainty on cash rates. L (H) refers to the frequency of the observations for which measured uncertainty is lower (higher) than the sample median. Figures in bold indicate that investment under high uncertainty is significantly greater than under low uncertainty. Bold S indicates difference of means tests to determine whether the differences in average investment under high and low uncertainty are statistically significant. A value of S indicates significance at 10%, and a value of N indicates no significance at 10%.
other is the model with all additional firm features. Section 7.6.1 uses the RE and FE methods for the preliminary test of Australian mining investment (1990–2012) at the firm level. Section 7.6.2 continues the estimation using the GMM method. Sections 7.6.3 and 7.6.4 re-estimate the RE, FE, and GMM methods. Section 7.6.5 concludes.

### 7.6.1 RE and FE Methods without Firm Features

Given the specification of the ECM in Chapter 4 and unbalanced panel data for Australian mining firms, the RE method (GLS) was first applied to the data for 1990–2012 to avoid the issue of heteroscedasticity across firms. The RE method is expressed by:

$$
\frac{I_{i,t}}{K_{i,t-1}} = \frac{0.548}{(0.148)***} + \frac{0.060(\Delta \text{logsal}_{i,t})}{(0.032)**} + \frac{0.011(\Delta \text{logsal}_{i,t})^2}{(0.008)} \\
+ \frac{0.046(\text{logsal}_{i,t-1} - \log K_{i,t-1})}{(0.019)***} + \frac{0.023\Delta \text{logtax}_{i,t}}{(0.020)} - \frac{0.019\Delta \text{loger}_{i,t}}{(0.015)} \\
- \frac{0.005 \text{usal}_{i,t}}{(0.006)} - \frac{0.001 \text{usal}_{i,t} \times \Delta \text{logsal}_{i,t}}{(0.001)} + \frac{0.008 \text{utax}_{i,t}}{(0.020)} \\
- \frac{0.056 \text{uer}_{i,t}}{(0.043)} + \frac{0.930 \text{usal}_{i,t} \times \text{urat}_{t}}{(1.424)} \\
+ \frac{0.039 \text{usal}_{i,t} \times \text{ucgdp}_{t}}{(0.062)} + \frac{0.010 \frac{C_{it}}{K_{i,t-1}}}{(0.002)***}
$$

(7.2)

*** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates.

where $\frac{I_{i,t}}{K_{i,t-1}}$ is the ratio of private investment to private capital stock for firm $i$ at times $t$ and $t-1$, $\Delta \text{logsal}_{i,t}$ is firm demand shocks at time $t$, $(\Delta \text{logsal}_{i,t})^2$ is squared demand shocks at time $t$, $(\text{logsal}_{i,t-1} - \log K_{i,t-1})$ is the difference between firm sales and private capital stock at time $t-1$, $\Delta \text{logtax}_{i,t}$ is the changes in firm tax expenses at time $t$, $\Delta \text{loger}_{i,t}$ is changes in exchange rate costs at time $t$, $\frac{C_{it}}{K_{i,t-1}}$ is adjusted cash flow, $\text{usal}_{i,t}$ is firm level demand uncertainty at time $t$, $\text{usal}_{i,t} \times \Delta \text{logsal}_{i,t}$ is
the effect of demand uncertainty on the short-run investment response to demand shocks at time $t$, $utax_{i,t}$ is firm uncertainty in tax expense at time $t$, $urer_{i,t}$ is firm uncertainty in exchange rate costs at time $t$, $usal_{i,t} * urat_{t}$ is interacted uncertainty between demand and the interest rate at time $t$, and $usal_{i,t} * ucgdp_t$ is interacted uncertainty between demand and Chinese GDP growth at time $t$.

The chosen variables in Equation 7.2 are consistent with those at the macroeconomic and industry levels. As shown in Equation 7.2 and Table 7.9, the coefficients for the changes in firm sales are positive and significant. Although the coefficient for squared firm sales ($\Delta (\log sal_{it})^2$) is insignificant, those of the differenced firm sales ($\Delta \log sal_{it}$) and the long-term error correction term ($\log sal_{i,t-1} - \log K_{i,t-1}$) are significantly positive and have marginal effects at 0.106. This suggests that a rise in firm sales facilitates mining investment, which is in line with the accelerator theory (Clark, 1917). Cash flow adjusted by capital stock ($\frac{C_{it}}{K_{i,t-1}}$) shows a significantly positive relationship with investment, ensuring the role of internal finance in supplying investment funds (Meyer and Kuh, 1966). Apart from that, the additional control variables, such as all uncertainty terms, changes in exchange rate costs, and changes in tax expenses are insignificant. These insignificant variables raise concerns about heterogeneity and endogeneity in this panel set.

To remove the issue of heterogeneity across the panel data, the FE method for the same specification in Equation 7.6.1 at the firm level was also estimated. Table 7.9 reports the estimation of the FE method. Compared with the results of the RE method, the signs on all coefficients are identical. These results imply that the RE and FE methods are not ideal for the estimation of mining investment at the firm level. Due to the suspicions of endogeneity and over-identification, the GMM estimation method was then used.

7.6.2 GMM without Firm Features

This section re-estimates firm level Australian mining investment using the GMM method. The GMM method is devoted to addressing issues of endogeneity and over-
identification in panel data. In addition, the effects of changes in firm sales, changes in tax expenses, and uncertainty terms on Australian mining firm investment are determined. The specification of the GMM method (from 1990 to 2012) for panel data is the same as in Equation 7.2. For the GMM estimation, a lagged error correction term, lagged number employed and lagged market capitalisation were used as instrumental variables for the error correction term, numbers employed and market capitalisation in the tests of GMM(1) and GMM(2). In the tests of GMM(3) and (5), a lagged error correction term, lagged exchange rate uncertainty, lagged number employed, and lagged market capitalisation were used as instrumental variables for the error correction term, numbers employed, market capitalisation, and exchange rate uncertainty. In the tests of GMM(4) and (6), a lagged error correction term, lagged exchange rate uncertainty, lagged number employed, lagged market capitalisation, and lagged demand uncertainty were used as instrumental variables for the error correction term, numbers employed, market capitalisation, exchange rate uncertainty and demand uncertainty. The validity of instruments is confirmed by the insignificant results of Hansen’s over-identification tests at the 5% level of significance. This is the same as those in (Bloom et al., 2007).

Table 7.9 demonstrates a different composition of variables at the firm level. GMM column (1) of Table 7.9 introduces the baseline model, in which the variables range from demand shocks (changes in firm sales $\Delta logsal_{i,t}$), the error correction term $(logsal_{i,t-1} - logK_{i,t-1})$, tax expense changes $(\Delta logtax_{i,t})$ and adjusted cash flow $(\frac{C_{i,t}}{K_{i,t-1}})$ to changes in exchange rate costs $(\Delta loger_{i,t})$. Among these variables, significant effects are embodied in the positive linear demand changes at 0.05, and the positive adjusted cash flow variable at 0.007. In this regard, the positive and significant coefficients for demand shocks and cash flow variables suggest that positive demand shocks and cash flow encourage mining investment. This firm level finding is consistent with Bloom et al. (2007), who found that linear demand shocks dominate the effects on investment.

GMM column (2) of Table 7.9 compares the effect of linear demand changes
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with that of squared demand changes \((\Delta \log sal_{i,t})^2\). As indicated, the signs and significances on the coefficients for demand shocks, the coefficients for error correction term, changes in tax expenses, adjusted cash flow, and cost changes in exchange rates are in line with those of column (1). However, the additional squared demand changes have no significant effects on mining investment. The absence of any effect of nonlinear demand shocks on investment is not aligned with the findings in Bloom et al. (2007) or this thesis’s Chapter 5. One possible explanation is the difference in the years of investment and the chosen economy.

GMM column (3) of Table 7.9 investigates the effects of uncertainty variables, such as uncertainty in tax expenses, uncertainty in exchange rate costs, interacted uncertainty in interest rates \((usal_{i,t} \times urat_t)\), and interacted uncertainty in Chinese GDP growth \((usal_{i,t} \times ucgdp_t)\) on mining investment. Similar to the GMM estimates in column (2), the signs and significances of the coefficients in column (1) remain unchanged. The only significant uncertainty variable is uncertainty in tax expenses, which has a negative impact on investment at −0.026. This suggests that the negative effect of tax expense uncertainty on Australian mining firm investment outweighs that of demand uncertainty.

GMM column (4) of Table 7.9 displays the results for the model of Australian mining investment at the firm level. Unlike the GMM estimates in column (3), the coefficients for tax expense uncertainty \((utax_{it})\) and uncertainty in exchange rate costs are significant at −0.025 and −0.031. These observations imply that uncertainty in tax expenses and exchange rate costs deter investment. This confirms the finding of uncertainty behaviour at the macroeconomic level, which is in line with the nature of the mining industry. The results of the coefficients for linear demand changes, and adjusted cash flow and the uncertainty in tax expense conform with those in column (3). Apart from that, the significant coefficient for interacted uncertainty on firm sales \((usal_{it} \times \Delta \log sal_{it})\) is negatively signed at −0.002, indicating that the effect of demand uncertainty on the short-run investment response to demand shocks is negative. This result is similar to that in Bloom et al. (2007). Moreover, these facts
indicate that without firm features under the effect of interacted demand uncertainty in demand shocks, exchange rate cost uncertainty and tax cost uncertainty mining firms are reluctant to commit investment. The effects of uncertainty in interest rates and Chinese GDP growth on investment are ambiguous.

GMM column (5) of Table 7.9 omits demand uncertainty ($usal_{it}$) to investigate the single effect of demand uncertainty on the short-run investment response to demand shocks ($usal_{it} \times \Delta \logsal_{it}$). Although there is an omission of demand uncertainty in column (5), the number of significant coefficients and their signs is the same as column (4), confirming the significant effects of demand uncertainty on the short-run investment response to demand shocks, exchange rate cost uncertainty and tax cost uncertainty. Considering the statistics of the tests for goodness-of-fit (0.036 in column(4) and 0.025 in column (5)), the explanatory power of the variables in column (4) of Table 7.9 seems to be superior to that of column (5). In addition, the overall diagnostic tests (Hansen’s over-identification tests) support the unbiased results of the GMM estimates in Table 7.9.

In short, the positive effect of demand shocks on investment is significant, along with the negative effect of demand uncertainty on the short-run investment response to demand shocks. In addition, adjusted cash flow is an impulse of firm investment. The impact of the user cost of capital on investment is significant and positive, while investment has a negative response to uncertainty in tax expenses. In contrast, the impact of changes in exchange rate costs has an ambiguous effect on investment, while its uncertainty factor significantly dampens investment.

### 7.6.3 RE and FE Methods with Firm Features

As highlighted in Section 7.3, firm size, firm age in 2012, market capitalisation, and Chinese ownership play important roles in investment decisions; thus, it is worth examining the impacts of these firm specific features on mining investment. The RE
method (1990–2012) is given by:

\[
\frac{I_{i,t}}{K_{i,t-1}} = -0.255 + 0.075(\Delta \text{logsal}_{i,t}) + 0.012(\Delta \text{logsal}_{i,t})^2
\]

\[
+ 0.05(\text{logsal}_{i,t-1} - \log K_{i,t-1}) - 0.011\Delta \text{logtax}_{i,t} + 0.001\Delta \text{loger}_{i,t}
\]

\[
- 0.007\text{usal}_{i,t} - 0.001\text{usal}_{i,t} \times \Delta \text{logsal}_{i,t} + 0.009\text{utax}_{i,t}
\]

\[
+ 0.019\text{uer}_{i,t} + 0.041\text{usal}_{i,t} \times \text{urat}_{t} - 0.082\text{logemp}_{it} - 0.001\text{age}_{it}
\]

\[
+ 0.248\text{usal}_{i,t} \times \text{ucgdp}_{t} + 0.032\frac{C_{it}}{K_{i,t-1}} + 0.072\text{logmkt}_{it} + 0.445\text{ocn}_{it}
\]

\[(7.3)\]

*** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates.

where \(\frac{I_{i,t}}{K_{i,t-1}}\) is the ratio of private investment to private capital stock for firm \(i\) at times \(t\) and \(t-1\), \(\Delta \text{logsal}_{i,t}\) is firm demand shocks at time \(t\), \((\Delta \text{logsal}_{i,t})^2\) is squared demand shocks at time \(t\), \((\text{logsal}_{i,t-1} - \log K_{i,t-1})\) is the difference between firm sales and private capital stock at time \(t-1\), \(\Delta \text{logtax}_{i,t}\) is the changes in firm tax expenses at time \(t\), \(\Delta \text{loger}_{i,t}\) is changes in exchange rate costs at time \(t\), \(\text{usal}_{i,t} \times \Delta \text{logsal}_{i,t}\) is the effect of demand uncertainty on the short-run investment response to demand shocks at time \(t\), \(\text{utax}_{i,t}\) is firm uncertainty in tax expense at time \(t\), \(\text{uer}_{i,t}\) is firm uncertainty in changes in exchange rate costs at time \(t\), \(\text{usal}_{i,t} \times \text{urat}_{t}\) is interacted uncertainty between demand and interest rates at time \(t\), \(\text{usal}_{i,t} \times \text{ucgdp}_{t}\) is interacted uncertainty between demand and Chinese GDP growth at time \(t\), \(\text{logemp}_{it}\) is firm size, \(\text{age}_{it}\) is firm age in 2012, \(\text{logmkt}_{it}\) is market capitalisation, and \(\text{ocn}_{it}\) is a dummy variable for Chinese ownership, which equals to one if there is Chinese ownership and equals zero otherwise.

Equation 7.3 and Table 7.10 provide the RE estimation. As exhibited, the coefficients on linear demand shocks \((\Delta \text{logsal}_{it})\) and the error correction term \((\text{logsal}_{i,t-1} - \log K_{i,t-1})\)...
logK_{i,t-1}) are significant and positive. These demand variables as well as cash flow \((\frac{C_{it}}{K_{i,t-1}})\) foster a positive relationship between demand shocks, cash flow, and mining investment. However, the effects of changes in tax expenses and exchange rate costs on investment are not significant. Moreover, the uncertainty variables, such as demand uncertainty (usal_{it}), interacted demand uncertainty (usal_{it} \times \Delta \logosal_{it}), uncertainty in tax expenses (utax_{it}), uncertainty in exchange rate costs (uer_{it}), and interacted uncertainty in interest rates (usal_{it} \times urat_{it}), show ambiguous effects on investment, while interacted uncertainty in Chinese GDP growth (usal_{it} \times ucgdp_{it}) has a positive effect on investment. Turning to firm features, a negative relationship between firm size (logemp_{it}) and investment, along with a positive relationship between market capitalisation (logmkt_{it}), Chinese ownership (ocn_{it}) and investment is dominant. Firm age (age_{it}) does not have a significant effect on investment.

Table 7.10 shows a noticeable difference between the RE and FE estimations as expressed by the coefficients for the demand variables. As revealed in the FE estimation, apart from the significant coefficients on linear demand shocks and the error correction term, the coefficient for squared demand \((\Delta \logosal_{it})^2\) is significant and positive. Except for firm size, other firm features are insignificant. Uncertainty in interest rates is significant but is positively signed. Due to different results between the RE and FE estimations, the concern for endogeneity is raised. The GMM is used to correct for issues of endogeneity and over-identification.

### 7.6.4 GMM with Firm Features

Following the specification of the RE and FE methods in Equation 7.6.3, the estimation of Australian mining investment at the firm level, along with firm features, was reconsidered using the GMM estimation method.

Table 7.10 presents the results for the GMM estimation of firm investment with firm features. GMM columns (1) and (2) of Table 7.10 assess the basic variables associated with the nonlinear demand variable. The effects of firm features on the coefficients for all demand variables, including squared demand shocks, are in-
7.6. MODELS OF FIRM INVESTMENT

significant, suggesting that the effect of demand shocks on investment is alleviated. Contrary to the expected positive sign in Table 4.1, the coefficient for firm size is significantly negative. However, it corresponds to the preliminary findings for the nature of the mining industry given in Table 7.1; that small mining firms in Australia are more interested in investing than large mining firms. In addition, except for the insignificance of firm age in 2012, the coefficients for market capitalisation and Chinese ownership are significant and positive. These coefficient signs are in line with the expected signs in Table 4.1. As revealed by these firm features, mining investment in Australia is influenced by small firms, large market capitalisation, and Chinese investors at the firm level.

GMM columns (3) and (5) of Table 7.10 show similar results. In particular, the changes in tax expenses and uncertainty in tax expenses are negatively related to mining investment at the firm level. Demand variables show no significant effects on investment. Instead, effects such as the negative effect of firm size and the positive effects of market capitalisation and Chinese ownership on investment, are noticeable. It suggests that with those firm features uncertainties of exchange rate costs and tax costs, interest rates and Chinese GDP growth have significantly negative effects on investment.

Notably, in GMM columns (3), (4) and (5), the coefficients for changes in exchange rate costs are significantly positive, which differs from the expected sign in Table 4.1. Thus, under different uncertainties the changes in exchange rate costs encourage firm investment. However, this can be explained by the fact that due to rising Chinese demand for mineral resources during the mining boom, the Australian mining industry gained large profits and investment even under a strong Australian dollar (Convey, 2012).

Despite the similar results for changes in tax and exchange rate costs, cash flow, firm features and uncertainties of tax and Chinese GDP growth among columns (3), (4) and (5), column (4) shows more significant effects of interacted demand uncertainty and demand uncertainty. Under these circumstances, the effect of demand
uncertainty on the short-run investment response to demand shocks is positive at 0.005, while the long-run effect of demand uncertainty is negative at −0.013. Although this result is different from that contained in the extensive literature on investment. Carruth et al. (2000) suggest that a possible reason could be the existence of a positive uncertainty-investment relationship (Hartman-Abel effect). In a competitive market, if the marginal product of capital is convex in price, an increase in price variance raises the expected return on the marginal product of capital and thus drives investment. Importantly, the positive relationship in this estimation may be closely linked with mining firm features.

In GMM columns (3), (4) and (5), the insignificant effect of demand shocks on investment may lie in the overwhelmingly significant effect of Chinese ownership on Australian mining firms. The result of additional investigation without the variable of Chinese ownership was identified by the GMM estimates in column (6) of Table 7.10. In this model specification, without Chinese ownership, the demand variables of the error correction term \((\log \text{sal}_t - \log K_t)\) and interest rate uncertainty \((u \text{sal}_t \times u \text{rat}_t)\) are shown to be significant. Other significant factors (changes in exchange rate costs and tax costs, cash flow, firm features and tax uncertainty) remain as in column (4). This may support the assertion that the effect of Chinese ownership outweighs that of demand shocks on investment, suggesting that the Chinese economy has a profound effect on Australian economic behaviour. This result may also suggest that financial constraints for the mining industry are relaxed or that Chinese ownership opens up new markets in China. The statistics for goodness-of-fit tests and F tests suggest that columns (4), (5) and (6) of Table 7.10 have reasonable explanatory power.

All these analyses suggest that compared to the analyses at the macroeconomic and industry levels in Tables 5.7 and 6.8, the significant effects of user cost of capital and foreign trade on Australian investment were observed at the macroeconomic and firm levels during 1990–2012, but were diminished at the industry level. However, the nonlinear relationship between demand shocks and macroeconomic investment
is not found at the industry and firm levels; instead, a positive linear relationship is dominant between them at the industry and firm levels. The same negative effect of export uncertainty is significant at the macroeconomic and firm levels, but not at the industry level. This suggests that investment behaviour at the macroeconomic and firm levels share some similar characteristics, especially regarding the nature of the mining industry. Furthermore, investment is sensitive to tax uncertainty at the firm level, while it is positively related to tax uncertainty at the industry level. This suggests that tax uncertainty has a unique effect on mining firm investment. The effects of demand uncertainty on the short-run investment response to demand shocks at the macroeconomic and industry levels from 1990 to 2012 are characterised by insignificant and positive coefficients. At the firm level, this effect shifts from positive with mining firm features to negative without them. The negative effect of demand uncertainty on investment is observed at the industry level and the firm level with firm features.

7.6.5 Conclusion

This chapter has examined whether Australian mining investment at the firm level is affected by macroeconomic and microeconomic factors. The general framework from the analysis of investment was tested using the RE, FE, and GMM methods. The analysis in this chapter was principally split into two parts: estimation with general variables, and testing by the addition of firm-specific features. Taking into account macroeconomic and industry investment, investment estimation at the firm level proposes new variables: for instance, adjusted cash flow. Hence, in the analysis without firm features, the coefficients for linear demand shocks, the user cost of capital, uncertainty in exchange rate costs and tax costs, and adjusted cash flow are significant. These results are consistent with the analyses at the macroeconomic and industry levels, highlighting the nature of the mining industry, such as its capital-intensive and export-oriented natures. On the other hand, analysis with firm features reveals the significantly positive effect of cost changes in exchange rates and
<table>
<thead>
<tr>
<th>Dependent variable: ((I_{i,t}/K_{i,t-1}))</th>
<th>RE</th>
<th>FE</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \log\text{sal}_{i,t})</td>
<td>0.060</td>
<td>0.135</td>
<td>0.050</td>
<td>0.045</td>
<td>0.044</td>
<td>0.063</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>(0.032)**</td>
<td>(0.105)</td>
<td>(0.020)**</td>
<td>(0.020)**</td>
<td>(0.020)**</td>
<td>(0.026)***</td>
<td>(0.026)***</td>
</tr>
<tr>
<td>((\log\text{sal}<em>{i,t-1} - \log\text{K}</em>{i,t-1}))</td>
<td>0.046</td>
<td>0.226</td>
<td>0.004</td>
<td>0.004</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.019)***</td>
<td>(0.170)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>(\Delta \log\text{tax}_{i,t})</td>
<td>0.003</td>
<td>0.004</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>(\Delta \log\text{er}_{i,t})</td>
<td>-0.003</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
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</tr>
<tr>
<td>(C_{i,t}/K_{i,t-1})</td>
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<td>0.007</td>
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<tr>
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<td>(0.006)</td>
<td>(0.004)*</td>
<td>(0.004)*</td>
<td>(0.004)*</td>
<td>(0.004)*</td>
<td>(0.004)*</td>
</tr>
<tr>
<td>((\Delta \log\text{sal}_{i,t})^2)</td>
<td>0.011</td>
<td>0.020</td>
<td>-0.001</td>
<td>-0.001</td>
<td>0.007</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.017)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.006)</td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>utax_{i,t}</td>
<td>0.008</td>
<td>0.013</td>
<td>-0.026</td>
<td>-0.025</td>
<td>-0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.019)</td>
<td>(0.009)**</td>
<td>(0.010)**</td>
<td>(0.009)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wcr_{i,t}</td>
<td>-0.056</td>
<td>-0.046</td>
<td>-0.028</td>
<td>-0.031</td>
<td>-0.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.043)</td>
<td>(0.022)</td>
<td>(0.023)*</td>
<td>(0.024)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>usal_{i,t} * urat_{t}</td>
<td>0.930</td>
<td>-0.035</td>
<td>0.124</td>
<td>0.369</td>
<td>0.185</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.424)</td>
<td>(0.923)</td>
<td>(0.654)</td>
<td>(0.949)</td>
<td>(0.641)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>usal_{i,t} * ucdp_{t}</td>
<td>0.039</td>
<td>0.070</td>
<td>0.001</td>
<td>0.024</td>
<td>0.018</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.043)*</td>
<td>(0.012)</td>
<td>(0.042)</td>
<td>(0.013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>usal_{i,t}</td>
<td>-0.005</td>
<td>-0.003</td>
<td></td>
<td>-0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.002)</td>
<td></td>
<td>(0.003)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>usal_{i,t} * \Delta \log\text{sal}_{i,t}</td>
<td>-0.001</td>
<td>-0.001</td>
<td></td>
<td></td>
<td>-0.002</td>
<td>-0.002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td>(0.001)***</td>
<td>(0.001)**</td>
<td></td>
</tr>
</tbody>
</table>

No. Observations 792 792 600 600 600 600 600
Hansen's over-identification test 5.660 6.145 7.850 6.431 5.876
goodness-of-fit 0.053 0.028 0.031 0.029 0.031 0.036 0.025
F-test statistic 23.46*** 15.63*** 24.86*** 27.54*** 36.21*** 39.39*** 33.96***

Notes: *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to \((\log\text{sal}_{i,t-1} - \log\text{K}_{i,t-1})\) for (1) and (2) and to both \((\log\text{sal}_{i,t-1} - \log\text{K}_{i,t-1}), \text{utax}_{i,t}, \text{usal}_{i,t} \times \text{ucd}_{t}\) for (3) and (5), and to \((\log\text{sal}_{i,t-1} - \log\text{K}_{i,t-1}), \text{usal}_{i,t} \times \text{ucd}_{t}, \text{ural}_{t}, \text{usal}_{i,t} \times \Delta \log\text{sal}_{i,t}\) for (4). The goodness-of-fit measuring \(\text{corr}(I/K, \hat{I}/K)^2\) is the squared correlation coefficient between actual and predicted levels of the dependent variable.

The F-test statistic measures the overall significance of the regression.
### Table 7.10: RE, FE and GMM Estimation Results for Annual Firm Level Data (1990–2012) (2)

<table>
<thead>
<tr>
<th>Dependent Variable: ((I_i/K_i)_{t-1})</th>
<th>RE</th>
<th>FE</th>
<th>GMM(1)</th>
<th>GMM(2)</th>
<th>GMM(3)</th>
<th>GMM(4)</th>
<th>GMM(5)</th>
<th>GMM(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \log \text{sal}_i)</td>
<td>0.075</td>
<td>0.107</td>
<td>0.031</td>
<td>0.025</td>
<td>0.074</td>
<td>0.040</td>
<td>0.047</td>
<td>0.100</td>
</tr>
<tr>
<td>((\text{logsal}<em>i - \log K_i)</em>{t-1})</td>
<td>0.050</td>
<td>0.088</td>
<td>0.035</td>
<td>0.025</td>
<td>0.049</td>
<td>0.040</td>
<td>0.032</td>
<td>0.088</td>
</tr>
<tr>
<td>(\Delta \log \text{tax}_i)</td>
<td>-0.001</td>
<td>-0.003</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.004</td>
</tr>
<tr>
<td>(\Delta \log \text{er}_i)</td>
<td>0.001</td>
<td>0.002</td>
<td>0.004</td>
<td>0.005</td>
<td>0.006</td>
<td>0.005</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>(C_i/K_i)_{t-1})</td>
<td>0.032</td>
<td>0.039</td>
<td>0.033</td>
<td>0.035</td>
<td>0.023</td>
<td>0.022</td>
<td>0.024</td>
<td>0.031</td>
</tr>
<tr>
<td>(\Delta \log \text{emp}_i)</td>
<td>-0.002</td>
<td>0.005</td>
<td>-0.089</td>
<td>-0.081</td>
<td>-0.112</td>
<td>-0.096</td>
<td>-0.097</td>
<td>-0.141</td>
</tr>
<tr>
<td>(\Delta \log \text{mkt}_i)</td>
<td>0.072</td>
<td>0.016</td>
<td>0.077</td>
<td>0.067</td>
<td>0.084</td>
<td>0.079</td>
<td>0.073</td>
<td>0.118</td>
</tr>
<tr>
<td>(\Delta \log \text{ocn}_i)</td>
<td>0.445</td>
<td>-0.182</td>
<td>0.813</td>
<td>0.866</td>
<td>0.598</td>
<td>0.703</td>
<td>0.699</td>
<td></td>
</tr>
<tr>
<td>((\Delta \log \text{sal}_i)^2)</td>
<td>0.012</td>
<td>0.015</td>
<td>0.005</td>
<td>0.015</td>
<td>0.017</td>
<td>0.006</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{tax}_i)</td>
<td>0.009</td>
<td>-0.027</td>
<td>-0.040</td>
<td>-0.032</td>
<td>-0.039</td>
<td>-0.041</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{er}_i)</td>
<td>0.019</td>
<td>0.049</td>
<td>0.049</td>
<td>0.049</td>
<td>0.046</td>
<td>0.057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{emp}_i)</td>
<td>0.041</td>
<td>3.096</td>
<td>4.966</td>
<td>2.520</td>
<td>4.647</td>
<td>4.834</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{mkt}_i)</td>
<td>0.248</td>
<td>-0.066</td>
<td>-0.666</td>
<td>-0.658</td>
<td>-0.632</td>
<td>-0.372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{ocn}_i)</td>
<td>-0.007</td>
<td>0.006</td>
<td>-0.013</td>
<td>-0.013</td>
<td>-0.003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta \log \text{sal}_i)</td>
<td>-0.001</td>
<td>-0.013</td>
<td>0.005</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.002</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. Observations: 244
Hansen’s over-identification test: 24.56***
Hansen's goodness-of-fit: 6.374
Hansen's F-test statistic: 24.56***

Notes: *** indicates significance at 1%, ** significance at 5% and * significance at 10%. The coefficient on ages in column (2) is eliminated due to fixed effects.

The figures in parentheses are the standard errors of the estimates. The test of endogeneity is applied to \((\log \text{sal}_i - \log K_i)_{t-1}\), \(\log \text{emp}_i\), and \(\log \text{mkt}_i\) for (1) and (2) and to both \((\log \text{sal}_i - \log K_i)_{t-1}\), \(\log \text{emp}_i\), and \(\log \text{mkt}_i\) for (3) and (5), \(\log \text{sal}_i - \log K_i)_{t-1}\), \(\log \text{emp}_i\), \(\log \text{mkt}_i\), and \(\log \text{ocn}_i\) for (4) and (6). The goodness-of-fit measuring \(\text{corr}(\hat{I_i}/K_i, I_i/K_i)^2\) is the squared correlation coefficient between actual and predicted levels of the dependent variable. The F-test statistic measures the overall significance of the regression.
the positive effect of demand uncertainty on the short-run investment response to
demand shocks, while the effects of firm size and demand uncertainty are negative.
Notably, as confirmed by the descriptive findings and the estimation with firm fea-
tures, the largest proportion of observed mining firms in Australia that undertake
investment are small. More importantly, at the firm level, compared to other aggre-
gate factors, Chinese demand by means of Chinese ownership has an overwhelmingly
significant effect on investment.
Chapter 8

Discussion and Conclusions

8.1 Introduction

This study has developed different empirical models for Australian private investment at the macroeconomic, industry, and mining firm levels. These models have shown that:

(1) at the macroeconomic level the coefficients of foreign trade, the user cost of capital, terms of trade uncertainty, Chinese GDP growth uncertainty and demand uncertainty are significant. This is also true for the effect of demand uncertainty on the short-run investment response to demand shocks. In 1969–2012 demand shocks had a concave effect on investment, while during 1990–2012 demand shocks had a convex effect;

(2) at the industry level, the results for 1960–2012 and 1990–2012 are identical. The effects of tax uncertainty, interest rate uncertainty, and demand uncertainty on investment are significant, while the nonlinear effect of demand shocks on investment is diminished;

(3) at the firm level, considering firm features, there are positive effects in demand shocks, cash flow, changes in exchange rate costs, market capitalisation, and Chinese ownership, and negative effects in tax uncertainty, firm size and demand uncertainty. In particular, the effect of demand uncertainty on the short-run investment response to demand shocks is positive. Notably, compared to demand shocks,
8.1. INTRODUCTION

Chinese ownership has an overwhelmingly significant effect on Australian investment at the macroeconomic, industry and firm levels.

These principal estimations are in accordance with the discussed literature review and research framework, unveiling the main determinants of the dynamics of Australian mining investment, and the relationship between uncertainty and irreversible investment in the Australian mining industry. The Australian mining industry has unique features, which are not fully identified by the reviewed literature. These findings have some important implications that can also apply to other industry behaviour.

This research has led to several intriguing contributions. Firstly, it demonstrates empirical procedures to identify the main determinants of private investment, and examines the extent to which private investment is affected by these determinants. In these empirical estimations, the data set encompasses the macroeconomic, industry and firm levels during the period 1960–2012. Secondly, this study reviews historical changes in the Australian macroeconomy and the mining industry at both aggregated and disaggregated levels, reinforcing the understanding of relevant policies and firm operations. Thirdly, the period examined is split into 1960–2012 and 1990–2012, demonstrating the investment variation and structural changes in different periods. Fourthly, consistent variables at different levels clarify the relationships between the user cost of capital, export orientation, demand shocks, firm features, various uncertainties and private investment in Australia at those levels. Among them, interacted uncertainty combines with the aggregate and disaggregate variables, which helps to forecast their future behaviour. Some relationships are in accord with the literature, while others are not. These differences are interpreted by possible theories and practices.

Section 8.2 compares the findings in this study to the literature. Sections 8.3, 8.4, and 8.5 summarise the merits and disadvantages of this study, its implications, limitations, and possibilities for future research, respectively.
8.2 Conclusions

8.2.1 Macroeconomic Level Investment

The analysis of investment behaviour at the macro level sets up a general framework of research, and constructs an estimation model. In this analysis, two major issues help in identifying the main determinants of Australian macroeconomic investment. The first is the degree to which systematic uncertainty behaviour varies with different macroeconomic variables. The second is the degree to which the dynamics of macroeconomic investment are reflected by shifts in some main determinants. Given the degree to which systematic uncertainty and macroeconomic investment have interplayed, these two issues are below.

The uncertainty behaviour at the macroeconomic level shows that relatively low uncertainty is more likely to be observed in the Australian macroeconomy. Except for interest rate uncertainty and company income tax uncertainty, Australian investors are prone to investing more under relatively high uncertainty. This preliminary finding is at odds with that of Pattillo (1998), who found that high uncertainty raises the trigger level of investment, especially for irreversible investment. Next, this uncertainty-investment relationship is tested by a model in a broader context.

The difference in the uncertainty-investment relationship may lie in the examined target and the designed framework. The result of Pattillo (1998) is derived based on Ghanaian manufacturing firms for the years 1994–1995. The variables embodied in Pattillo (1998) are constructed in a different economic background to that in this study, and the selected time span is shorter. Moreover, Pattillo (1998) focuses on the firm level, examining different features.

The investment behaviour at the macroeconomic level shows a number of principal results. Firstly, the elasticity of macro investment with respect to changes in taxes and exchange rates is significant and positive over both 1990–2012 and 1969–2012. These estimates are not in line with the view of neoclassical economists in that the user cost is negatively related to investment (Price, 1995). Moreover, some
studies claim that a more open economy is more sensitive to changes in exchange
rates (Cavalcanti et al., 2012).

The distinct investment behaviour at the macroeconomic level in this study is closely linked with the economic conditions of the Australian mining industry. For example, the Australian mining industry contributed to considerable revenues and profits for the macroeconomy, especially during the period of the mining boom (Pham et al., 2013). As discussed when examining the income effect in Chapter 2, the rapid rise in tax and exchange rates was driven by strong growth in mining revenues, and thereby caused an increase in investment demand.

Secondly, although the coefficient for linear demand shocks was not significant, the regression at the macroeconomic level produced a significantly marginal effect of demand shocks to macroeconomic investment at –1.366 in the period 1969–2012. In contrast, when the period is shortened to 1990–2012, the marginal effect of demand shocks on macroeconomic investment was derived at 3.25. This suggests that under high levels of different uncertainties demand shocks in the short-run have a convex effect on macroeconomic investment, while in the long-run demand shocks have a concave effect.

This result is different to the findings of Bloom et al. (2007) for the UK manufacturing industry; they found that investment had a convex response to demand shocks, while it was supported by the description of macroeconomic uncertainty behaviour. This contradiction can be explained by the unique features of mining investment (Slade, 2013), because mining revenue is a main driver of the Australian economy. In particular, the capital intensity and long-time cost-recovery process in most mining production plays an important role in shaping the relationship between demand shocks and investment. As noted by Finch (2014), the increase in demand shocks in the mining industry is ahead of lagged production output. Therefore, demand uncertainty, which is a proxy for forward expected demand, may help in addressing the lagged response of production to demand shocks, and trigger or delay investment.
Thirdly, terms of trade uncertainty over 1990–2012 and 1969–2012 is shown to have a negative effect on investment, while uncertainty of Chinese GDP growth has a positive effect. It is noted that the negative effect of uncertainty variables on investment is observed in most literature (Bloom et al., 2007; Bond and Lombardi, 2006). This indicates that the Australian economy does not have the same response to all types of uncertainty. Hence, the positive association between uncertainty of Chinese GDP growth and investment, coupled with the negative association between terms of trade uncertainty and investment are observed. In this sense, uncertainty around China’s demand plays a leading role in the growth of Australian investment.

In short, Australian macroeconomic investment relies on the contribution of the mining industry. To a certain extent, capital intensity, export orientation, long-term cost or investment recovery, and expected Chinese economic growth are determinants of Australian macroeconomic investment behaviour. Noticeably, demand shocks under high uncertainty have a concave effect on macroeconomic investment.

### 8.2.2 Industry Investment

The analysis of investment behaviour at the industry level is instrumental in explaining the path of fostering investment, and connecting macro and microeconomic analyses. In theory, the industry analysis adds more information on the extent to which investment is affected at the disaggregated level, and illuminates the relationship between investment and various factors. In practice, the industry analysis provides evidence for which channels can be used to adjust investment behaviour. All these important issues are discussed below.

Across all industries in Australia, the mining industry has proven to have the highest value in investment, industry GDP, and exports, underscoring its significant role in the Australian economy. As described by the uncertainty behaviour, except for tax uncertainty, low uncertainty is more likely to occur in all industries. Except for demand uncertainty, mining investors have more incentive to invest under relatively high uncertainty. This pattern is consistent with that at the macroeconomic
8.2. CONCLUSIONS

level, confirming that more Australian macroeconomic investment under high uncertainty is highly underpinned by firms’ behaviour in the mining industry. The detailed investment behaviour at the macroeconomic level is rooted in the disaggregated level. Notably, the investment patterns over 1990–2012 and 1960–2012 are identical, and imply that the flow of resources across different industries is stable.

At the industry level, investment behaviour is shown to be different to that at the macroeconomic level. Firstly, significant coefficients of tax and export variations no longer exist. Compared with the macroeconomic level, the weak relationship between tax variation, export variation, and investment at the industry level may be attributed to joint effects across different industries.

The difference in investment behaviour across industries was also studied by Guimarães and Unteroberdoerster (2006), revealing that the effect of sales profitability on investment is sluggish across all sectors in Malaysia, although it is relatively strong and evident in the industrial sector. Due to the similar nature of the Australian mining industry, a more detailed analysis at the industry level is worthwhile.

Accordingly, in contrast to the macroeconomic level, the negative coefficient for nonlinear demand shocks at the industry level is insignificant, while that of linear demand is significant at 0.132. At the same time, the effect of demand uncertainty on the short-run investment response to demand shocks and the effect of demand uncertainty are not significant at the industry level. This shows that in terms of uncertainty behaviour at the industry level, the concave effect of demand shocks on investment is tempered. In this sense, long-run investment is more likely to be impeded by demand shocks under low uncertainty. A short-run relationship between demand shocks, high uncertainty and investment is not evident.

As shown, although the signs of demand shocks and demand uncertainty are consistent with those at the macroeconomic level, the degree to which they affect investment is reduced. The main characteristics in the mining industry, such as capital intensity, export orientation, and demand stimulus, are not dominant across
all industries.

The behaviour of tax uncertainty and interacted interest rate uncertainty with demand uncertainty have significantly positive coefficients at 9.684 and 3.141, respectively. These positive relationships are not aligned with those in Bloom et al. (2007) or Bond and Lombardi (2006), where uncertainty has a negative effect on investment. Intuitively, these positive behaviours are derived from the joint effects of different industries. In these industries, investment is sensitive to different types of uncertainty and has different responses, such as tax uncertainty, export uncertainty and demand uncertainty. More importantly, the use of interacted uncertainty bridges the gap between the effects of uncertainty at the aggregated and disaggregated levels.

To summarise, as a whole, across different industries the role of the mining industry in Australian investment is less dominant at the industry level than that at the macroeconomic level. This corresponds to the transfer effect highlighted in Chapter 2. The concave effect of demand shocks on investment is weak at the industry level. However, the effects of different uncertainties on investment are still strong.

### 8.2.3 Firm Level Investment

Although the investment analysis at the macroeconomic level reveals some dominant effects of the mining industry, these effects are mitigated at the industry level. It poses the question as to whether these dominant effects identified at the macroeconomic and industry levels are strengthened or reduced at the firm level. Indeed, the uncertainty and investment behaviour categorised by different firm features at the mining firm level are worth exploring as detailed below.

Mining investment at the firm level is grouped by firm size, firm age in 2012, market capitalisation, and Chinese ownership. These firm features correspond to capital intensity, long-term cost recovery, and expected Chinese economic growth, which are discussed in the macroeconomic analysis. In this sense, in terms of the
description of firm investment by different firm features, a large number of mining firms are observed in the group of firms with small size and small market capitalisation that have been operating for less than 5 years and have an average share of Chinese ownership. In contrast, except for the average share of Chinese ownership, a large volume of investment is observed in the group with large size, large market capitalisation, and over 20 years since establishment. These results suggest that with large production capacity, sufficient capital stock, long periods of operation, and stable foreign financing sources, mining firms tend to invest more. This finding also conforms with that of Slade (2013), where large projects and long completion times are pre-determinants of substantial investment in US copper mines.

As assessed by different uncertainty behaviour, almost all mining firms face more low uncertainty than high uncertainty. On the other hand, when facing demand uncertainty, large mining firms stand to gain more when investing under high uncertainty than under low uncertainty. This finding confirms the pattern at the macroeconomic and industry levels, suggesting that the positive relationship between demand uncertainty and investment is founded at the firm level.

With the addition of different firm features, investment behaviour regarding the user cost of capital is similar to that at the macroeconomic level. Firstly, the elasticity of investment with respect to tax expense variation is negative and significant at the firm level at \(-0.032\), while the coefficient for changes in exchange rate costs is positive at 0.018, suggesting that investment in mining firms is encouraged by changes in exchange rate costs. As explained in the macroeconomic analysis, even under high volatility in exchange rates, the mining boom provides abundant resources for the Australian economy, which has led to an increase in tax payments and mining investment. Furthermore, at the firm level the user cost of capital is negatively related to investment, which is consistent with the argument of the Neoclassical economists (Jorgenson, 1963).

Secondly, with the introduction of adjusted cash flow at the firm level, mining investment has a different response. In particular, the positive coefficient is signifi-
cantly marked by the adjusted cash flow at 0.022. The effect of adjusted cash flow on investment is in line with that in Yoon and Ratti (2011), who found that adjusted cash flow has a positive effect on investment. This suggests that with greater cash flow, Australian mining firms have more resources to undertake investment.

Thirdly, firm features exert different effects on mining investment at the firm level. More specifically, the estimation shows significantly negative elasticity of investment with regard to firm size at –0.106, while a positive and significant elasticity of investment with respect to market capitalisation and Chinese ownership is observed at 0.079 and 0.703, respectively. Although it is opposite to the expected sign in Table 4.1, the significantly negative coefficient for firm size supports the descriptive findings that the majority of observed investment in Australia is committed by small mining firms. Apart from these coefficients, the effect of firm age in 2012 on investment is not significant. These facts suggest that production capacity, capital intensity, and Chinese ownership play major roles in adjusting mining investment, which is in line with the analysis at the macroeconomic level. However, the effect of firm age on investment is not significant. As noted by Pattillo (1998), in the manufacturing industry firm features, such as firm size and firm age, rather than the mining features, influence investment decisions.

The different results for firm age can be explained by the sensitivity of different industries to demand shocks. Compared with the manufacturing industry, the mining industry is an upstream industry and has more concerns about future demand than the time taken to complete projects. Any changes in expected demand may result in large shifts in revenues and profits in the mining industry (Finch, 2014). Hence, the analysis of investment at the firm level has been growing in importance when accounting for the effects of demand shocks and demand uncertainty on investment.

With the introduction of firm features, the effects of demand shocks on investment at the firm level become insignificant. This relationship between demand shocks and investment is not witnessed at the macroeconomic and industry lev-
Moreover, the weakly nonlinear effect of demand shocks on investment at the industry level is also eliminated. This relationship is not supported by Neoclassical and Keynesian investment theories. This behaviour may be anchored in other determinants of the Australian mining industry.

However, the unique relationship between demand uncertainty and investment is identified at the firm level. Demand uncertainty seems to have a particularly negative effect on investment in the long run, while the effect of demand uncertainty on the short-run investment response to demand shocks is positive. This difference from most of the literature may lie in the Hartman-Abel effect (Carruth et al., 2000). As argued, in a competitive market, if the marginal product of capital is convex in price, an increase in price variance raises the expected return on the marginal product of capital and thus drives investment. This positive relationship may rely on mining firm features.

Unlike the positive effects of tax uncertainty and Chinese GDP uncertainty on investment at the macroeconomic and industry levels, the firm level analysis includes the significant negative effects of tax uncertainty and interacted Chinese GDP uncertainty on investment at \(-0.032\) and \(-0.573\), respectively. These negative relationships between uncertainty and investment are ascertained in Bloom et al. (2007) and Bond and Lombardi (2006). This is consistent with the explanation in Drakos and Goulas (2006), who found a negative relationship between uncertainty and investment, as uncertainty friction and disturbance increases at the firm level; for example, both aggregate demand uncertainty and idiosyncratic demand uncertainty, and other external and internal uncertainty.

After removing the effect of Chinese ownership, the relationship between demand shocks and investment is different. It is evident that the elasticity of investment with respect to long-run demand shocks is significantly positive at 0.088. Simultaneously, when other variables remain unchanged, the coefficient for interest rate uncertainty is significantly negative at \(-4.834\). These facts indicate that at the firm level long-run mining investment is promoted by long-run demand shocks under low uncertainty.
In addition, as revealed at the macroeconomic level, the profits of the Australian mining industry are affected by interest rate volatility.

The effect of Chinese ownership overtakes the effects of demand shocks, demand uncertainty, and changes in exchange rate costs on investment at the firm level. Since 2005, the Australian mining boom has been driven by industrialisation and urbanisation in China (Finch, 2014). Meanwhile, a large number of Chinese investors are engaged in the operation of Australian mining firms. Changes in the share of Chinese ownership in Australian mining firms may be the reason for the shift in demand shocks and forward expected demand.

In summary, Australian firm investment in the mining industry is highly affected by tax variations, cash flow, firm size, market capitalisation, Chinese ownership, and uncertainty of taxes, interest rates and Chinese GDP growth. Notably, the effect of Chinese ownership overshadows the effects of demand shocks and demand uncertainty on investment, and changes in exchange rate costs.

8.3 Theoretical Considerations

Investment analyses in this study explore and synthesise the development of investment theories. Neoclassical theory specifies the interest rate, user cost of capital and cash flow as key factors of investment behaviour. As shown by the outcomes of the macroeconomic analysis, investment behaviour is highly affected by the variation and uncertainties in tax and exchange rates, while at the industry level, tax uncertainty and interacted interest rate uncertainty are dominant. Concurrently, at the mining firm level, tax uncertainty and interacted interest rate uncertainty, coupled with cash flow are influential factors. It is noted that Australian private investment behaviour is partially explained by Neoclassical theory.

Keynesian theory emphasises the role of expected demand in determining investment behaviour. On the one hand, the role of expected demand is evident in the analysis of macroeconomic, industry, and firm investment, presenting both linear and nonlinear relationships between demand shocks and investment. Thus, Keynes’s
theory is important but does not give the full picture in interpreting Australian private investment behaviour.

The uncertainty theory, especially with regard to the real options theory, is closely related to this study. As examined by the uncertainty theory, uncertainty and irreversibility are the main determinants to investment adjustments. In this research, irreversibility is established as a premise of the empirical model it uses. Simultaneously, at the macroeconomic, industry, and firm levels, demand uncertainty, tax uncertainty, exchange rate uncertainty, and Chinese GDP growth uncertainty, have various relationships with investment. In this sense, Australian private investment behaviour is explained by a combination of Neoclassical theory, Keynes’s theory and uncertainty theory.

8.4 Policy Considerations

Due to the Asian financial crisis, the global financial crisis, and the European sovereign debt crisis, not only mining prices, but also mining investment are subject to large volatility in exchange rates, tax, and revenues. As emphasised by this research, various uncertainties in various factors can worsen expectations of future behaviour. Furthermore, this research proposes that some uncertainties at the firm level, such as interest rate uncertainty and Chinese GDP growth uncertainty, have a significant effect on investment. To mitigate future risks, policy makers and investors at the macroeconomic, industry, and firm levels should draw attention to reducing uncertainty and influencing market expectations. As discussed in Chapter 2, this policy consideration corresponds to reform in the exchange rate regime for shielding against foreign shocks, such as the introduction of the floating exchange rate in 1983. Also, value based mining taxes to increase government income, such as the Minerals Resource Rent Tax and the expanded Petroleum Resource Rent Tax have been implemented (Convey, 2012).

Similarly, policy in the short and long runs should be formulated to target different factors. As indicated by investment analyses in the periods 1990–2012 and
1969–2012, the relationship between macroeconomic investment and demand shocks is marked by different patterns. In particular, 1990–2012 displayed a convex relationship, while the relationship in 1969–2012 was concave. Therefore, short-term and long-run policy for demand and investment stimulus should be based on caution. Economic recovery after significant economic downturn cannot be accomplished immediately.

Growing Chinese demand has been an important driver of the development of the Australian economy and the mining industry. Notably, the 1990–2012 analyses at the macroeconomic and firm levels have demonstrated that Chinese GDP growth uncertainty and Chinese ownership affect investment to a large extent. Adjusting the investment cost more flexibly is a possible way to maintain Chinese-driven investment and the long-run interests of Chinese investors.

8.5 Limitations of the Study

This research employs multiple approaches to explain Australian private investment behaviour. Some of the selected variables raise the issue of endogeneity. To avoid this issue, unrelated proxy variables are chosen. For instance, interest rates are closely related to investment, while interest rate uncertainty is not a key element in investment theory. Thus, interest rate uncertainty is an appropriate variable for investment analysis.

To examine the effects of interest rate uncertainty and Chinese GDP growth uncertainty on investment at the macroeconomic, industry, and firm levels, interacted terms are applied to the analyses at the industry and firm levels. Therefore, interest rate uncertainty and Chinese GDP growth uncertainty interact with demand uncertainty, suggesting that they have an indirect impact on investment.

Although Tobin’s q theory is introduced in the literature review, the Tobin’s q ratio is not examined in this thesis. The exclusion of Tobin’s q in the investment model may lead to a lack of analysis of the financial market.

In addition, deriving the uncertainty variables for panel data is a key prob-
8.5. **LIMITATIONS OF THE STUDY**

lem in investment analysis. This study adopts the GARCH model to estimate the uncertainty variables for panel data. As discussed above, the GARCH model simultaneously constructs the mean and variance equations to eliminate serial correlation and heterogeneity across panel data. More importantly, the GARCH model directly obtains the conditional variance.

To examine the determinants of the dynamics of investment behaviour at the macroeconomic, industry, and firm levels, the augmented error correction model (ECM) is used. In the ECM of this study, assuming that investment is partially irreversible, the dependent variable is designated by the ratio of investment to capital stock. This dynamic model simultaneously captures the short-term and long-run effect of investment and relevant variables.

Although Australian investment analysis is examined across macroeconomic, industry, and firm levels, the presented variables represent only a small fraction of Australian investment behaviour in practice. Perhaps an extension to this work would be to test for foreign debt and financial markets at the macroeconomic level, and for the cost and revenue of firms’ research and development.

Furthermore, it should be noted that the time span for the selected variables at the macroeconomic, industry, and firm levels is not consistent, reducing the explanatory power for consistency. Due to the current unavailability of data (such as exchange rate and interest rate at industry and firm levels), especially for the limited number of observations in the macroeconomic analysis, future work may depend on a more complete information source or database.

As suggested by the investment estimation at the industry level, the relationship between uncertainty and industry investment is not significant because resources can be reallocated to other industries (such as from mining tax revenues). Therefore, this estimation may be extended to investigate how the expansion in the mining industry transmits its impact to other industries.

Lastly, this study primarily focuses on structural changes in the Australian economy and the mining industry, investigating the determinants of dynamic shifts
in investment levels in the short and long terms. Less attention in this study is
given to identifying the timing of investment and its relevant triggers, an aspect
that is emphasised in some theoretical papers. Thus, the timing of investment can
be explored through both theoretical and empirical work in the future.
Bibliography


Appendices
Appendix A

Number of Observations at the Firm Level

In Chapter 7, the reason for the number of observations changing from 8096 in Table 7.4 to 138 in Table 7.10 is data limitations. Data limitations are a big challenge for the empirical estimation in this study. As highlighted by Muris (2011), nearly 40% of all papers in four top empirical economic journals have a missing data issue. Abrevaya and Donald (2011) also argue that in a dataset an explanatory variable may be unavailable for large portions of the observational units, while a model is empirically estimated by observations with complete data. This method results in a much smaller sample size. As noted by Baum (2006), the GMM method ignores observations for which any of these variables has a missing value.

Table A.1 presents the number of observations in GMM estimations with and without firm features. As shown, the number of complete observations in GMM estimation without firm features is 600, while those in GMM estimation with firm features decrease. Especially for the addition of firm size (number of employees $\log emp_{it}$), the number of observations is 138. This is due to large portions of unavailability in number of employees, which is not mandatory accounting information disclosure in firm’s annual report.
Table A.1: Comparison of No. of Observations in Tables 7.9 and 7.10 GMM Estimations under Different Variable Combination

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<th>(I_{i,t}/K_{i,t-1})</th>
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Notes: