University of New South Wales
School of Economics

Honours Thesis

The Role of House Prices in the Monetary Transmission Mechanism within Australia

---

Author:
Kelvin Guo
Student ID: z3416799

Supervisor:
Assoc. Prof. Glenn Otto

Bachelor of Economics (Honours in Economics)

and

Bachelor of Commerce (Finance and Financial Economics)

28th October, 2016

Declaration

I declare this thesis is my own work and that, to the best of my knowledge, it contains no material that has been published or written by another person(s) except where due acknowledgement has been made. This thesis has not been submitted for award of any other degree or diploma at the University of New South Wales or at any other educational institution.

Kelvin Guo

28th October, 2016

Acknowledgements

First and foremost, I would like to gratefully thank my supervisor, Glenn Otto, for his guidance throughout this year. I am so thankful for the time you have taken out of your busy schedule to provide your expertise. Getting through the challenges in completing this thesis would not have been possible without your patience in assisting me with my questions and complex problems.

I would also like to thank my family for their support up to this point and always having my back. I thank my friends for continuously catching up with me on my progress. Thank you to Julia, for all her love and patience in putting up with my occassional rants and being there for me during times of hardship.

And, finally, I give thanks to the 2016 Honours cohort for all the laughter and banter we've had in our conversations which I will always remember and cherish. I'd like to especially thank Calvin, Jeff and Kai for their support through the rigorous coursework this year and giving advice on my thesis.

Contents

List of Figures

List of Tables

Abstract

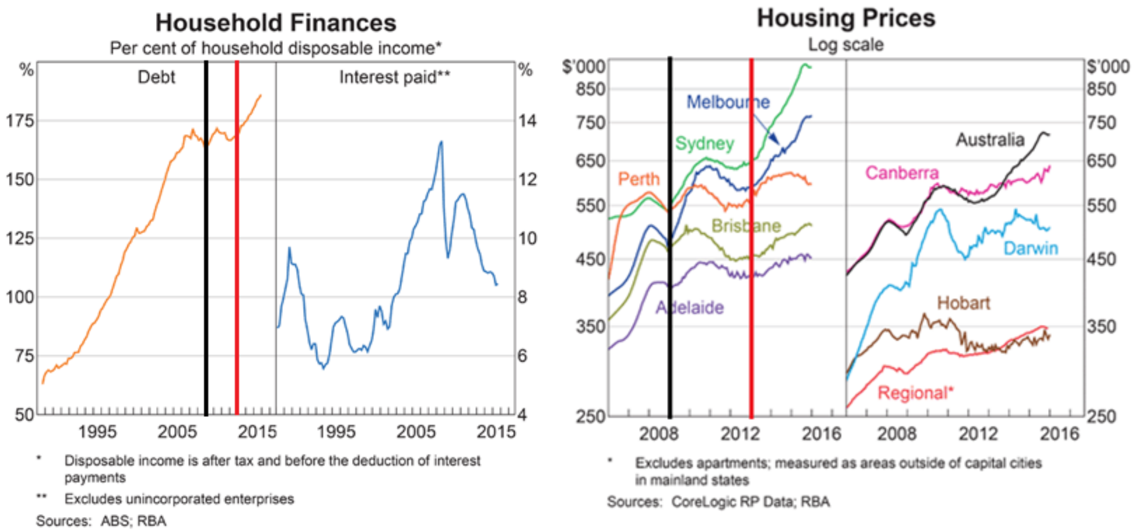
As of 2011, 67% of Australian households are homeowners and owning a house constitutes a large proportion of most households' net wealth. Along with rising house prices, the housing market is becoming more pervasive in influencing aggregate consumption and economic acitivity within Australia. Policy makers are placing more attention on the housing market as they become concernced of rising house prices leading to financial instability. I implement a structural vector autoregression using a benchmark model from Kim and Roubini (2000) to model Australian monetary policy transmission. I also investigate the significance of house prices in the monetary transmission mechanism within Australia and find falling house prices contribute to a substantial proportion of the fall in retail sales during contractionary monetary policy. I find most of the fall in retail sales is coming from credit-channel effects. This suggests house prices are having a considerable impact on aggregate output and monetary policy makers should factor this in when implementing monetary policy.

Chapter 1
Introduction

The housing market in Australia has become a major concern for policy makers, especially with growth of house prices in Australia nearly doubling in real terms between the years of 1991 and 2012 (Knoll, Schularick, and Steger, 2014). This has led to fears of decreasing housing affordability within the younger generation. This paper focuses on identifying the importance of the channels working through house prices within the monetary transmission mechanism, specifically the wealth effect channel and the credit effect channel. Monetary policy is known to affect macroeconomic development through many channels and these channels have been analysed in a multitude of studies (Bernanke, Blinder, et al., 1992; Bernanke and Gertler, 1995; Gerlach, Assenmacher-Wesche, et al., 2008). Most economists agree monetary policy has an influential role in the real economy but reaching an agreement on the channels that have the most significant effect on economic activity has yet to be settled. Studies investigating monetary transmission channels are vast. For instance, some studies have analysed the significance of the intertemporal substitution channel where movements in interest rates are commonly known to affect the trade-off between consumption and saving. Others have looked at the importance of the exchange rate channel which suggests increases in interest rates causes an appreciation in the exchange rate. This appreciation is expected to have an effect on domestic output due to changes in trade coming from decreases in exports and increases in imports (Cushman and Zha, 1997).

Figure (1.1) reveals a comparison between the movement of debt percentage to household income (on the left) and the movements of house prices for 5 Australian capital cities (on the right). For both graphs, the vertical black line corresponds to the year 2008 and the vertical red line corresponds to the year 2012. Visual comparison suggests the debt percentage moves in similar fashion to house prices between 2005-2015. Between 1990-2015, the level of debt within households exceeds the level of dispoasble income. Assuming both series are closely correlated, this proposes increase in the household debt percentage is coming from rises in house prices. It suggests average house price inflation has been exceeding the average growth of household income and implies a rise in credit-constrained households.

Figure 1.1: Graphs of Australian household debt and housing prices



Australia's housing market is sufficiently well-developed in connecting housing wealth with consumer spending. For credit-constrained homeowners, rises in house prices would aid in financing for higher consumer spending through home equity withdrawals or reverse mortgages. Thus, I use a structural vector autoregression (SVAR) methodology to determine the significance of house price movements on consumption within the overall monetary transmission mechanism. I use impulse responses to model the overall monetary transmission mechanism from a positve interest rate shock and calculate how much of the change in house prices is causing the response of retail sales from a interest rate shock. My results find that 17% - 25% of the fall in consumption after a contractionary monetary policy is due to decreasing house prices.

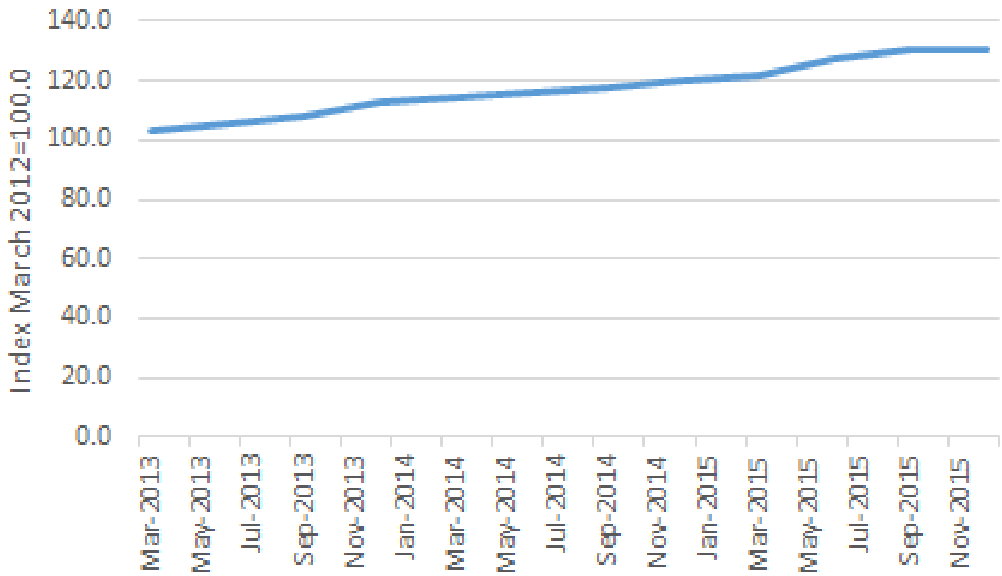
There are few studies that investigate the effect of Australian monetary policy on the economy, let alone analysing the role of house prices in the monetary transmission mechanism. Furthermore, there is a degree of uncertainty with regards to housing-related monetary policy where, aside from using current macroeconomic models, a certain level of judgement is still needed by monetary policy makers. I perform the first SVAR study that uses monthly data in Australia to contribute and provide insights into the workings of the monetary transmission mechanism and possibly help policy makers set appropriate policy instruments.

Chapter 2
The Australian housing market

2.1 Changes in the housing market

Over the past few decades, Australian communities have experienced several apparent demographic and economic changes but few have been as prevalent as the development of the Australian housing market. Especially since the start of the 21st century, Australian capital cities have experienced a sequence of booms, leading to a rapid increase in house prices (Figure 2.1). The past decade has shown the average annual growth rate of weighted average house prices in the 8 capital cities to be 6% per year. Australia's largest capital city, Sydney, has experienced annual house price growth of 15%, 12% and 14% in 2012-13, 2013-14 and 2014-15 respectively.

Figure 2.1: Weighted average house price index for all 8 eight capital cities



Source:ABS

Transitions in the distribution of housing wealth has also been prominent, driven by recent property price movements. Since 1971, the proportion of households being homeowners lowered by approximately 2% by 2011 while, at the same time, an increase in renters by 2% (Dufty-Jones and Rogers, 2015). The percentage of households that own an investment property has also been increasing where the Reserve Bank of Australia (RBA) determined the proportion was at 10.3% in the 2002 HILDA Survey and Kohler, Rossiter, et al. (2005) states it was about 17% in 2005. This amounts to an approximate 7% increase across 3 years. In addition, the RBA's 2015 'Submission to the inquiry into home ownership' showed the percentage of investment-specific housing loan approvals to all housing loan approvals increased from 10% to 40% between 2011-15.

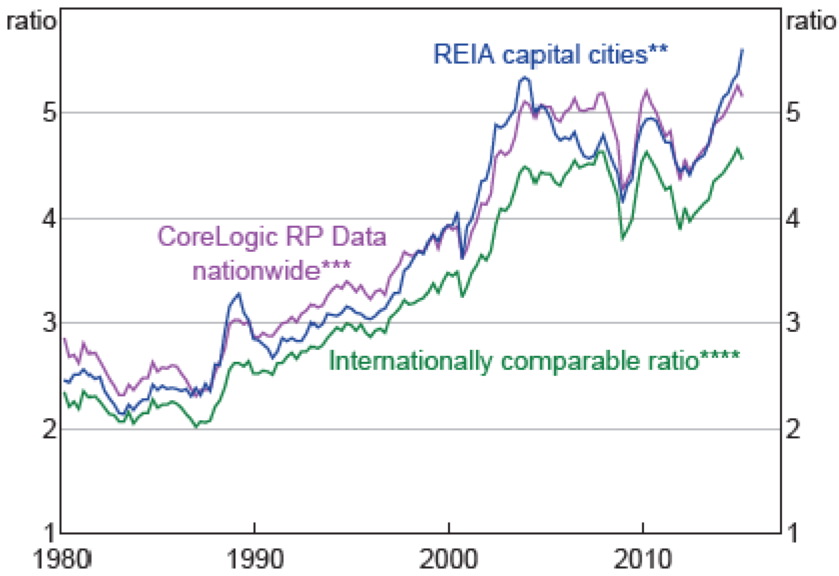
The proportion of the population in home ownership has been relatively stable over recent years but could exhibit significant changes in the coming years. Especially for younger households, renting in Australia is becoming an increasingly popular choice for permanent tenure rather than a temporary transition before heading into homeownership. The drivers that push people towards owning a home have weakened due to the shift in demographics within Australia. The average age in getting married or having kids is increasing and, on average, people have been spending longer periods in education which is detering or delaying the younger generation into making the transition towards home ownership.

2.2 Housing affordability

Another housing-related factor that has received considerable attention by Australian government policy has been the issue of declining housing affordability. Concerns have been raised on the issue of foreign investment into the Australian property market which is suspected to be causing an overvaluation of house prices in the Australian market. Rowley and Ong (2012) use a particular housing aforadability stress ratio for their analysis into the level of affordable housing within Australia. The housing affordability measure states a household is under affordability stress if it is having to use over 30% of its disposable income to pay for housing costs. Their results found a rise in housing affordability stress among households, increasing from 11% of all households in 2001 to 16% in 2010. This result can be consolidated with Figure 2.2 which shows an increase in the ratio of house prices to income over the past 20 years and provides a possible explanation into the decrease of homeownership among younger households.

Some ongoing changes in Australian society are suspected in increasing the systematic risk of low housing affordability. Decreases in married couples and increases in divorces would lead to an rise in single person households. Transition in the proportion of 'multiple income earner' households into 'single income earner'

Figure 2.2: Ratio of house prices to household income



* Ratio of dwelling price to average household disposable income; income is before the deduction of interest payments

** Excluding income of unincorporated enterprises; median dwelling prices

*** Excluding income of unincorporated enterprises; mean dwelling prices

**** Including income of unincorporated enterprises; mean dwelling prices

Sources: ABS; Core Logic RP Data; RBA; REIA

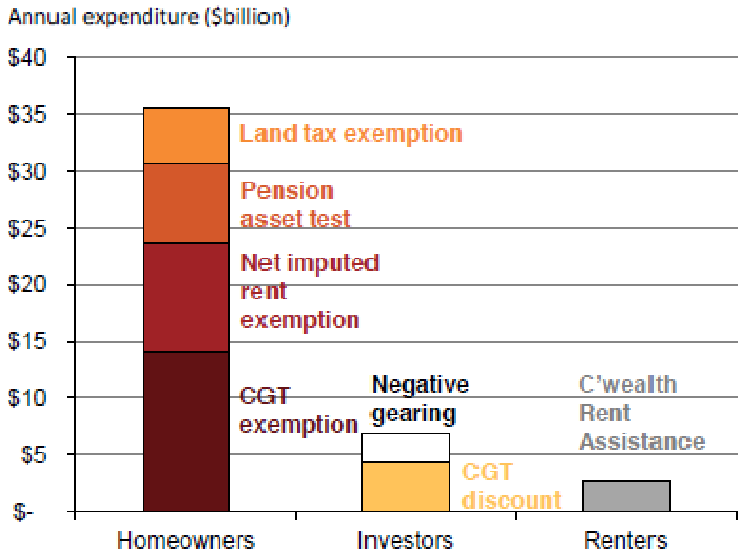
households would greatly increase the risk of housing costs becoming unaffordable. Single person households now make up almost one quarter of all Australian households compared to 14% in 1971 (Dufty-Jones and Rogers, 2015). The possibility of an ageing population in future years would augment the increase in single people households. Yates (2008) suggests there is a lack of housing which reflects the needs of smaller households, leading to a mismatch of housing desires and what is available in the housing market. This adds to the risk of housing unaffordability when households are unable to obtain the appropriate housing that can fulfill their needs in terms of housing size and costs.

These problems are a larger concern for households that are locked into a mortgage contract. Increases in affordability pressures among households would lead to more households suffering credit-constraints, especially when there are increases in interest rates. Furthermore, responses to the lack of housing affordability within major cities has caused a trend where people search for homes further away from the CBD where there is more affordable housing. Potentially, this increases risk of losing one's job or have access to jobs due to living in areas immensely far away from work or work opportunities. These inefficiencies could also lead to increased credit pressures among households. The more credit-constrained a household is, the more that changes in house prices would have an effect on the level of consumption within the household.

2.3 Housing policy

Over the years, the Australian government has placed a great deal of focus in implementing policies that promote homeownership and increase aggregate housing supply. However, there is a concern that government policies tend to favour towards homeowners and property investors over renters. For instance, homeowners don't need to pay capital gains tax on a sale of their primary residence and the First Home Owner's Boost, introduced in 2008 for New South Wales, assists first home buyer purchases by providing additional cash benefits. The focus towards policies promoting home ownership has worsened the inequality between homeowners and renters which has also been fueled by the lack of attention on the rental sector.

Figure 2.3: Annual government expenditure on housing policy



Source: Grattan Institute analysis of ABS (2013a) Survey of Income and Housing 2011-12
Note: The items in Figure 4.1 focus on annualised benefits. As the First Home Owners Grant is a one off payment, and is relatively small once annualised, it is not covered in this analysis. Estimates vary depending on assumptions and data sources. For consistency we use the Survey of Income and Housing 2011-12. See the Commonwealth Treasury Tax Expenditure Statement and individual state budget papers for alternative measures of tax expenditures.

In Figure (2.3), the Grattan Institute calculated the level of government policy expenditure on home owners to be approximately $36 billion per year while expenditure on renters is calculated to be less than $5 billion per year (Kelly, Hunter, Harrison, and Donegan, 2013). This lack of reform has left policies that target the rental sector to lag behind the dynamic market and social trends in the

21st century where renting is becoming more of a long-term choice rather than a flexible provisional choice.

Policies that incentivise homeownership may push some households to make the move to become home owners even though it may be an unwise decision, leading to increased stress on meeting credit and debt deadlines. There are also greater risks making the transition to homeownership if the household is not financially insured for unfavourable economic changes. Factors that disadvantage credit-constrained homeowners could be rises in the interest rate, loss of employment or devaluation of house prices. These factors would tighten household finances and lead to greater credit constriants within households.

Given these factors, there are potential rises in the proportion of Australian credit-constrained households and also continuing pressures on the real estate market caused by greater housing demand, both domestically and internationally. Asia-Pacific countries are showing rises in their speed of growth within their economies due to stronger links with the Chinese market. China has predominantly been the leading country influencing the rapid increase for approved foreign investment in the real estate market but this could start to amplify as other Asian-Pacific countries increase their exposure in Australian property markets. Looking at how domestic economic activity and output is impacted by changes in the housing market can challenge the government to look at the importance of regulating the property development and real estate market.

Chapter 3
Literature Review

3.1 Monetary policy and its effects

Monetary policy is a process by which the central bank controls the money supply of the economy in order to maintain price stability and other economic variables. The magnitude to which monetary policy affects certain macroeconomic variables and how it transmits its effect onto the economy has been an ongoing controversial issue among economists. There have been many studies into the identification of monetary policy transmission that model in-sample forecast responses of macroeconomic variables from major shifts in monetary policy that are exogenous from the movement of other economic disturbances (Romer and Romer, 1989; Sims and Zha, 2006).

The interest rate is considered to be a reasonable instrument by most economists in implementing monetary policy. Bernanke et al. (1992) uses the Federal funds rate as an instrument for monetary policy in the US and shows it is useful in predicting the changes in economic activity. They argue the Federal Reserve, historically, conducted policy changes predominantly through the Federal funds rate (FFR) and discovered that it was more statistically significant in predicting macroeconomic variables than other interest rates and monetary aggregates. Bernanke et al. (1992) finds the FFR is very sensitive to shocks in the US inflation rate and unemployment rate and, specifically, finds the FFR falls when there is a positive inflation rate shock while increasing when there is a positive unemployment rate shock. These findings also coincide with economic theory on the effects of monetary policy. Similarly, Brischetto, Voss, et al. (1999) use the overnight interbank cash rate as an instrument for monetary policy when investigating Australian monetary policy.

Traditional theory on the effect of monetary policy suggests increases in interest rates would push up the cost of capital and lead to lower consumer investment in durables or housing. The decrease in aggregate demand would reduce the inflation rate as well as output. Gerlach and Smets (1995) investigate this effect in the G-7 countries and their results show a one standard deviation shock on interest rates ledd to a fall in consumer prices among all countries. They also find a 0.2%-0.4% decrease in output response among all countries, except for Japan[1]. Gerlach and Smets (1995) also discuss that slight discrepancies in the timings of consumer price responses between countries are due to differences in the structure of each country's exchange rate system. Brischetto et al. (1999) model the effects of Australian monetary policy on the domestic economy by using a SVAR. They attempt to identify the contemporanous relationship between variables by using economic intuition on the features of a small open economy but find counter-intuitive results in their impulse responses. However, Brischetto et al. (1999) impose further restrictions on their model and find that a contractionary monetary policy follows with an approximately 0.2% fall in domestic output and price level.

3.2 The transmission channels of monetary policy

Monetary policy transmission has many channels through which it can affect the economy and has brought about various theories on the workings of monetary policy. The following is a summary by Mishkin (1996) and Bernanke and Gertler (1995) on some of the major theories and channels by which monetary policy can work through.

3.2.1 Intertemporal substitution channel

Noteably, the intertemporal substitution channel is the most straightforward and main channel by which monetary policy can affect key components of the economy. The intertemporal substitution channel relies on the preferences of consumers to choose between saving or consuming. For instance, a rise in interest rates causes consumers and businesses to become more inclined to invest in assets, such as bonds, in order to obtain greater returns in the future rather than use their wealth to fulfill current consumption. Mishkin (1996) notes that the long-term real interest rate is viewed to having the greatest effect on spending decisions. But central banks can have an influence on consumer expenditure through monetary policy decisions, despite monetary policy only being able to control for short-term interest rates. This is because the expectation hypothesis for the term structure of interest rates suggests the long-term interest rate is actually derived from the expected values of future short-term interest rates.

[1] A one standard deviation shock varies between countries. Among most countries, the interest rate shock ranged around a 60-100 basis point shock.

3.2.2 Exchange rate channel

The next well-known channel for monetary policy transmission is the exchange rate channel. Under flexible exchange rates, this channel works through changes in net exports in affecting aggregate output within an open economy. This channel is fundamentally based on the interest rate parity theory. If domestic interest rates were to decrease, foreign deposits would become more desirable relative to domestic deposits. Thus, the domestic currency will depreciate due to greater demand for foreign currency and lower demand for domestic currency. A depreciation in domestic currency causes an upsurge in demand for domestic goods which leads to a rise in exports and lowering in imports. Several studies have investigated the exchange rate channel to improve our understanding on the effects of monetary policy on the economy. Eichanbaum and Charles (1995) interprets exchange rate movements using three measures of monetary policy shocks; the Federal Funds rate, ratio of nonborrowed to total reserves and the Romer and Romer (1989) index which uses a historical narrative to identify periods of contractionary monetary policy. The results find evidence of US contractionary monetary policy having a significant effect towards the appreciation of domestic exchange rates for all three monetary policy shocks.

3.2.3 Credit channel

Monetary policy transmission through credit effects involves channels that arise from the information asymmetries between lenders and borrowers. Bernanke and Gertler (1995) state that the effects of monetary policy is augmented by the credit channel through changes in the *external finance premium*. The external finance premium is the difference between a borrower's cost of funds acquired from outside sources (securities and bonds) to cost of funds coming from personal wealth and retained earnings. The bank lending channel is a channel that can have an effect on the external finance premium through shifts in the quantitiy of loans available from banks. This is based off monetary policy being able to change the money supply through changing bank reserves and deposits. For instance, this can be performed by open market trading by the Federal Reserve or quantitative easing. Increasing bank reserves and deposits will motivate banks to increase the amount of loans available and become more lenient on their lending regulations. This would reduce the borrower's cost of funds and, ultimately, reduce the external finance premium, inducing greater investment and consumer spending. However, there are doubts whether this channel is having significant effect on banks within the 21st century due to the relaxation of regulatory barriers for banks to raise funds.

A more prominent credit channel is the balance sheet channel. This channel uses the fact that a borrower's financial position influences the external finance premium that the lender should be compensated for (Bernanke and Gertler, 1995). Borrowers that exhibit a lack of personal wealth suggest a greater risk in defaulting. This would result in greater costs of borrowing due to banks accounting for moral hazard effects. Thus, the financial position of borrowers determines how significant the impact of monetary policy movements can have on consumers and businesses. Increasing the interest rate can directly increase interest expenses for borrowers that already have debt outstanding and are under a variable interest rate. This reduces personal wealth at the consumer level and net cash flows at the business level, both of which depresses a borrowers financial position, leading to banks increasing the cost of borrowing.

3.3 Relationship between the housing market and monetary policy

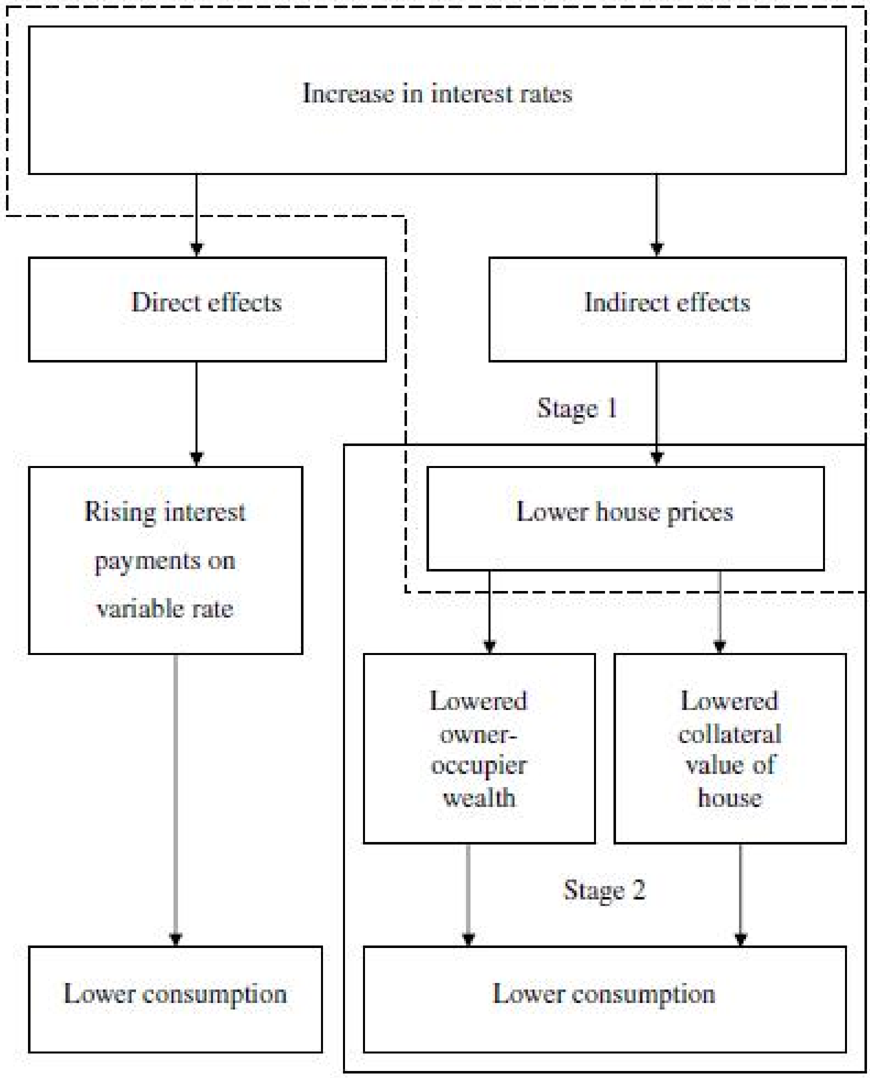
This section discusses literature and research that consider the effect of monetary policy on asset prices, particularly housing prices, and how these factors affect consumption and output. Figure (3.1) provides a good overview of the monetary transmission mechanism through the housing market.

3.3.1 The effect of monetary policy on house prices

In order for monetary policy to have a significant effect on house prices, interest rates should either affect the supply of housing or demand for housing (or both). On the supply side, Mishkin (2007) suggests that, over the years, amount of housing construction has become more dependent on short-term interest rates rather than long-term rates. This is due to improvements in the technology for construction work which has decreased the time it takes for buildings to be completely constructed and makes short-term debt more sought after. As a result, rising short-term interest rates would increase the cost of taking up new construction and decrease the net present value (NPV) of housing projects, causing a reduction in housing construction activity.

On the demand side, modern models for housing demand view the user cost of housing capital as an essential aspect in determining demand for housing (DiPasquale and Wheaton, 1994). The user cost of capital formula, uc, is as follows:

Figure 3.1: Direct and indirect housing market channels in the monetary transmission mechanism



Source:Elbourne (2008)

$$uc = p[(1-t)i - (\pi_h - \pi_i) + \delta]$$

p is the price of the house, i is the interest rate on mortgage debt, t is the marginal tax rate on property, π_h is the expected rate of appreciation of housing, π_i is expected inflation and δ is the depreciation rate. The equation for user cost of housing capital specifies interest rates are negatively related to housing demand. An increase in long-term interest rates will increase the level of mortgage debt payments which is associated with the costs of buying a house (Elbourne, 2008). Since short-term interest rate are relavant in interpreting long-term interest rates, tightening of monetary policy decreases demand for housing which pushes down house prices. Elbourne (2008) estimated the dynamics of the UK economy by observing the response of the UK housing market from monetary policy shocks and found an immediate house price decrease of 0.5% after a 100 basis point positive shock on the interbank rate.

3.3.2 The effect of house prices on consumption

There are both direct and indirect effects that take part in the monetary policy transmission through the housing market. The direct effect is known as the cash flow effect and, in the context of the housing market, is specific towards affecting existing borrowers that have a mortgage under a variable interest rate. This channel can be followed along on the left side of Figure (3.1). When monetary policy increases the official interest rate, this translates to a rise in mortgage interest rates that banks charge towards consumers. As a result, the discounted future debt outstanding increases and this lowers household disposable income.

On the other hand, the wealth effect and the credit channel effect are shown on the right side of Figure (3.1). According to the life-cycle hypothesis by Ando and Modigliani (1963), an increase in asset wealth should have a positive effect on household consumption since the long-run marginal propensity to consume out of wealth is larger than the real interest rate. Hence, an increase in house prices would be considered as an increase in asset wealth and should increase household consumption . One argument put forward is consumption responds more elastically to changes in housing wealth than compared to other assets. This is because housing wealth has a more even spread among the population unlike other assets, such as stocks. Belsky (2004) mentions that, in 2001, one-third of the total US stock market wealth was held by 1% of shareholders while only one-eighth of the US housing market wealth was held by the top 1% of homeowners. However, the view that housing wealth has a significant direct effect on household consumption has been challenged. For instance, bequest motives suggests that housing wealth may only have small effects on consumption since homeowners may wish to bequest and pass on their home to their children when they die (Mishkin, 2007). These type of homeowners would experience an increase in the cost of living when increases in house prices occur due to rises in the cost of housing services.

On the other hand, the credit channel effect through house prices generally finds more economically significant results and these results have been explained by several theories, such as the financial accelerator and the flight-to-safety within the lender-borrower relationship. Bernanke, Gertler, and Gilchrist (1994) finds the financial accelerator theory explains the reason for the puzzling large cycle changes in investment spending and output that ensue from small shocks on macroeconomic variables within the economy and this can be illustrated using housing wealth as an example. When there is a decrease in house prices, the asset wealth of the homeowner reduces and this increases the external finance premium since lenders will increase the cost of borrowing to compensate for adverse selection. This usually results in a flight-to-safety away from low net worth borrowers by implementing higher barriers to borrowing through either lower credit limits, higher collateral requirements or higher interest rates. If housing wealth contributes to the majority of a household's total net worth, the credit-channel effect would be larger and, ultimately, consumer spending will lower due to higher restrictions to credit.

Chapter 4
Data

I use 8 variables in my model; these are commodity prices, US FFR, retail sales, inflation rate, mortgage debt, interest rate, exchange rate and house price index (HPI). All data is logged except for the FFR, inflation rate and interest rate which kept at their percentage level. The data is also seasonally adjusted.

4.1 Data characteristics

The frequency of my data is monthly, ranging between 01/1996-12/2015, and totals to 240 observations. Considering the scope of this research field, the number of variables appear to be insufficient in spanning the information sets followed by monetary policy makers; central banks are known to follow hundreds of data sets when making policy decisions (Bernanke, Boivin, and Eliasz, 2004). However, Cushman and Zha (1997) use a similar set of variables and find these variables capture the sufficient and essential features of a more appropriate and larger dimensioned open economy model. In addition, fewer variables within a VAR model greatly conserves the degrees of freedom as an additional variable exponentially increase the degrees of freedom. I am limited to 240 observations due to data restrictions[1] so conserving degrees of freedom in this study is especially important to provide statisical power in my estimations.

The estimation of the model is done in levels and involves the aggregate population of Australia. Data for the HPI and retail sales series are sourced from the Australian Bureau of Statistics (ABS). Data for the commodity price index, interest rate, exchange rate, inflation rate and mortgage debt are sourced from the RBA statistics website while the US FFR is obtained from the Federal Reserve Economic Data online database. Further information on the 8 data series can be found in Appendix A and B.

The inflation rate is the year-ended inflation rate and is calculated by compounding the values of the previous 4 quarters of inflation. The inflation data excludes interest

[1]The data series that restricts my sample to 01/1996 is the related series I use to interpolate a monthly house price index.

and tax changes that occurred during the quarters in 1999-2000, accounting for the introduction of the Goods and Servces Tax. The house price index is the index for established houses in all 8 capital cities in Australia. The ABS constructed a new house price index that backdates to 2002 due to a improved methodology for stratification. Fortunately, the ABS maintained the older series and so I combine the older index with the new index to construct the required sample size. I calculate the growth rates of the older index between 1996-2002 and use these to backdate HPI values using the first value of the new house price index index as a starting point. However, the inflation rate and house price index are reported in quarterly frequencies which does not align with the monthly data that I need. I address this issue by using an interpolation method with a related series to generate the necessary monthly observations and a detailed explanation of this method is provided later in this section.

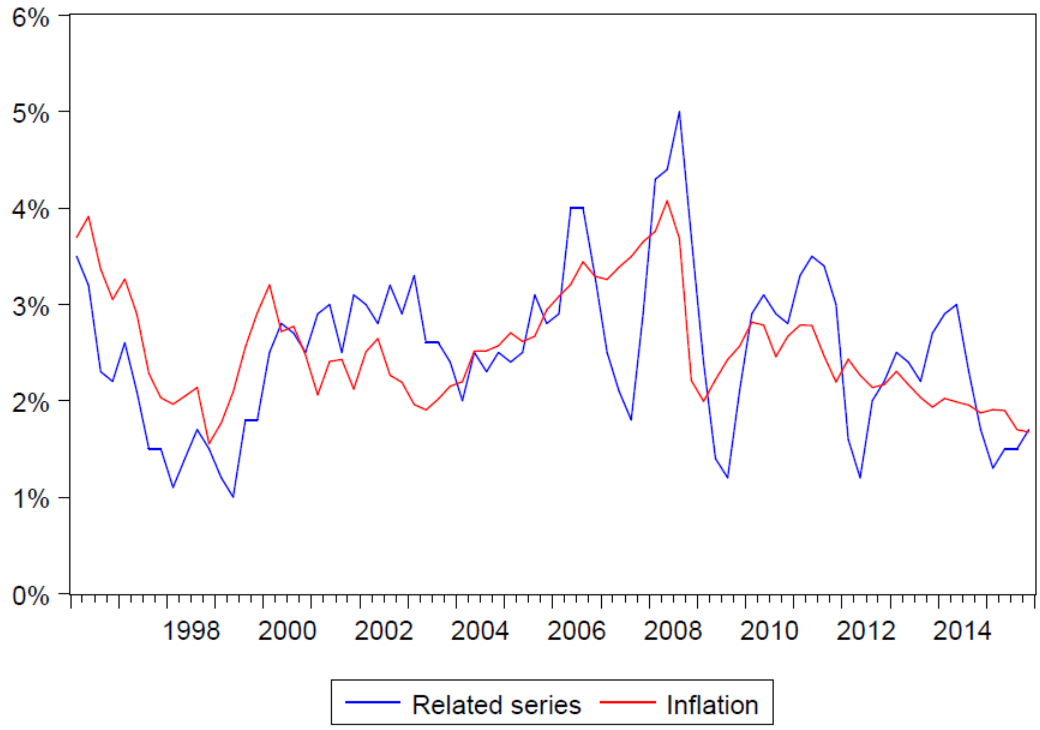
The commodity price is reported as an index of all commodity prices with the base year in 2013/14. The index is denominated in AUD and is calculated as a monthly weighted average. The interest rate is the interbank overnight cash rate and is the instrument for monetary policy in the model. Similarly, the FFR is an effective interest rate and the central instrument for monetary policy in the US. Retail sales is used as a measure of consumption for my model and reflects the total sum of the retail turnover value among major sectors in the retail industry. The exchange rate is the trade-weighted exchange rate index. Lastly, the mortgage debt is the sum of the loans outstanding to individuals for the purchase of owner-occupied housing, investor housing and land for the construction of housing.

4.2 Constructing a monthly series using a related series

Using a related series to interpolate monthly observations for the inflation rate and HPI provides more economic richness than using no related series. Cuche and Hess (2000) argue that when interpolation is based solely on the series being interpolated, it makes questionable assumptions on the stochastic process of the series.

To interpolate the inflation rate, I construct a related series using theory on the relationship between interest rates and inflation rates put forward by the Fisher effect. Cooray et al. (2002) review of Fisher's literature explains that the nominal interest rate can be decomposed into a sum of two parts; a real interest rate and an inflation premium. The market of Australian Treasury securities provides a way to obtain close approximations of the nominal and real interest rates. The yield of a

Figure 4.1: Comparison between inflation rate and related series



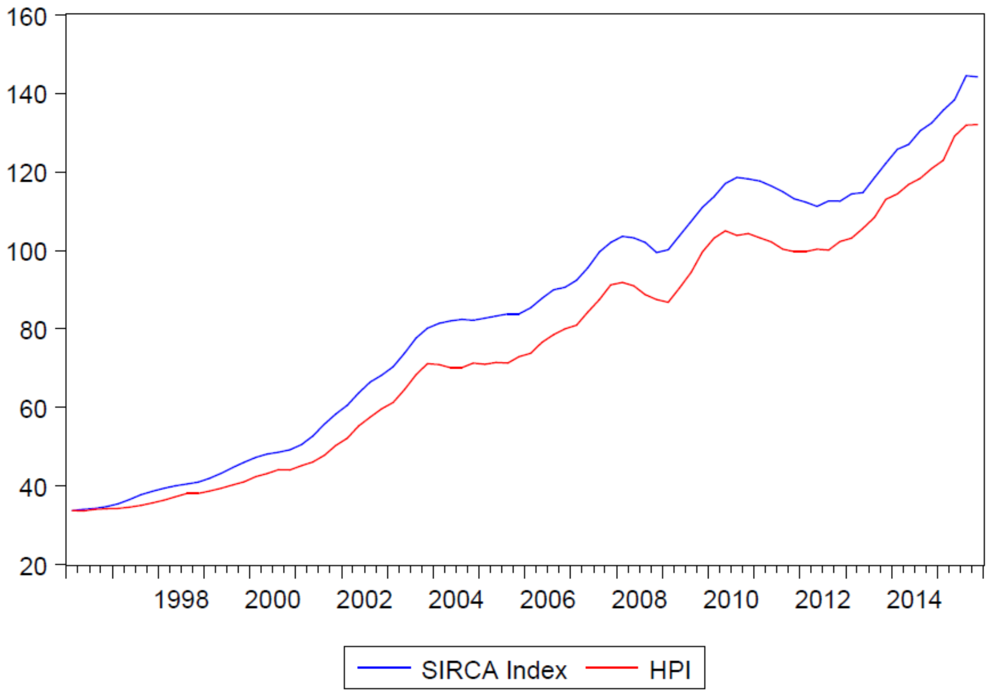
government indexed[2] bond pays an interest the represents that real yield while the yield of a 10-year maturity government bond provides a close measure of the nominal interest rate. Taking the difference between these two yields gives a measure of the bond markets expected inflation rate. Fortunately, these yields can be obtained in monthly frequencies from the RBA. A visual comparison also show similar timings in spikes and dips between the actual inflation rate and the related series[3], suggesting this related series is an appropriate choice for my interpolation (Figure 4.1).

The related series I use in constructing a monthly HPI data is the SIRCA's Daily Home Value Index, sourced from SIRCA's CoreLogic RP database. This index is estimated using a 'hedonic imputation' methodology which accounts for the observed characteristics of properties, such as number of bedrooms, into its analysis of house price movements. Growth measurements of the index are calculated by average price changes in repeated sales across three housing types; these are houses, units and combined dwellings. The index numbers are updated daily for all capital cities and releases a monthly aggregate composite index of all 8 capital cities in Australia at the last calendar day of every month. I use the aggregate composite index as a related series. Figure (4.2) shows the comparison of the SIRCA index and the HPI.

[2]The bond is indexed to the Australian consumer price index

[3]In Figure (4.1), I average the monthly related series into quarterly values for comparison purposes.

Figure 4.2: Comparison between the HPI and related series



Making it easier for comparison, I adjust the starting value of the SIRCA index to the starting HPI index value and I find similar movements in the trend and patterns between both series. This suggests the SIRCA index is an appropriate related series to use for interpolation on the HPI.

I use the Chow-Lin procedure, described by Cuche and Hess (2000), to interpolate my existing quarterly observations and generate a monthly series for inflation rate and HPI. I make two assumptions when implementing this procedure. From Equation (4.1), I assume the estimated monthly observations, Y, for the HPI and inflation rate are described by a linear regression on the monthly related series, X. Second, I assume the retrieved quarterly series, Y^+, and quarterly related series, X^+, have the same linear relationship at the quarterly level as shown in Equation (4.2).

$$Y = X\beta + u \tag{4.1}$$

$$Y^+ = X^+\beta + u^+ \tag{4.2}$$

I perform an ordinary least squares (OLS) regression for Equation (4.2), where the dependent variable, Y^+, is the series to be interpolated. The quarterly related series, X^+, is created by converting the monthly related series into the same frequency as the data that is being interpolated. I take the average of every three consecutive monthly observations to generate a quarterly related series. Based on previous assumptions, the β in Equation (4.2) should be the same estimator for the linear equation of the monthly variables in Equation (4.1). However, I find evidence of autocorrelation in the OLS residuals for the house price index and inflation rate regression, shown in Appendix C. Thus, I account for the serial correlation by instead estimating a generalised least squares (GLS) method for the house price index and inflation rate regression (Equation 4.3). Since the errors from a straightforward OLS are not independently and identically distributed, the variance-covariance matrix, Ω, of the error, u, is not diagonal (Equation 4.4). To implement the GLS estimation requires the original OLS to be transformed by multiplying with a non-singular matrix, C. This variance of Cu is the new error term which corrects the error variance into a diagonal matrix[4] in order to produce an efficient coefficient estimate, β_{GLS} (Equation 4.5). Shown below, Y is the series being interpolated and X is the related series.

$$CY = C\beta_0 + CX\beta_1 + Cu \tag{4.3}$$

$$Var(u) = \Omega \tag{4.4}$$

$$\beta_{GLS} = [X'\Omega^{-1}X]^{-1}X\Omega^{-1}Y \tag{4.5}$$

I need to obtain a consistent estimate of Ω to estimate β_{GLS}. I run an OLS of Y on X and obtain the fitted OLS residuals, $\hat{u}$. I assume an autoregression of order one on the fitted residuals to account for the auto-correlation (Equation 4.7). Obtaining the variance-covariance matrix of $\hat{u}_t$ by OLS estimation of (4.7) is equivalent to obtaining Ω (Equation 4.8).

$$Y = \hat{\beta}_0 + X\hat{\beta}_1 + \hat{u} \tag{4.6}$$

$$\hat{u}_t = \hat{\rho}\hat{u}_{t-1} + \epsilon_t \tag{4.7}$$

$$\Omega = \frac{\sigma_\epsilon^2}{1-\rho^2}\begin{bmatrix} 1 & \rho & \cdots & \rho^{T-1} \\ \rho & 1 & \cdots & \rho^{T-1} \\ \vdots & \vdots & \ddots & \vdots \\ \rho^{T-1} & \rho^{T-2} & \cdots & 1 \end{bmatrix} \tag{4.8}$$

[4]Appendix D shows how the error term is adjusted so that the variance of the errors is orthogonal.

In practice, estimation of β_{GLS} is performed by using the estimator of the AR(1) regression, $\hat{\rho}$, to adjust the Y and X specifically, shown in Equation (4.9) to (4.12) which is shown in terms of y and x.

For $t = 1$

$$Cx_1 = (1 - \hat{\rho}^2)^{\frac{1}{2}} x_1 \tag{4.9}$$

$$Cy_1 = (1 - \hat{\rho}^2)^{\frac{1}{2}} y_1 \tag{4.10}$$

For $t \geq 2$

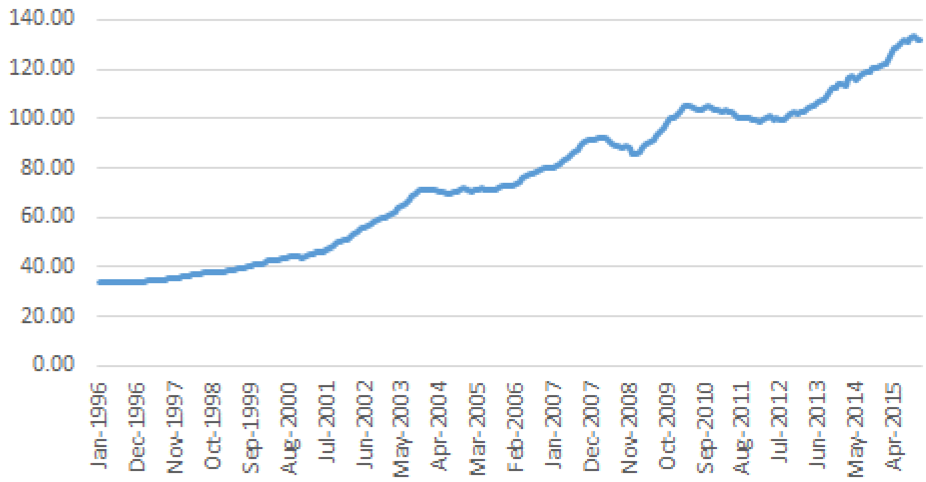
$$Cx_t = (1 - \hat{\rho}) x_t \tag{4.11}$$

$$Cy_t = (1 - \hat{\rho}) y_t \tag{4.12}$$

Thus, I obtain a coefficient estimator and a series of residuals to assist in constructing the monthly data. I produce my monthly data by multiplying the GLS estimator with the monthly related series. Adding on the residuals ensures the monthly values sum up to the quarterly observations. However, the GLS residuals come from a quarterly regression and needs to be distributed into the monthly estimates. The distribution of the residuals is done according to the weighting matrix which is the inverse of the variance-covariance matrix, Ω. Figure (4.3) and (4.4) shows the final estimates of the monthly HPI and inflation rate. I find the peaks and dips of both estimated monthly series move in a similar fashion to the actual series.

Figure 4.3: Constructed monthly inflation rate

Figure 4.4: Constructed monthly HPI



4.3 Integration and cointegration

Before running my model, an important matter to address is the possibility for integration and cointegration in the variables. Implementing VARs when variables are not covariance-stationary could lead to problems with spurious regressions and standard inferences, such as non-standard asymptotic distributions and differing limiting representations of the t-statistic (Sims, Stock, and Watson, 1990). To account for these issues, a series with a unit root, I(1), can be differenced before running a VAR on the transformed data. In addition, Engle and Granger (1987) raise the idea that two I(1) series can form some linear combination such that it produces an I(0) process which is covariance stationary. Regressions accounting for cointegration provide more optimal estimates than differencing due to signs of integration. Table (4.1) displays the augmented Dickey-Fuller (ADF) and Kwiatkowski Phillips Schmidt Shin (KPSS) tests which check for integration and stationarity in my variables. I find that commodity prices, FFR, retail sales, exchange rate and the house price index are of I(1). Test statistics on the inflation rate indicate it is stationary. Further tests by second differencing indicates mortgage debt is I(2).

I test the cointegration between variables using the Johansen cointegration test. The Johansen cointegration test uses quasi maximum likelihood estimates to obtain eigenvalues of Π from the transformed VAR equation (Equation 4.1). Johansen proposes two likelihood ratio tests to test for the rank of Π matrix with nonstandard distributions. These are the trace test and maximum eigenvalue test. I carry out

Table 4.1: Integration and stationarity tests

Series	ADF test	KPSS
	Test stat	Test stat
log(commodity)	-1.83681	1.574629***
dlog(commodity)	-8.315742***	0.116714
FFR	-2.27234	0.866223***
dFFR	-3.563062***	0.188473
log(retail)	-0.55044	0.427522***
dlog(retail)	-6.35929***	0.340862
Inflation	-4.231132***	0.151917
dInflation	-8.422711***	0.040676*
log(mortgage)	0.105365	0.469434***
dlog(mortgage)	-2.4769	1.344742***
Interest	-2.18992	1.043756***
dInterest	-6.097308***	0.062359**
log(exchange)	-1.76383	1.409675***
dlog(exchange)	-14.3187***	0.079096**
log(HPI)	-1.50152	0.373907***
dlog(HPI)	-4.190972***	0.144929

*** p<0.01, ** p<0.05, * p<0.1

Note: The 'd' in front of each variable indicates it is first differenced. The ADF and KPSS test for retail sales, mortgage debt and house prices include a time trend and constant. The rest include only a constant. The 5% critical values for the ADF tests are -0.287 and -0.343 for the test equation with a constant and the test equation with a constant and time trend respectively. The 5% critical values for the KPSS tests are 0.463 and 0.146 respectively in the same order.

the trace test and determine the cointegration rank for my set of variables (Table 4.2). I use 2 lags in the Johansen test which is determined by choosing the lowest SIC from running VARs of differing lags with the set of variables. The trace test indicates there are 4 cointegrating equations at the 5% level.

$$\Delta Y_t = \phi_0 + \Pi Y_{t-1} + \sum_{j=1}^{p-1} \phi_j^* \Delta Y_{t-j} + e_t \tag{4.13}$$

The test statistics suggest there are unit roots and cointegration between variables which should be addressed by either running a VAR with cointegration and integration operators imposed on the variables or using a multivariate VECM specification. Running a VAR in levels when there is presence of cointegration produces inconsistencies in impulse responses over long-run horizons. However, transforming the data can potentially lead to making incorrect identification restrictions to the model. Thus, I decide to estimate my model in levels; making a trade-off for loss of estimation efficiency with minimising the risk of a mis-specifed model. Faust and Leeper (1997) suggest that running VARs in levels and focusing

Table 4.2: Johansen test

	With intercept		With intercept and trend	
Cointegrating equations	Trace Statistic	Prob	Trace Statistic	Prob
None	237.4832	0*	289.2715	0*
At most 1	161.8227	0.0001*	208.8295	0*
At most 2	112.0202	0.0024*	136.4864	0.0019*
At most 3	74.19051	0.0214*	97.89693	0.0094*
At most 4	42.54101	0.1441	62.98131	0.0593
At most 5	25.26885	0.152	31.33772	0.4249
At most 6	1.04E+01	0.2528	16.38571	0.462
At most 7	1.373962	0.2411	7.170034	0.3271

* denotes rejection of the hypothesis at the 5% level using Mackinnon-Haug-Michelis (1999) p-values.

on short-run responses is a safer approach than potentially making mistakes in the specification of cointegration relationships. I should still be able to produce consistent estimates for my VAR parameters despite any cointegration that may be present (Elbourne, 2008).

Chapter 5
Model and methodology

5.1 Vector autoregression models

A vector autoregression (VAR) is a system of endogenous variables that are functions of lagged values of all the endogenous variables and is a useful tool for making forecasts and policy analysis. The motivation behind using VARs is that many macroecnomics variables are assumed to be endogenous between each other and VARs are able to capture these dynamics in multiple time series.

VARs are useful for policy analysis because they are capable in computing impulse responses. Impulse responses simulate the current and future responses of the chosen vector of variables from an exogenous shock on one of the errors in the VAR. Reduced form VARs are equations of variables as a linear function of their own and other variable's lagged values. Carrying out shocks on these error terms would not result in appropriate impulse responses because the error terms dont correspond to one particular variable due to the correlation between errors in the system of reduced form OLS equations. One method to account for this is to use a recursive VAR approach which uses a Choleski decomposition methodology to estimate impulse responses. More specifically, orthogonalised error terms can be obtained by using a Choleski decomposition on the variance-covariance matrix in the reduced form VAR.

A recursive VAR involves making restrictions on parameters that is based off economic theory on the contemporaneous relationship between variables. In a recursive VAR, the matrix containing the parameters that associates the contemporaneous relationships is of lower triangular form where zero restrictions are imposed on the upper triangle. Thus, it is neccessary to consider the ordering of the equations in a recrusive VAR as different orderings would produce different parameter estimates and impulse responses. Suppose I am concerned with the effects of an interest rate shock. Variables ordered before the interest rate equation do not react contemporaneously to interest rate shocks but the interest rate responds contemporaneously to shocks on these variables. On the other hand, variables ordered after the interest rate equation are assumed to respond contemporaneously to shocks in interest rates but not affect interest rates contemporaneously. When modelling small open economies, Kim and Roubini (2000) suggest the recursive VAR poses a limitation in implementing appropriate economic theories. For example, if interest rates were to have a contemporaneous effect on the exchange rate within a recursive VAR model, then it would need to be ordered such that the exchange rate has no contemporaneous effect on the interest rate. So, Kim and Roubini (2000) suggest this model identification may not bode well with small open economies, like the UK and Australia, which is suggested to respond quickly to fluctuations in exchange rates due to concerns of its impact on the inflation rate.

Further studies on VAR identification has led to the development of the SVAR model, put forward by Sims, Rolnick, and Weber (1986). Similar to the recursive VAR, this involves making explicit contemporaneous or long-run restrictions based off economic intuition on the assumed relationship between variables. In this case, I am not restricted to the limitations of casual ordering.

I use the model from Kim and Roubini (2000) because their model has generally worked well across various types of countries and is consistent with theory on the expected effects of monetary policy changes. This suggests it is a robust model in modelling a dynamic open macroeconomy. The model makes over-identifying restrictions on the contemporaneous interactions between the variables, providing me with a baseline framework to model the dynamics of monetary policy and its effects through house prices. In an Australian context, I make modifications to the model by omitting variables which I believe are not needed in modelling the monetary business cycle. I also include new variables which I deem necessary for the purpose of the study and I believe is more suitable than what is put forth by Kim and Roubini (2000).

5.2 Method

An SVAR with n variables is written as[1]:

$$A_0 y_t = A_1 y_{t-1} + A_2 y_{t-2} + .. + A_p y_{t-p} + e_t \tag{5.1}$$

$$Eee\text{'} = \Lambda_e = \begin{bmatrix} \sigma_{e1}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{e2}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \\ 0 & 0 & & \sigma_{en}^2 \end{bmatrix} \tag{5.2}$$

There is a simpler way to present Equation (5.1). In Equation (5.3), $A(L)$ is the matrix of all the coefficients of the lagged varables while, in Equation (5.4), $A^*(L)$

[1] I omit the constant term for the sake of simplicity.

is formed by combining the coefficient matrix, $A(L)$, with the contemporaneous structural matrix, A_0.

$$A_0 y_t = A(L) y_t + e_t \quad (5.3)$$

$$A^*(L) y_t = e_t \quad \text{such that } A^*(L) = A_0 + (-A(L)) \quad (5.4)$$

The reduced form VAR is written as:

$$Y_t = A_0^{-1} A_1 y_{t-1} + A_0^{-1} A_2 y_{t-2} + .. + A_0^{-1} A_p y_{t-p} + A_0^{-1} e_t \quad (5.5)$$

$$Euu' = \Sigma_u = \begin{bmatrix} \sigma_{u1}^2 & \sigma_{u2u1} & \cdots & \sigma_{unu1} \\ \sigma_{u1u2} & \sigma_{u2}^2 & \cdots & \sigma_{unu2} \\ \vdots & \vdots & \ddots & \\ \sigma_{u1un} & & & \sigma_{un}^2 \end{bmatrix} \quad (5.6)$$

$$(5.7)$$

I simplify the format of Equation (5.5) into Equation (5.9).

$$Y_t = A_1^* y_{t-1} + A_2^* y_{t-2} + .. + A_p^* y_{t-p} + u_t \quad (5.8)$$

$$Y_t = A^*(L) y_t + u_t \quad (5.9)$$

As shown in Equation (5.10), the relationship between the structural errors and reduced form errors is be obtained by equating the errors from Equations (5.5) and (5.8). Thus, the variance-covariance matrix of the structural form and reduced form can also be equated, as shown in Equation (5.11) where Σ_u is the variance-covariance matrix of the reduced form errors and Λ_u is the diagonal covariance-variance matrix of the structural errors. To solve the parameters in the structural model, A_0 needs to be estimated.

$$u = A_0^{-1} e_t \quad (5.10)$$

$$\Sigma_u = A_0^{-1} \Lambda_u A_0^{-1\prime} \quad (5.11)$$

(5.12) is the expansion of Equation (5.10) where the 8×8 matrix is A_0. Variables that are labelled with an 'e' are the structural shocks towards their respective category. e_c is for the commodity price, e_{ffr} is for the FFR, e_{rs} is for retail sales, e_{inf} is for the inflation rate, e_m is for the mortgage debt level, e_r is for the interest rate, e_{er} is for the exchange rate and e_h is for the house price index.

$$\begin{bmatrix} e_c \\ e_{ffr} \\ e_{rs} \\ e_{inf} \\ e_m \\ e_r \\ e_{er} \\ e_h \end{bmatrix} = \begin{bmatrix} 1 & b_{12} & b_{13} & b_{14} & b_{15} & b_{16} & b_{17} & b_{18} \\ b_{21} & 1 & b_{23} & b_{24} & b_{25} & b_{26} & b_{27} & b_{28} \\ b_{31} & b_{32} & 1 & b_{34} & b_{35} & b_{36} & b_{37} & b_{38} \\ b_{41} & b_{42} & b_{43} & 1 & b_{45} & b_{46} & b_{47} & b_{48} \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & b_{56} & b_{57} & b_{58} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 & b_{67} & b_{68} \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 & b_{78} \\ b_{81} & b_{82} & b_{83} & b_{84} & b_{85} & b_{86} & b_{87} & 1 \end{bmatrix} \begin{bmatrix} u_c \\ u_{ue} \\ u_{rs} \\ u_{inf} \\ u_m \\ u_r \\ u_{er} \\ u_h \end{bmatrix} \tag{5.12}$$

Estimation of A_0 is performed by Full Information Maximum Likelihood Estimation [2] (FIML). The estimation cannot be performed without making identifying restrictions on A_0 or Λ_u. Given my model involves 8 variables, the Σ_u matrix has 36 known parameters while $A_0^{-1}\Lambda_u A_0^{-1}$' has 72 unknown parameters. After normalising the diagonals in the A_0 matrix to 1, there are still 28 parameters unaccounted for. To uniquely identify the A_0 parameters, I need to make at least 28 restrictions; without restrictions, there are many possible solutions to the A_0 matrix. My model only imposes zero restrictions on the short-run parameters in the A_0 matrix[3] (Equation 5.14).

$$\begin{bmatrix} u_c & u_{ffr} & u_{rs} & u_{inf} & u_m & u_r & u_{er} & u_h \end{bmatrix} \tag{5.13}$$

$$\begin{bmatrix} e_c \\ e_{ffr} \\ e_{rs} \\ e_{inf} \\ e_m \\ e_r \\ e_{er} \\ e_h \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & 0 & 1 & 0 & b_{35} & 0 & 0 & b_{38} \\ b_{41} & 0 & b_{43} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{53} & 0 & 1 & b_{56} & 0 & 0 \\ b_{61} & b_{62} & 0 & 0 & b_{65} & 1 & b_{67} & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 & 0 \\ 0 & 0 & 0 & b_{84} & 0 & b_{86} & 0 & 1 \end{bmatrix} \tag{5.14}$$

I use maximum likelikhood estmation because of the non-linearity coming from the non-recursive restrictions I impose in the A_0 matrix. The log likelihood function associated with A_0 is:

$$\zeta(A_0) = c + \frac{T}{2}log[A_0^2] - \frac{T}{2}tr(A_0\text{'}A_0\hat{\Sigma}_u) \tag{5.15}$$

[2] I use a time series analysis program called JmulTi to conduct my estimations. This program can be downloaded from http://www.jmulti.de/

[3] The column vector (5.13) is placed on top as a row vector for the sake of helping link the contemporaneously shocks to the response of variables.

Equation (5.15) is conditional on the estimated variance-covariance matrix in the reduced form equation, $\hat{\Sigma}_u$. The identification restrictions in A_0 are assumed to be in the form of Equation (5.16) such that the parameters in A_0 follow a set of 'r' local, linear identification restrictions which are independent and non-homogenous[4] (Giannini et al., 1991). $vec\, A_0$ is a column vector of 'n^2' rows that is constructed by stacking the columns of A_0 below each other, R is a full rank $r \times n^2$ matrix, where r is the number of restrictions imposed in the A_0 model, and d is a non-zero $r \times 1$ vector. Equation (5.16) can also be written in explicit form as shown in Equation (5.17), where s is a $n^2 \times 1$ vector and K is a full rank $n^2 \times m$ matrix, such that $m = n^2 - r$.

$$R\, vec\, A_0 = d \tag{5.16}$$
$$vec\, A_0 = K\gamma + s \tag{5.17}$$

Using the explicit form of identification restrictions, the first derivative of the log likelihood function is calculated with respect to γ by implementing the chain rule (Equation 5.18), where $f'(\gamma)$ is the transposed score vector of $f(\gamma)$. So after tranposing (5.18), $f(\gamma)$ is obtained, where Z' is the partial derivative vector of the explicit form identification restrictions (Equation 5.19). Equating the first derivative to zero satisfies the maximisation of the log-likelihood function (Equation 5.20). Taking the second derivative of the log-likelihood function with respect to γ acquries the Hessian matrix of γ. The information matrix of γ, $I_T(\gamma)$, can also be obtained since it is taking the negative of the expectation of the Hessian matrix. The score vector and information matrix of γ are placed into a scoring algorithm (Giannini et al., 1991) which recursively updates γ into a consistent estimate (Equation 5.21) and finally I obtain parameter estimates for A_0. However, there is a slight drawback because I am making over-identifying restrictions. Because of this, a FIML estimation would not compute efficient estimates but the estimates will still be consistent. (Brischetto et al., 1999).

$$f'(\gamma) = \frac{\partial \zeta}{\partial vec\, A_0} \times \frac{\partial vec\, A_0}{\partial \gamma} \tag{5.18}$$
$$f(\gamma) = Z' \times f(vec\, A_0) \tag{5.19}$$
$$f(\gamma) = 0 \tag{5.20}$$
$$\gamma_{n+1} = \gamma_n + [I_T(\gamma_n)]^{-1} f(\gamma_n) \tag{5.21}$$

Next, I form impulse response functions to predict how much house prices play a role

[4] I use the explanation from Giannini et al. (1991) to interpret the methodology implemented by JmulTi.

in the monetary transmission mechanism. Firstly, I impose an exogenous shock on the interest rates to model contractionary monetary policy and observe the responses of variables, especially focusing on the responses of retail sales (consumption) and the HPI. Secondly, I perform another impulse analysis by shocking the HPI and observe the response of retail sales. This gives an idea on how much of an influence does changing house prices have on consumption. By combining the estimates from these separate impulse response analysis, I can infer how much of an effect house prices have within the monetary transmission mechanism in Australia. To check the validity of my results, I perform a several counterfactual simulations by shutting off the effects of house prices in my SVAR model and re-estimate the impulse responses.

5.3 Variable specifications and identification restrictions

5.3.1 Modifications on the set of variables

The commodity price index is included to control for the feedback rule of policy makers responding to anticipated inflation. I use commodity prices instead of the oil price index which the Kim and Roubini (2000) (KR) model includes. At times, empirical literature analysing the transmission of monetary policy discover counter-intuitive response of macroeconomic variables, commonly known as 'puzzles' among macroeconomists. For example, a contractionary monetary policy innovation in VAR models have shown results that predict an increase in price level rather than a fall. Sims (1992) suggests that the prize puzzle could be explained by monetary policy innovations partly reflecting the inflationary pressures that lead to price increases. Thus, my model includes commodity prices to control for inflationary pressures and supply puzzles that commonly appear in impulse responses.

Mortgage debt is included to control the direct effects of monetary policy transmission through the housing market. This helps with isolating the credit channel and wealth effects of monetary policy transmission through house prices. Lastly, I exclude money supply from my model since the RBA pays less attention on monetary aggregates as instruments in maintaining price stability. Models used for policy analysis within the RBA considers setting interest rates as the major determinant for monetary policy implementation. Woodford (2008) tests several arguments that support the importance of tracking money supply by analysing Keynesian models that include and do not include monetary aggregates. He tracks the changes of monetary aggregates after monetary policy decisions are made and finds that none of the arguments show satisfactory reasons in following a monetary growth target.

5.3.2 Identifying restrictions

My identification model is based off Kim and Roubini (2000) which applies economic intiution and assumptions about the timing of responses between movements in macroecnomic variables. Because some of my variables deviate from the KR model, I also make my own identifying assumptions based off other empirical works and findings on the functions of the macroeconomy. One 'period' ahead in my model is identified as one month ahead which makes it easier to make identification assumptions based off whether shocks affect variables within a month rather than within a quarter or half year. The first row is the commodity price equation which I assume is exogenous from movements in Australian macroeconomic variables and shouldn't respond contemporaneously to any variables within my model.

Next, the FFR controls for the responses of Australian monetary policy to U.S financial variables. Brischetto et al. (1999) suggests that Australia has relatively open capital markets, similar to the G6 countries, and it would be safe to assume that domestic interest rates strongly react to movements in the FFR. Changes in the FFR would influence the actions of domestic traders and impact the Australian stock market and exchange rates. A response from the RBA would be to adjust interest rates to maintain price stability and economic activity. The restrictions made on the FFR equation are based off similar reasons made in the commodity price equation, given the sheer difference in size between the Australian and US economy. Craine and Martin (2008) performs a generalised method of moments to examine the effects of US monetary surprises on Australian yield and equity returns and finds there is a significant correlation of US monetary surprises to the movements in the Australian 5 year bond yield and 10 year bond yield. They also find that Australian monetary surprises have no impact on US yields, considering the economy is too small to have such an influence on the world's superpower. Hence, I impose no contemporeaneous effects from any Australian macroeconomic variables on the movement of the FFR[5].

The third row is the retail sales equation. The unrestricted parameter, b_{31}, is due to Elbourne (2008) stating retail sales should respond quickly to changes in commodity prices because of the ability for the retail market to make swift mark-ups in the cost of goods. Deviating away from the benchmark model, I also make the assumption that consumption responds contemproaneously to movements in mortgage debt. I base this off the intertemporal substitiution effect where there is an immediate trade-off between spending and saving to pay off a mortgage or save for a mortgage. Lastly,

[5] I also make block exogenous restrictions in the commodity price and FFR reduced form equations since both variables shouldn't be influenced by lagged feedback from movements of Australian macroeconomic variables.

I identify movements in house prices to contemporaneously affect the aggregate demand as done in Elbourne (2008).

The inflation rate equation is in the fourth row. I assume the inflation rate is contemporaneously affected by movements in commodity prices because of the quick response of firms to adjust themselves from movements in the commodity market. The similar argument can be made for inflation rate responses to retail sale shocks. It is a common assumption among domestic and international emprirical studies that the inflation rate quickly adjusts to changes in spending (Bernanke et al., 1992; Brischetto et al., 1999). This is because movements in retail sales reflects the change in aggregate domestic demand and is commonly known to quickly impact the inflation rate.

For the inflation rate and retail sales equation, I've placed zero restrictions on the contemporaneous effects of interest rates and exchange rates. Economic theory and evidence suggests the exchange rate and interest rates are major determinants of inflation rates and retail sales and can be considered as lead indicators for these variables. However, Sims and Zha (2006) postulates the private sector responds sluggishly to macroecnomic movements. The reason comes from inertia and planning delays that setback the responses of prices to economic changes, as well as, responses of real economic activity to price signals. Elbourne (2008) indicates such nominal impermeabilities are common in DSGE models.

In the fifith row, I've included the mortgage debt equation. Mortgage debt should be swiftly affected by innovations in the interest rate as banks are assumed to quickly adjust their rates to shifts in the economy and that a decent majority of mortgage debt is under variable interest rates. Retail sales would contemporaneously affect mortgage debt due to the the intertemporal substitution effect. An increase in retail sales would result in delaying or forgoing housing investment within the month.

Kim and Roubini (2000) base their identifciation restrictions for the interest rate equation on the timing that policy makers receive information on economic variables. Based of this, I place zero restrictions on the contemporanously effect of inflation rates, retail sales and house price shocks on interest rates since the RBA is assumed to receive new information for these variables with at least a month delay. On the other hand, I assume that monetary policy makers have readily available information on the commodity price, FFR and mortgage debt within a month.

In the seventh row, exchange rates are known to be a forward-looking financial variable. Based off the efficient market hypothesis, I assume exchange rates react quickly to all new information on macro variables and fully reflect all available information in the private and public sector. The last row is the house price equation and is assumed to react immediately to movements in interest rates since interest rates are assumed to be a major determinant of demand for housing. I exclude mortgage debt having a contemporaneous effect within this equation since the mortgage debt variable controls for the direct effects of monetary policy transmission through the housing market, not through housing prices. I identify inflation rates having a contemporaneous effect in this equation as it is commonly known that house prices should be quickly affected by changes in the inflation rate. Inflation and house price growth in Australia moved closely together during the 1980s until they started to deviate in the late 1980s due to additional factors pushing up the growth of house prices, such as improvements in the quality of housing (Kohler, Van Der Merwe, et al., 2015).

Chapter 6
Results

I determine the optimal number of lags in the reduced form VAR by using the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), Hannan-Quinn (HC) Criterion and Final Prediction Error test (Appendix E.1). All tests also suggest using 2 lags of all variables in my model. I also check the residuals of the reduced form estimation for autocorrelation by using the Breusch-Godfrey LM test[1] (Appendix E.2 and E.3). (6.2) tests the null hypothesis for the Equation (6.1). The result indicates that 2 lags in the VAR computes a p-value that cannot reject the null at the 5% level. This suggests that a 2 lag VAR model is able to account for the autocorrelation in the residuals. As such, I regress the reduced form VAR using 2 lags with an intercept included. Results of the reduced form OLS estimates can be found in Appendix F.

$$u_t = B_1 u_{t-1} + e_t \tag{6.1}$$

$$H_0 : B_1 = B_2 = 0 \tag{6.2}$$

6.1 Estimation of the A_0 matrix

(6.3) shows the estimates of the parameter values in the A_0 matrix. The log likelihood ratio test shows a p-value equal to 0.7557 which does not reject the overidentifying restrictions in the A_0 matrix (Appendix G.1). The parameter indicating the effect of retail sale shocks on mortgage debt shows a positive and rather considerable magnitude. This seems to confirm the intertemporal substitution trade off between consumption and saving for a mortgage is in effect. However, the response of retail sales from a mortgage debt shock indicates a counter-intuitive effect. A possible interpretation is that taking on a mortgage would not hinder everyday consumption within the imminent future since debt payments have not yet begun. Making the choice to increase consumption is a rather small monetary commitment compared to making the decision to obtain a mortgage.

The contemporaneous response of house prices and mortgage debt from a shock in

[1] I also perform a Lagrange Multiplier F-Test to account for small biases in small samples and I find similar results.

interest rates shows a negative relationship. This falls in line with economic theory that assumes rises in interest rates decreases demand for housing and mortgages due to higher costs of taking on homeownership. However, there are some parameter values that are counter-intuitive. I find a negative effect of positive inflation rate shocks on house prices and a negative effect of positive house price shocks on retail sales. As a result, this indicates there might not be a strong wealth effect through house prices.

$$\begin{bmatrix} e_c \\ e_{ffr} \\ e_{rs} \\ e_{inf} \\ e_m \\ e_r \\ e_{er} \\ e_h \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.002 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.01 & 0 & 1 & 0 & 0.12 & 0 & 0 & -0.02 \\ -0.01 & 0 & 0.06 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1.3 & 0 & 1 & 1.89 & 0 & 0 \\ 16.2 & 0.11 & 0 & 0 & 0.5 & 1 & 32.08 & 0 \\ 0.43 & -2.82 & 7.3 & 2.16 & -10.6 & -32 & 1 & 0 \\ 0 & 0 & 0 & -0.29 & 0 & -0.87 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_c \\ u_{ffr} \\ u_{rs} \\ u_{inf} \\ u_m \\ u_r \\ u_{er} \\ u_h \end{bmatrix} \tag{6.3}$$

6.2 Block exogeneity for international variables

Cushman and Zha (1997) propose foreign variables should be exogenous when modelling economic acitivity in small open economies. This is a justifiable assumption since shocks and movements in Australian macro variables should not be expected to influence the international market and foreign policy movements throughout all lag periods, especially for the U.S economy since it is large and relatively closed. Implementing an exogenous block for foreign variables would be a suitable identification for the model and could possibly address the problem of VAR puzzles.

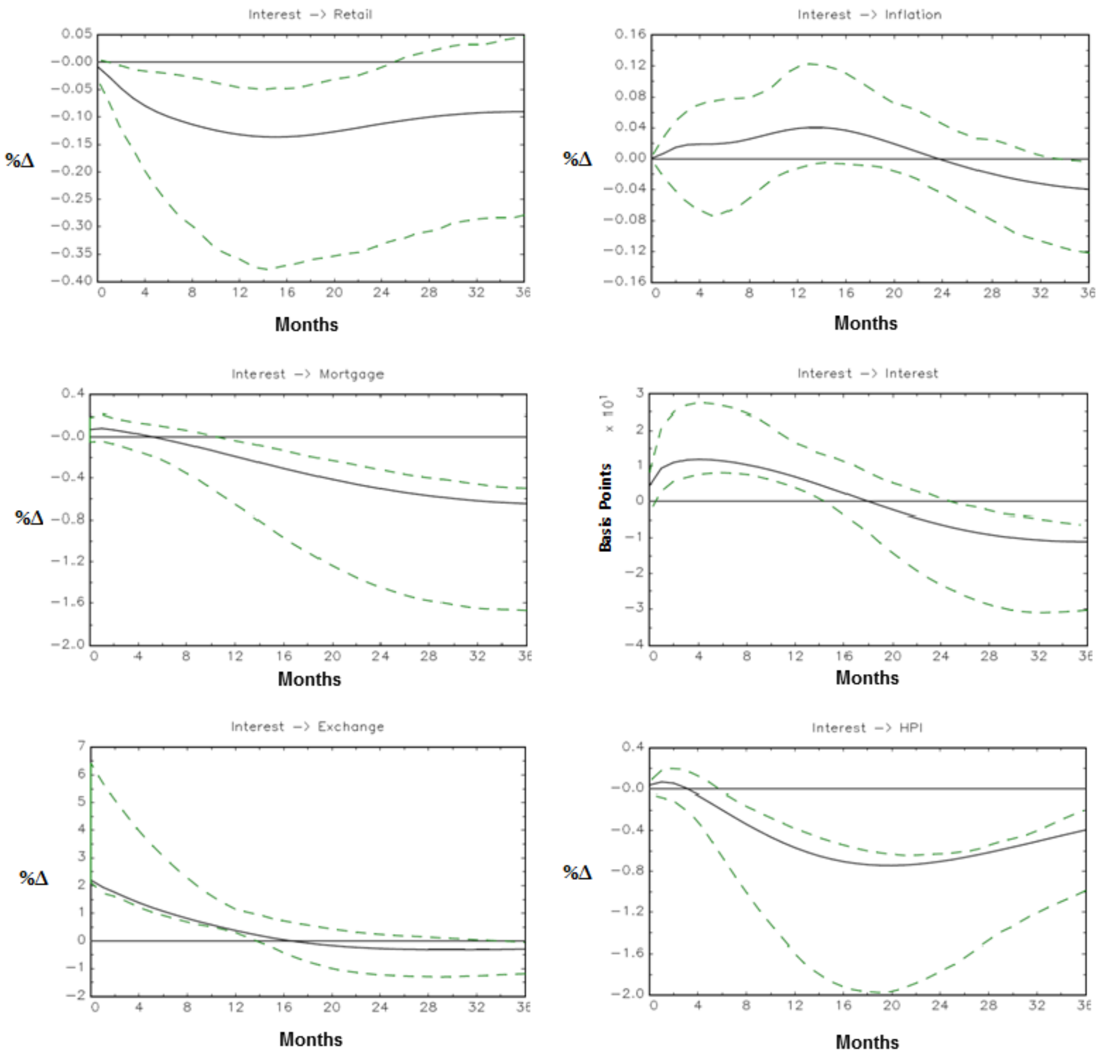
The lagged parameters in the commodity price and FFR equations for the reduced form VAR are adjusted using a search model[2] that determines which parameters should be restricted to zero based on t-ratios. The reduced form estimation in Appendix F shows the zero-restrictions indicated by the blank inputs in the reduced form parameters.

[2]I implement a search procedure in JMulTi which tests the t-stat of each parameter in the commodity price and FFR equation. t-stats below a certain threshold are eliminated from the equation.

6.3 Impulse responses

I first estimate impulse responses from my model to look at the overall montary transmission mechanism. Figure (6.1) displays the set of impulses responses of variables from a positive interest rate shock. The impulse responses extend to

Figure 6.1: Impulse responses from an interest rate shock



Impulse responses from a one standard deviation positive interest rate shock. Dotted lines are 95% confidence intervals bootstrapped with 500 repetitions using Hall's (1992) percentile method.

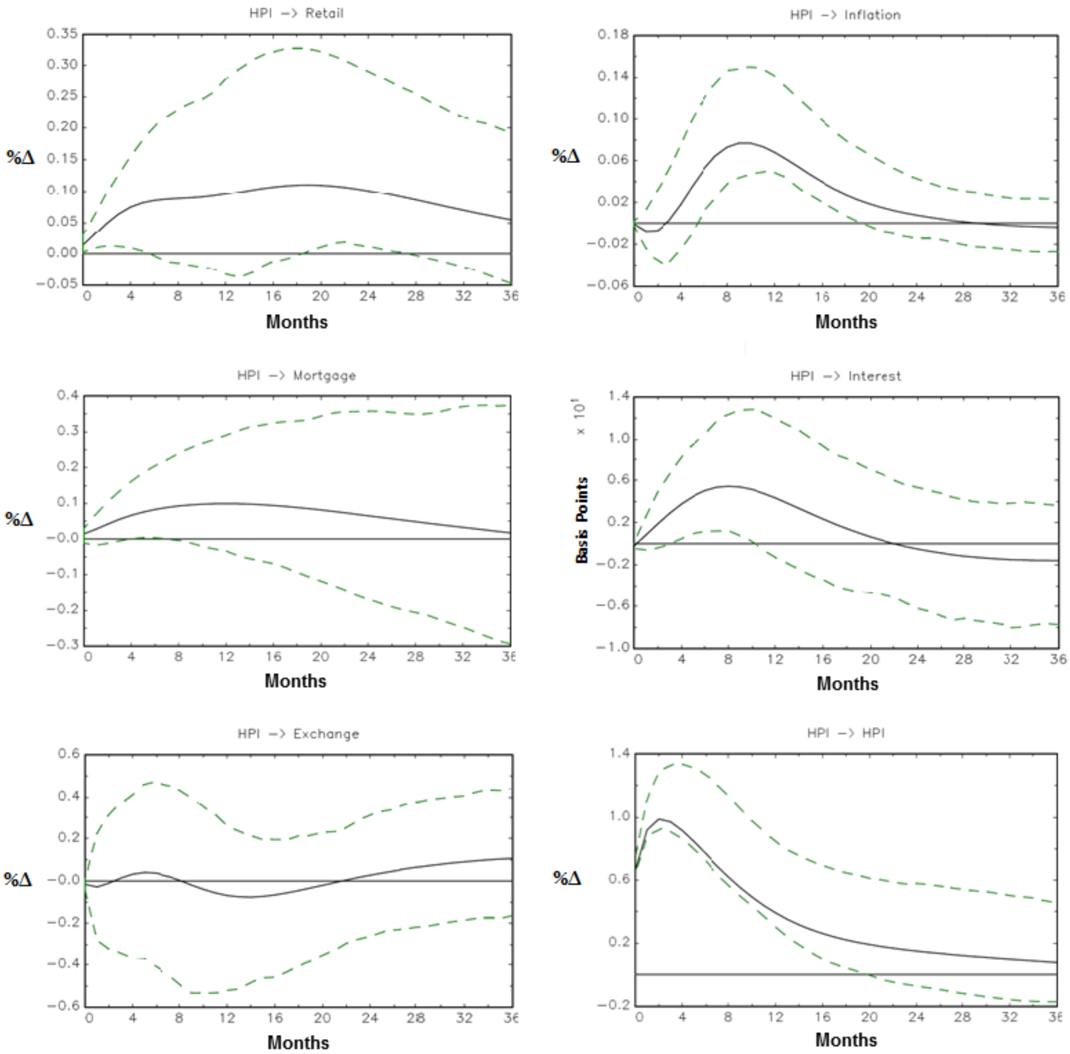
36 months (periods) ahead and the y-axis indicates the percentage change of macroeconomic variables, except for the interest rate which is presented as a basis point change. A one standard deviation cash rate shock amounts to a 4.3 basis point positive shock in the cash rate. The impulse responses based off my identification appear to capture the expected effects of monetary policy dynamics. Retail sales immediately drops and continues to fall to a negative peak of about 0.13% at the

16th month ahead. House prices exhibit an initial increase which is statistically insignficant, and quickly decreases to a peak percentage change of -0.74% at the 20th month ahead. These are in line with economic intuition where increases in interest rates should discourage consumer spending due to higher costs of borrowing. A similar argument can be made for house prices where increases in interest rates would also decrease housing demand due to higher costs in obtaining a mortgage.

The response of the inflation rate indicates a price puzzle, shown by an increase for 22 months ahead. The increase reaches a maximum percentage change of 0.04% but is not statistically significant. The inflation rate starts to decrease at the 22nd month and, beyond the 34th month, the decrease in inflation rate starts becoming statiscally significant. This result suggests a contractionary monetary policy would reveal a negative response on the inflation rate with a lengthy lag which, in this case, would be approximately a 2 year lag. This result is generally in line with Sims (1992) explanation of the price puzzle. Also falling in line with economic intuition, exchange rates immediately appreciate with an approximate 2.2% increase and mortgage debt starts off with a statistically insignificant increase but quickly becomes a gradual downward trend into a statistically significiant negative change. An explanation for the downward trend in mortgage debt level could be that positive interest rate shocks cause a decrease in the demand for housing. Furthermore, existing homeowners may opt towards renting or even default due to increases in mortgage interest payments under variable interest rates. Overall, it appears the Kim and Roubini (2000) model addresses most of the empirical puzzles associated with modelling economic activity in VARs.

Figure (6.2) shows the responses of variables from a house price shock. Measuring the response of consumption to a house price shock provides a general idea as to how much house prices contribute to the fall in consumption within the monetary transmission mechanism. The house price shock is a one standard deviation increase in house prices, specifically a 0.66% increase which continues to increase to a peak of 0.98%. Retail sales respond with a peak increase of 0.11% and follows with a gradual decrease back to the baseline. This increase is statistically significant for the first 6 months and between 20-24 months ahead. Interest rates respond with an increase which coincides with Elbourne (2008) estimates. The rise in interest rates could be a response to bring down inflation due to expectations of rising price levels. The response in the inflation rate falls in line with this expectation. There is a small drop in the inflation rate for 3 months ahead but, ultimately, can see the house price shock driving up the inflation rate, reaching to a peak increase of 0.077%.

Figure 6.2: Impulse responses from a house price shock



Impulse responses from a one standard deviation positive house price shock. Dotted lines are 95% confidence intervals bootstrapped with 500 repetitions using Hall's (1992) percentile method.

Combining the responses from the two shocks, I calculate the proportion of the change in consumption that is attributed to movements in house prices within the monetary transmission mechanism. Being aware of the presence of cointegration and integration in my variables, I decide to focus on the short-run values for my calculations by using the 6 month period ahead values from the impulse responses. Hence, a contractionary monetary shock of 4.3 basis points shows the 6 month period response to be a 0.1% decrease in retail sales and 0.196% decrease in house prices. Normalising the house price shock, a 1% positive house price shock raises consumption by 0.129%.

Table (6.1) shows the response from the overall monetary transmission mechanism. Table (6.2) shows the response of retail sales from changes in house price. In the

Table 6.1: Overall monetary policy transmission

Interest rate change	House prices response	Retail sales response
+4.3 basis point	-0.196%	-0.1%

Table 6.2: Response of retail sales to house price shocks

House price change	Retail sales response
+1%	+0.129%
-0.196%	-0.025%

second row of Table (6.2), I calculate the value of the retail sales response to a negative 0.196% change in house prices. I'm using house prices shocks to match with house price responses in the monetary transmission mechanism which means I need to make the assumption that consumption responds the same way to house price movements, no matter how the change in the house price is caused. I find in the overall monetary transmission mechanism that falling house prices is causing a negative 0.025% fall in retail sales. As a result, I deduce house prices contribute a 25% proportion of the total fall of retail sales in the overall monetary transmission[3]

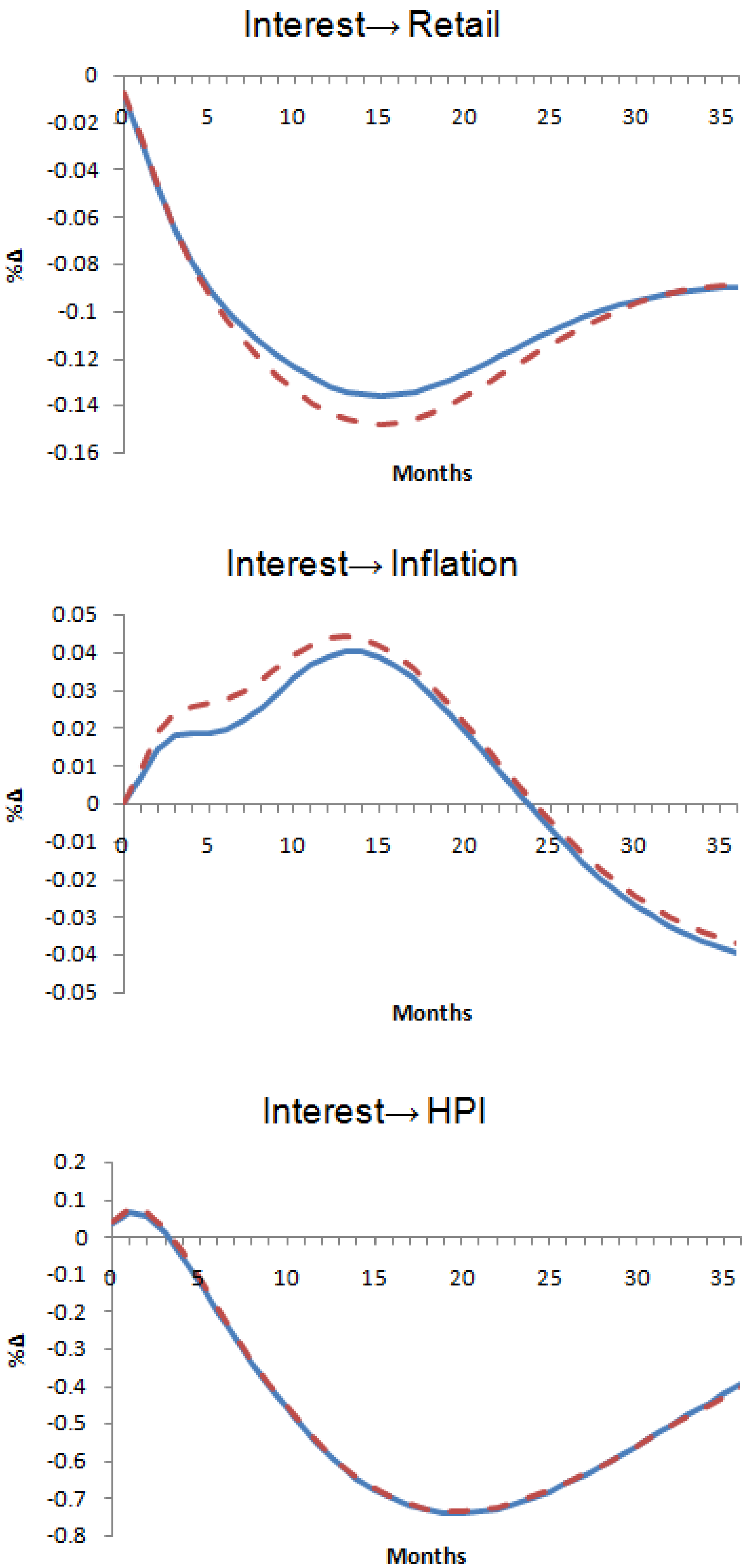
6.4 Counterfactual simulations

Next, I perform counterfactual simulations to conduct further analysis into the wealth and credit channel effects that work in the monetary transmission mechanism through house prices and allowing me to validate my results and calculations. I shut off the effects on consumption coming from movements in house prices which eliminates the direct wealth effect channel in the transmission mechanism. This involves setting the coefficients of the lagged house price variables in the retail sales equation and the contemporaneous effect of house prices on retail sales, b_{38}, to zero. I keep the other parameters as formerly estimated and compute my impulse responses again. Figure (6.3) displays the impulse response functions for retail sales, the inflation rate and house prices from a interest rate shock. Appendix H.1 shows the remaining variable responses.

Evidence of a direct wealth effect through house prices should show less of fall in consumption in the counterfactual simulation relative to the original impulse response. However, the counterfactual does not exhibit less of a fall in consumption than the original impulse response and rather indicates a distinctly greater fall at

[3] This proportion is obtained by dividing 0.025% with 0.1%.

Figure 6.3: Counterfactual impulse responses by shutting off direct effects of house prices



The dashed red lines are the counterfactual responses. The solid blue lines are the original impulse responses.

the 15th month. Inflation rates in the counterfactual show a higher response than the original response. The movement in house prices between the two impulse responses are almost comparable. Results suggests there is no direct wealth effect working through house prices but possibly there are indirect effects through house prices working through the other variables which may have an influence on decreasing consumption.

I perform another counterfactual simulation such that house prices are completely shut out of the monetary transmission mechaniam. This involves shutting down the effects of house prices in all equations within the system of reduced form equations. I impose zero restrictions on the coefficients of lagged house prices for all reduced form VAR equations and shut off the contemporaneous effects of house prices within the A_0 matrix. Figure (6.4) displays the impulse responses to a interest rate shock for the counterfactual in dashed lines and, again, I compare with the original responses in the solid lines. Appendix H.2 shows the remaining variable responses.

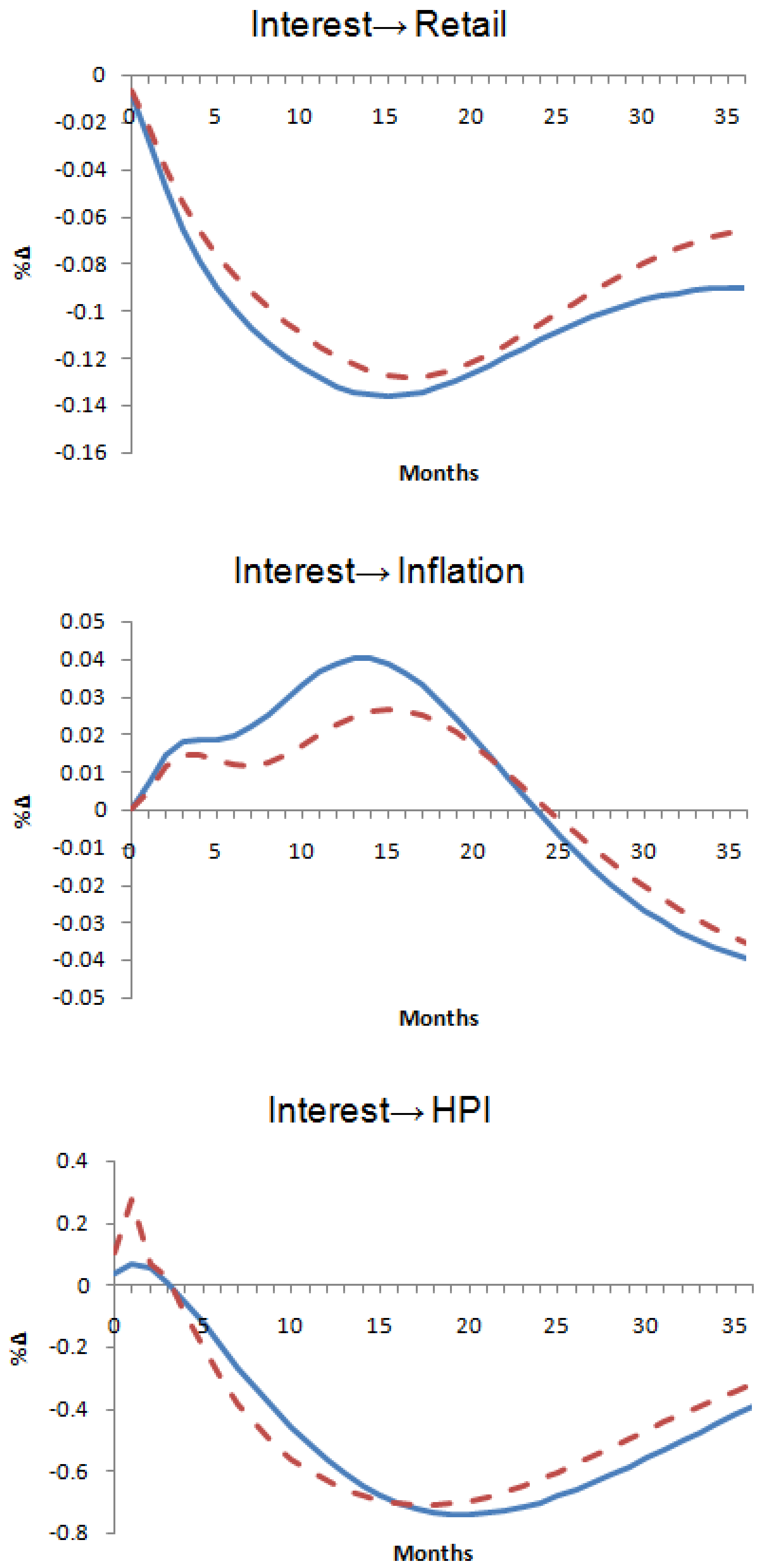
The response of consumption moves as expected where it can be seen that consumption doesnt fall as much throughout all months for the counterfactual. Therefore, this confirms that shutting off the house price effect reduces the impact of a monetary policy shock on consumption. I also find the greatest difference between the original and counterfactual occurs between 5-15 months ahead. Shutting off house prices also mitigates the response of house prices and inflation rate. Compared to the original impulse responses, the counterfactual response of the inflation rate appears to show a lower percentage increase after 3 months ahead and, after 24 months ahead, also shows less of percentage decrease. This acknowledges inflation rates are positively correlated to house prices and supports a recent micro-level study by Stroebel and Vavra (2014) where they find retail prices exhibit elastic responses to house prices changes. The counterfactual response for house prices emerges with an initial spike and shows a less significant decrease beyond the 15th period.

Table 6.3: Comparison between original and counterfactual impulse responses

	Response of retail sales at the 6 month period
Original	-0.099%
Counterfactual	-0.085%
Difference	0.014%

Using the 6 month period ahead values, I calculate a 0.014% difference between the counterfactual and baseline impulse responses of retail sales (Table 6.3). This

Figure 6.4: Counterfactual impulse responses by shutting off all effects of house prices



The dashed red lines are the counterfactual responses. The solid blue lines are the original impulse responses.

difference shows the contribution that the channels through house prices have on consumption within the transmission mechanism. Taking ratios of the values in Table (6.3), the counterfactual simulation shows that the presence of falling house prices attributes a 17% proportion of the percentage fall in consumption within the entire monetary transmission mechanism. This result is lower than my original calculation of 25%, however the difference is not significantly large.

6.5 Forecast error variance decompositions

I compute forecast error variance decompositions (FEVD) which is a standard VAR application to investigate the validity of the model. Decomposing the forecast error variance of the variables can interpret the significance of each innovation in the SVAR in explaining the movements in the impulse responses. It specifically looks at the proportion of the variance of a variable's forecast error attributed by the variance of each structural shock. Figure (6.5) displays the variance decompositions for retail sales, the interest rate and house prices. The other FEVDs can be found in Appendix I. The length of the FEVD extends to 36 months and the title denotes which variable's variance decomposition is under analysis.

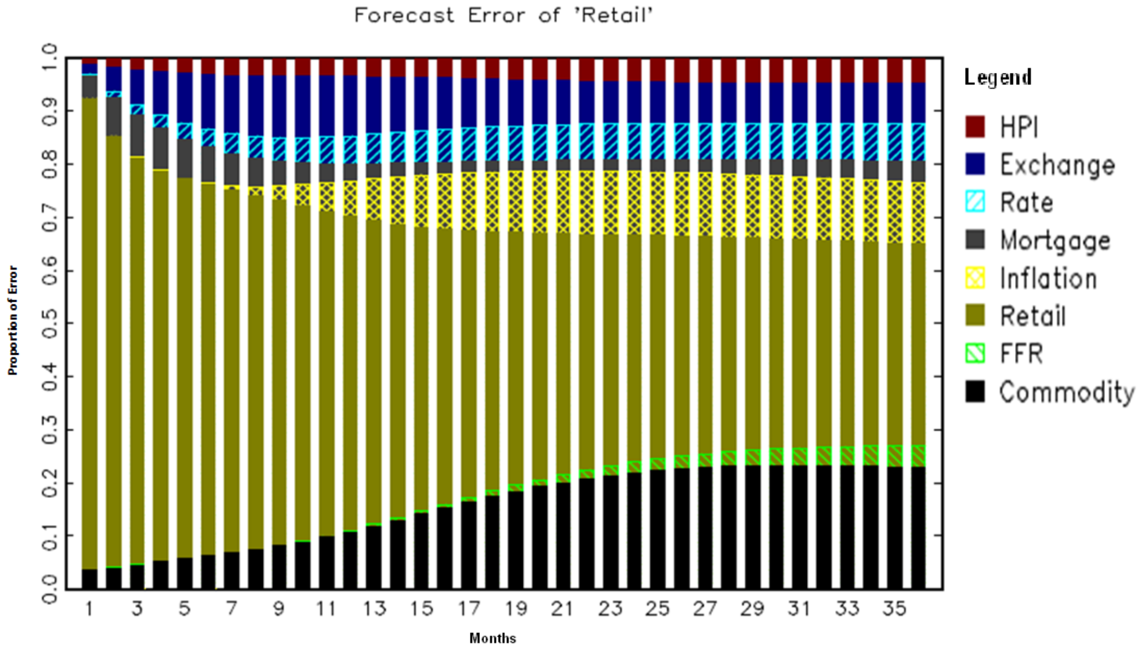
In the short run, the majority of the variation in retail sales is explained by retail sales shocks, attributing to about 89% of retail fluctuations at the first month and converges to 38% at the 36th month. Interest rate shocks initially explain a small variation of retail sales and reaches to about 7% at the long-run horizon. This indicates domestic monetary policy shocks contribute little in determining retail sales. This is similar to the results in Elbourne (2008) and Kim and Roubini (2000), suggesting Australia has a similar macro economy to the G-7 countries. Foreign shocks have an influential role in explaining about 27% of the variation of consumption in the long run, predominantly caused by commodity price shocks. This reflects Australia's increasing dependence for foreign goods, indicated by the positive trend in imports over the past 20 years. It is interesting to notice that FFR shocks have very little contribution to domestic activity which is contrary to findings found in G-7 countries and past domestic studies (Brischetto et al., 1999; Kim and Roubini, 2000). This suggests unanticipated movements in US interest rates has come to have less of an influence on Australian economic activity. My results acknowledges the path of Australia's economy diverging from the US economy in the 21st century. This is evident from the low correlation between recent Australian and US economic growth which is especially noticeable when comparing with America's recessions in 2001 and 2008/9.

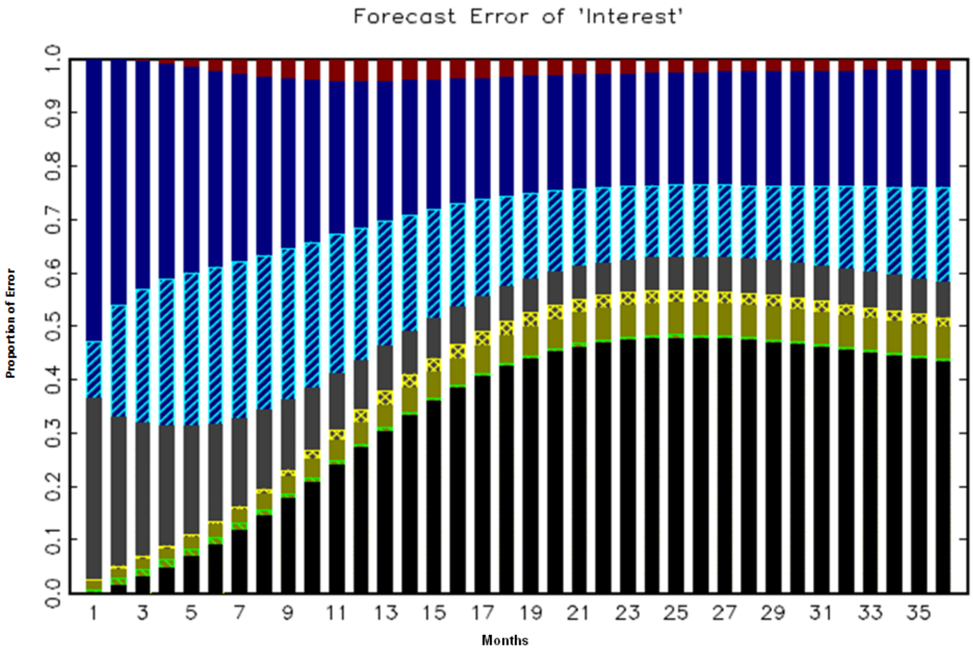
The variance decomposition for the interbank cash rate shows what shocks the RBA reacts the most to when setting monetary policy. In the first month, exchange rate shocks (53%) are the greatest contributor to the variance of the cash rate. This is consistent with the view that the RBA considers exchange rates as a key variable in monetary policy. This is because Australia is a small open economy and is likely for the inflation rate to be sensitive to exchange rate changes. My results show the central bank is concerned with the consequences in exchanges rate movements. Similar to the retail sales decomposition, there is a very small contribution of US monetary policy shocks to the variation in domestic interest in the short and long run, suggesting U.S policy initiatives are not influential in affecting Australian monetary policy. Mortgage debt shocks contribute 38% of variation in interest rates in the first month and house price shocks contribute 9% in the long run, suggesting the movements in the housing market is a major concern for monetary policy makers.

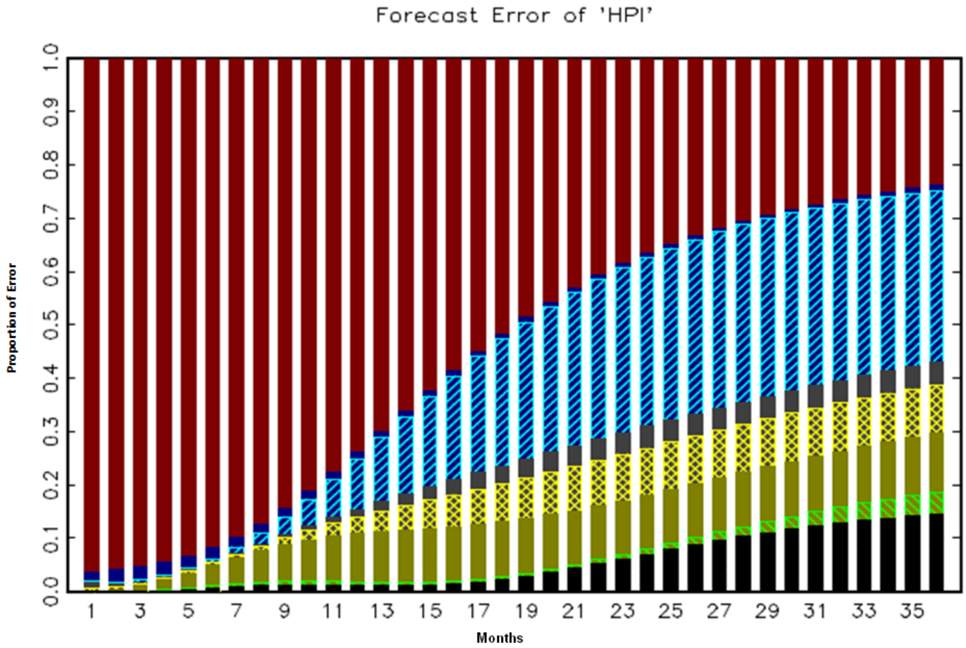
Similar to Elbourne (2008) results, house prices in the first month are determined by their own shocks but moving into longer horizons shows other variables starting to contribute to the variation in house prices. After 36 months, variation in house prices are mostly attributed by interest rate shocks (32%), possibly due to a large proportion of variable rate mortgages having a subtantial effect on the demand for housing.

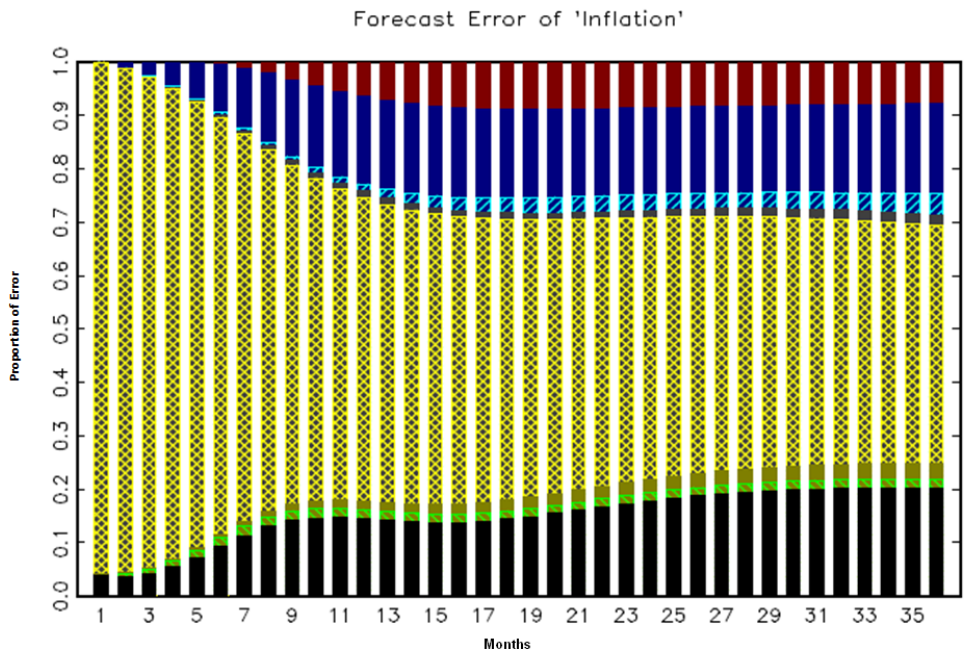
The variance decomposition of the inflation rate suggests the systematic part of monetary policy follows in line with the monetary policy strategy of inflation targeting which the RBA undertakes. New Keynesian theory suggests that a central bank that concentrates on achieving a stable inflation rate should mean that inflation rate shocks should be the main contributor to the variation of inflation rates (Bjrnland and Leitemo, 2005). My variance decomposition follows in line with this theory where the inflation rate is predominantly self determined in the first couple months and, at the 36th period, inflation rate shocks still explain 45% of the variation in the inflation rate.

Figure 6.5: Forecast error decompositions






Forecast Error of 'HPI'
Proportion of Error
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Months


Forecast Error of 'Inflation'
Proportion of Error
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Months

Chapter 7
Robustness checks

Robustness checks are essential to check the stability of my SVAR impulse responses. SVAR modelling tends to produce responses that are sensitive to the asusmptions made in the estimation, especially in the identification of contemporaneous effects. I perform three robustness tests and these are: (1) a recursive VAR identification (2) using first differenced endogenous variables and (3) a breakpoint test.

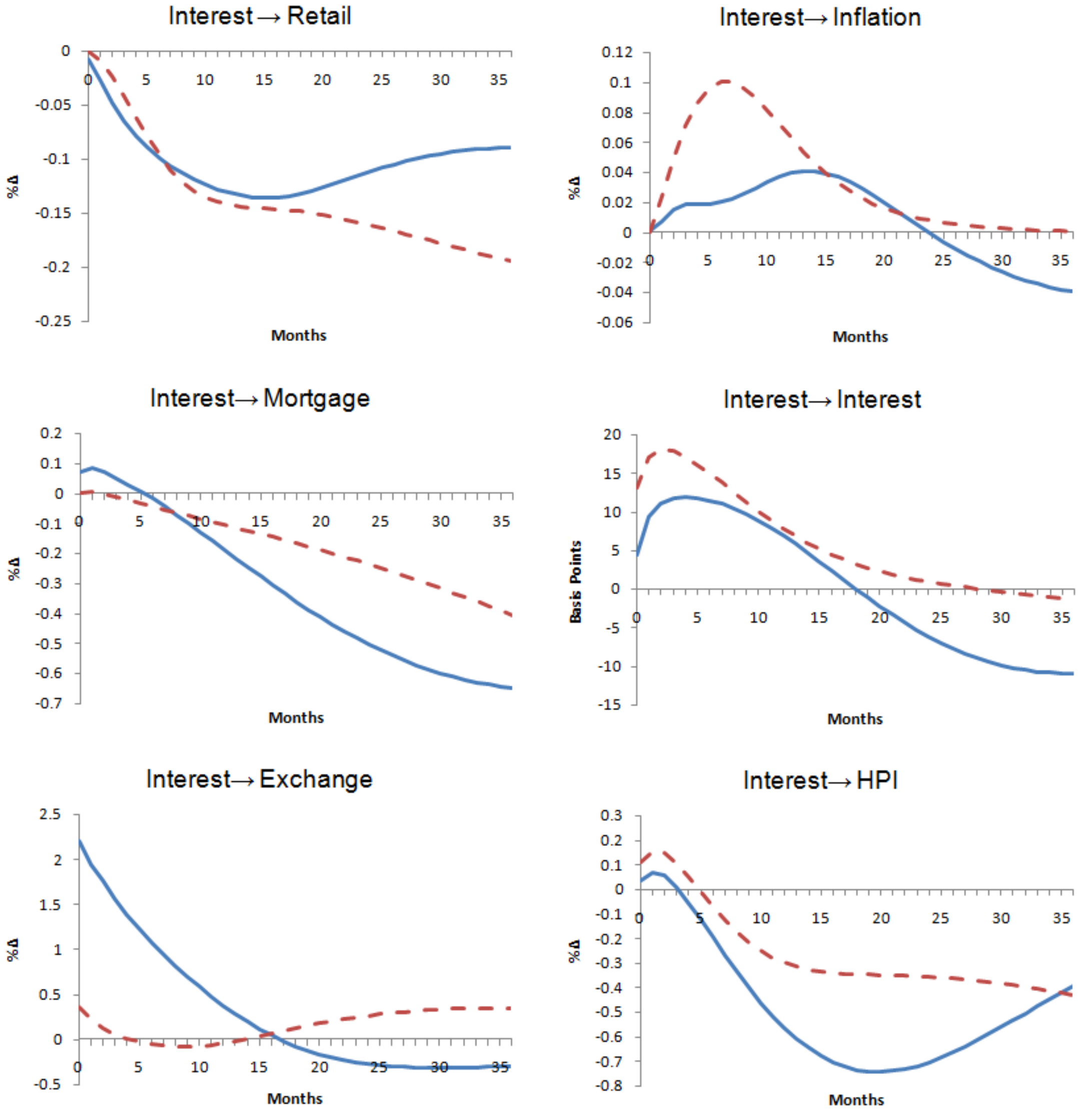
7.1 Recursive identification restrictions

In this section, I compare the impulse response functions of my SVAR model with a recursive identification VAR specification, estimated by Choleski decomposition, to check the stability of my non-recursive specifications. Furthermore, analysing the movement in the impulse responses from a recursive VAR enables me to judge the adequacy of the variable ordering in my SVAR. Recursive identification is a good baseline model to use as a comparison since my SVAR model does not impose many upper triangle unrestricted parameters. Thus, impulse responses should not be too sensitive to the additional identification restrictions I've implemented in comparison to the recursive model.

Figure (7.1) shows the original and the recursive impulse responses to a one standard deviation positive shock in the domestic interest rate. Specfically, the impulse responses displayed are for retail sales, inflation rate, mortgage debt, interest rate, exchange rate and the house price index. Overall, the general direction of responses between the recursive and original model all coincide with each other which demonstrates there are no significant differences across models. The recursive inflation rate responds with a higher positive spike in the inflation rate and suggests the prize puzzle I observed using my original identification scheme is not due to placing unrestricted parameters on the upper triangular part of the A_0 matrix.

It is also important to note that the interest rate shock from the recursive model is a 13 basis point shock which is about 3 times the shock from the original model's shock. But the two retail sales responses exhibit similar magnitudes where the recursive model is only slight greater after the 7th month. My model suggests that

Figure 7.1: Impulse response comparison with the recursive model

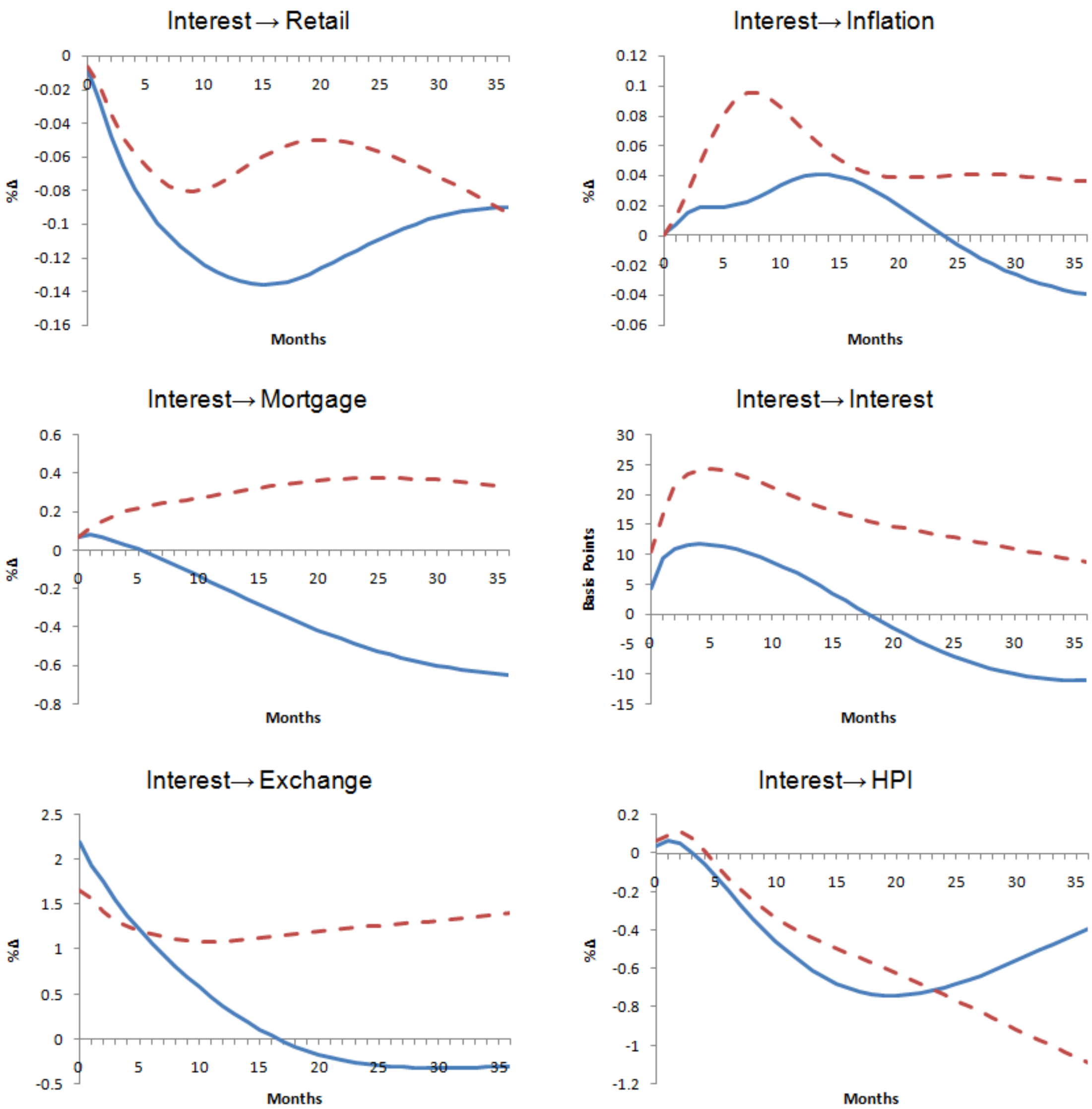


The dashed red lines are the responses from the recursive model. The solid blue lines are the original impulse responses.

interest rates have a much larger effect on consumption than the recursive model or it could be that an interest rate shock in my identification scheme is overstating the magnitude of the responses. But, quickly after the initial shock, this difference between the interest rate responses is reduced greatly. This indicates that the disproportionate differences in the very short-run may be caused by the difference in contemporaneous responses to other variables due to my distinct identification of the A_0 matrix. At the 2nd month period, the interest rate response from the recursive model reduces to less than double of the original model's interest rate response.

7.2 First differenced endogenous variables

Figure 7.2: Impulse response comparison with the differenced model



The dashed red lines are the responses from the difference model. The solid blue lines are the original impulse responses.

Another robustness test I use is computing impulse responses with variables that are first differenced. Specifically, first differencing is applied on the commodity price, retail sales, mortgage debt, exchange rate and house price index. It is commonly known in emprirical work to account for integration by first differencing so that the effect of shocks are not permanent. Though, Gospodinov, Herrera, and Pesavento (2013) find that using a short-run identification scheme should not exhibit large differences between unrestricted models with level variables to restricted models that transform variables based on unit root tests.

Figure (7.2) shows the original and the restricted model impulse responses to a one standard deviation positive shock in the domestic interest rate. The impulse responses for the first differenced variables are displayed as the accumulated response. The inflation rate response of the restricted model is similar to the recursive model but does not converge back to zero. For the other responses, in the long-run, it appears the restricted model exhibits persistence in the percentage change where the variables do not converge back to zero. Thus, in the long-run, the difference between responses are quite large. The response of mortgage debt is actually opposite to the original response which is positive for all 36 periods. This could be due to mortgage debt being tested to be I(2) rather than I(1) and demonstrates the implications of making incorrect specifications on the integration of variables. This could also suggest that non-unit root variables are more robust when running in levels. Other than mortgage debt, the responses of variables within the first 6 periods exhibit similar paths and coincides with Gospodinov et al. (2013) remarks. This provides support for my results on the calculation of the significance of house price in the monetary transmission mechanism.

7.3 Breakpoint test

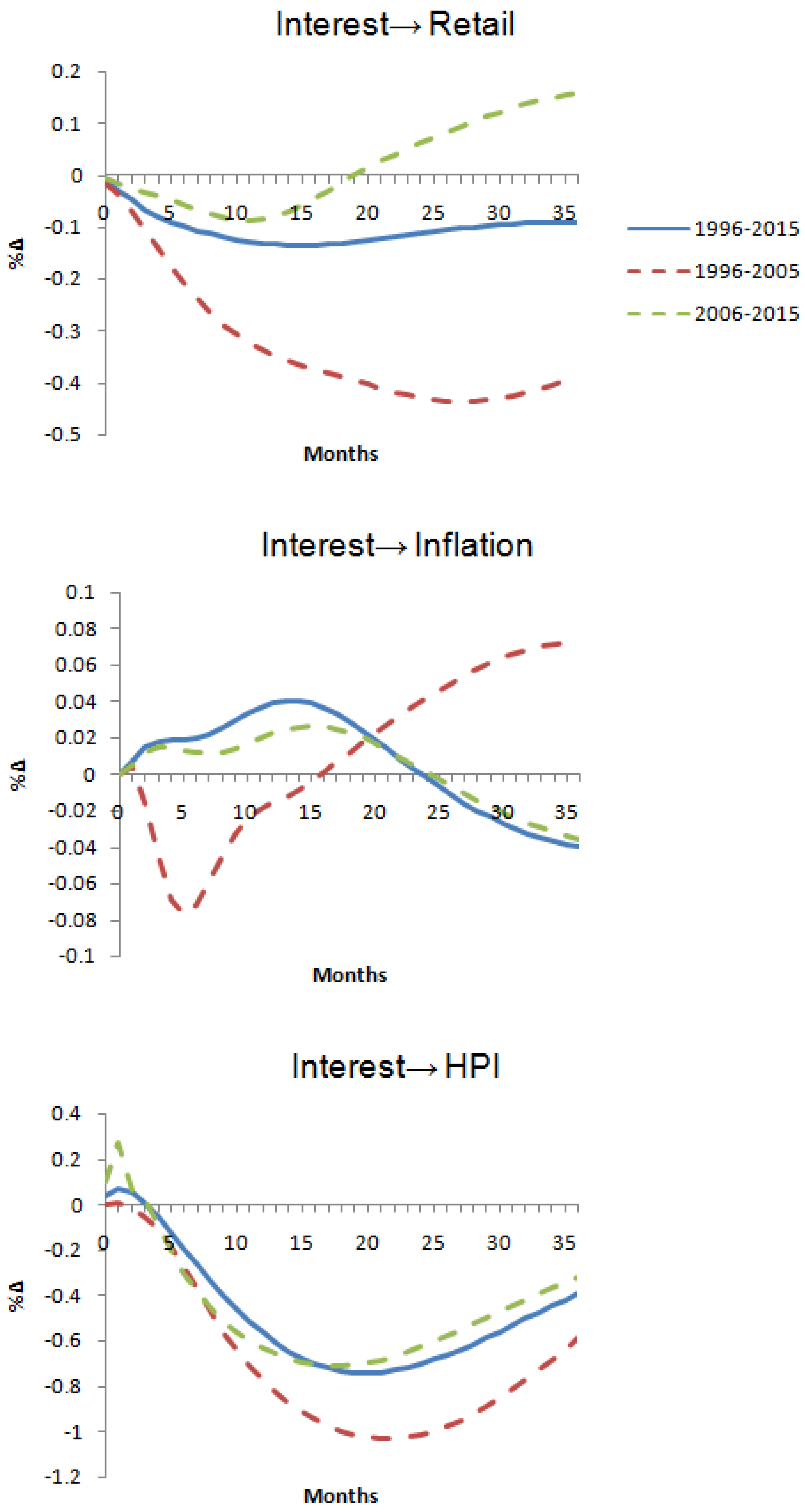
The breakpoint test is a very common robustness check for SVAR models where the total sample size from 01/1996-12/2015 is split into two even parts for impulse response analysis. I compute impulse responses for these two subsamples, ranging between 01/1996-12/2005 and 01/2006-12/2015. HQ criterion tests and SIC tests suggest the use of two lags for both subset samples[1]. I compare the two subsample responses with the original impulse responses and interpret any difference and similarities.

Figure (7.3) shows the original and two subsample responses to a one standard deviation positive shock in the domestic interest rate[2]. The retail sale responses for both subsamples indicate a fall in the consumption and this demonstrates the validity of my identification scheme in modelling the overall monetary transmission mechanism within Australia. The responses that show the biggest difference are the inflation rate responses from both subsamples. Contrary to my original results, the 1996-2005 period shows a very large drop in the inflation rate which this response indicates no puzzle price. Bigger falls in retail sales and house prices between 1996-2005 are most likely due to the higher positive shock of 14 basis points in the interest

[1] AIC indicates the use of 10 lags. Since SIC imposes more penalty for more lags than AIC, I decide to ignore AIC and take the more parsimonious approach.

[2] Other impulse responses are in Appendix J.

Figure 7.3: Impulse response comparison with different sample periods



rate.

It appears that the 1996-2005 responses present more convincing results and advocates the validity of my identification in modelling economic activity for modelling earlier periods. I infer the price puzzle observed in my original response may be due to big disparities in economic conditions between the different time frames. Over recent years, Australia has been experiencing decreasing interest rates which has led to very low interest rates and also Australia's macroeconomy has become less correlated with the U.S macroeconomy. It suggests my identification method needs to be adjusted in a way to account for these dynamics and possibly address the price puzzle in my results.

I also use the same calculation method to gauge the significance of house prices within the monetary transmission mechanism between 1996-2005. I find a similar proportion of 24% of the percentage fall in consumption coming from falling house prices. Overall, my original responses generally move between the two subsample responses and suggests my results are consistent among the responses of house prices and retail sales.

Chapter 8
Conclusion

This paper provides evidence of house prices having an impact on consumption within Australia's monetary transmission mechanism. Other than the inflation rate, I find my results generally fall in line with economic intuition where a positive interest rate rise causes a fall in consumption and house prices. I also find my results are generally robust to changes in the identification scheme, variables and sample period.

Calculations using my impulse responses and counterfactuals suggests that, when there is contractionary monetary policy shock, about 17% to 25% of the fall in consumption is attributed to the fall in Australian house prices. This result is higher than what was found in the UK where Elbourne (2008) obtains a result that suggests 12% to 15% of the fall in UK consumption is due to the movements in house prices. The counterfactual approach interprets the response of consumption coming from house prices is predominantly caused by credit channel effects. This supports the claim that there are a considerable amount of credit-constrained households that are reacting to movements in house prices which is indirectly affecting consumer consumption. On the other hand, the counterfactual approach indicates a lack of evidence for a direct wealth effect working through house prices.

There are some shortcomings and limitations in my paper that could be addressed in future studies. As mentioned, my results present a small price puzzle, as seen from the rise in the inflation rate from a positive interest rate shock. My robustness checks suggest the price puzzle exists due to the movement of economic variables within the past decade. Identification models and choice of variables may need to be adjusted to account for new and more recent theories on the workings of Australia's macroeconomy. A possible methodology could be the use of a factor augmented VAR (FAVAR) which addresses the issue of low-dimensional VARs in attempting to reflect the complexity of monetary policy decisions in setting interest rates. It may be that richer sets of information could address the prize puzzle.

Another aspect is that my counterfactual responses suggests that monetary policy makers would respond and react in the same way with the knowledge that house prices have no effect on macroeconomic variables. In reality, it is very unlikely this would be the case. If house prices were to play no part in affecting the economy, monetary policy makers would implement policy based off a different economic model and the economy would react differently. But this shouldn't be a problem since I only use the counterfactual to calculate the significance of house prices in my original model. Thus, it is important to notice that the counterfactual responses shouldn't be interpreted as what would happen if house prices did not play a part in affecting macroeconomic variables.

I conclude that credit-channel effects are contributing a substantial amount to the response of aggregate output within Australia's monetary policy transmission mechanism, however it does not account for the majority of the output. This means that house prices should not be the only important consideration when implementing policy instruments but also the debt level of consumers.

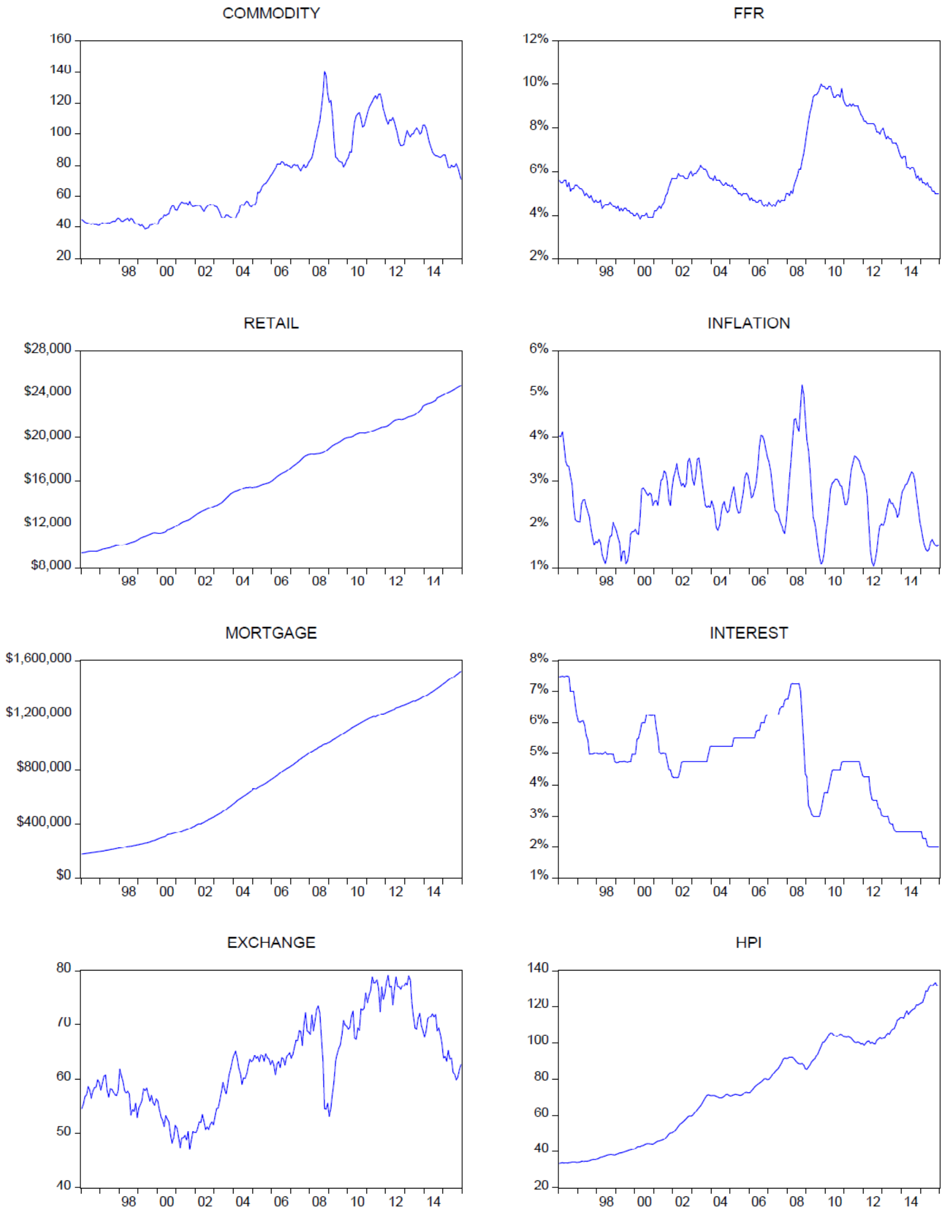
Appendix A
Data information

Table A.1: Description of data

Data	Units	Source	Description
Commodity prices	Index	RBA	The index is weighted according to 2011/12 export values. The measure for commodity prices is calculated by using average export values
Federal funds rate	Percentage	FRED	The federal funds rate is the US overnight effective interest rate which banks charge between each other when trading federal funds. The monthly rate is the weighted average of the rates that are negotiated between banks but the rate is mostly influenced by the Federal Reserve bank.
Retail Sales	$millions	ABS	This is the aggregate level of sales turnover for large and small businesses within Australia. It includes food retailing, department store, clothing retailing, household goods retailing and cafe/restaurant services and also other types of retailing goods.
Inflation rate	Percentage	RBA	This is the quarterly year-end inflation rate, excluding interest and tax changes. This series omits the change caused by the introduction of Goods and Service Tax (GST) in 2000/01.
Mortgage debt	$millions	RBA	This is the value of the loans provided to individuals for owner-occupied housing and housing investment. This value also includes outstanding loans.
Interest rate	Percentage	RBA	This is the interbank cash rate and is the monthly weighted average of interest rates lent and borrowed between banks through open market transactions.
Exchange rate	Index	RBA	This is a trade-weighted exchange rate index. It is calculated by combining the exchanges rates from the US and other countries.
House prices	Index	ABS	This a weighted average index showing the change in the value of the stock of housing in all 8 capital cities within Australia.

Appendix B
Data graphs

Figure B.1: Time series graphs of variables



Note: The x-axis units are in years and range between 01/1996-12/2015. Mortgage debt and retail sales are in $millions. Commodity prices, exchange rate and HPI are displayed in indexes

Appendix C
Autocorrelation from OLS errors of actual series with related series

Figure C.1: Autocorrelation of inflation rate errors

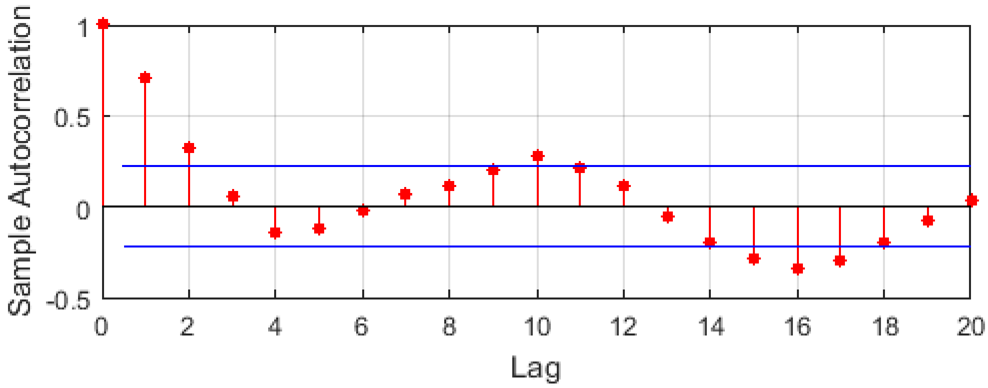
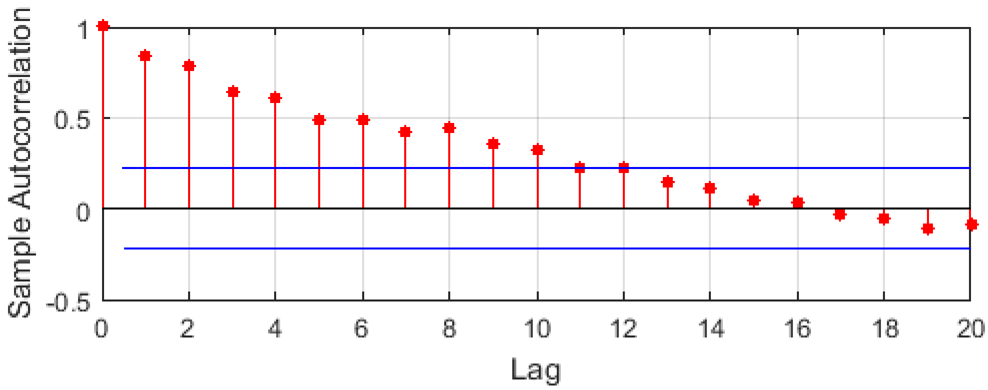


Figure C.2: Autocorrelation of HPI errors



Appendix D
GLS requirements

The OLS estimation is assumed to have serial correlation where the variance of u is non-diagonal.

$$Y = \beta_0 + X\beta_1 + u \tag{D.1}$$

$$Var(u) = \Omega \tag{D.2}$$

Multiply both sides by C such that the variance of u becomes a diagonal matrix, Σ.

$$CY = C\beta_0 + CX\beta_1 + Cu \tag{D.3}$$

$$Var(Cu) = \Sigma \tag{D.4}$$

I can write Ω as a combination of Σ and r, which is a non-zero matrix.

$$\Omega = r\Sigma \tag{D.5}$$

I find that C must satisfy Equation (D.13).

$$Var(Cu) = E(Cuu'C'|X) \tag{D.6}$$

$$\Sigma = E(Cuu'C'|X) \tag{D.7}$$

$$\Sigma = CE(uu'|X)C' \tag{D.8}$$

$$\Sigma = CVar(u)C' \tag{D.9}$$

$$\Sigma = C\Omega C' \tag{D.10}$$

$$\Sigma = C(r\Sigma)C' \tag{D.11}$$

$$I = CrC' \tag{D.12}$$

$$C'C = r \tag{D.13}$$

Appendix E
Test for optimal lags

Table E.1: Endogenous lag test

	Endogenous lags
Akaike Info Criterion	2
Final Prediction Error	2
Hannan-Quinn Criterion	2
Schwarz Criterion	2

Table E.2: Test for autocorrelation in residuals with 1 endogenous lag

LM statistic	512.9434
p-value	0
df	128
LMF statistic	5.9856
p-value	0
df1	128
df2	1505

Note: Test uses 1 lag

Table E.3: Test for autocorrelation in residuals with 2 endogenous lags

LM statistic	77.5502
p-value	0.1189
df	64
LMF statistic	1.1452
p-value:	0.2073
df1	64
df2	1194

Note: Test uses 1 lag

Appendix F
Reduced form estimation

Table F.1: Reduced form equations

Commodity(t-1)	1.299	—	0.002	-0.001	-0.007	0.033	-0.151	-0.01
	(0.000)	( )	(0.493)	(0.734)	(0.369)	(0.925)	(0.026)	(0.567)
FFR (t-1)	0.087	0.924	0.006	-0.114	0.07	-10.087	0.528	0.256
	(0.546)	(0.000)	(0.916)	(0.113)	(0.607)	(0.095)	(0.611)	(0.405)
Retail (t-1)	—	—	1.74	-0.024	-0.001	-2.729	0.567	0.379
	( )	( )	(0.000)	(0.626)	(0.994)	(0.516)	(0.432)	(0.076)
Inflation(t-1)	1.189	—	-0.06	1.504	-0.013	4.522	-0.398	-0.049
	(0.132)	( )	(0.147)	(0.000)	(0.892)	(0.283)	(0.631)	(0.818)
Mortgage (t-1)	—	—	-0.11	0.052	1.119	3.45	-0.733	0.283
	( )	( )	(0.000)	(0.124)	(0.000)	(0.227)	(0.136)	(0.052)
Interest (t-1)	0.044	-0.002	-0.001	0.002	0	1.243	-0.007	0
	(0.000)	(0.003)	(0.252)	(0.009)	(0.887)	(0.000)	(0.531)	(0.915)
Exchange (t-1)	-0.159	—	-0.001	-0.003	0.001	1.675	0.924	-0.001
	(0.027)	( )	(0.743)	(0.560)	(0.915)	(0.000)	(0.000)	(0.954)
HPI (t-1)	—	—	0.013	-0.01	0.017	1.668	-0.02	1.374
	( )	( )	(0.270)	(0.478)	(0.527)	(0.152)	(0.922)	(0.000)
Commodity(t-2)	-0.32	0.002	-0.003	0.006	-0.002	-0.086	0.122	-0.004
	(0.000)	(0.005)	(0.375)	(0.152)	(0.800)	(0.803)	(0.072)	(0.830)
FFR (t-2)	—	0.079	-0.025	0.109	-0.074	9.268	-0.025	-0.183
	( )	(0.209)	(0.679)	(0.133)	(0.596)	(0.131)	(0.981)	(0.557)
Retail (t-2)	—	0.001	-0.766	0.022	-0.046	0.675	-0.719	-0.332
	( )	(0.600)	(0.000)	(0.653)	(0.621)	(0.870)	(0.311)	(0.114)
Inflation(t-2)	-1.153	—	0.108	-0.648	0.054	-6.599	-0.055	0.089
	(0.141)	( )	(0.008)	(0.000)	(0.566)	(0.112)	(0.946)	(0.675)
Mortgage (t-2)	—	—	0.118	-0.056	-0.105	-3.019	0.796	-0.259
	( )	( )	(0.000)	(0.105)	(0.114)	(0.300)	(0.111)	(0.081)
Interest (t-2)	-0.039	0.002	0	-0.002	0	-0.279	0.011	-0.001
	(0.000)	(0.001)	(0.771)	(0.040)	(0.827)	(0.000)	(0.354)	(0.862)
Exchange (t-2)	0.227	-0.007	0.001	-0.002	-0.01	-1.382	-0.008	-0.008
	(0.002)	(0.000)	(0.792)	(0.716)	(0.253)	(0.000)	(0.913)	(0.687)
HPI (t-2)	—	—	-0.007	0.016	-0.004	-0.96	0.058	-0.435
—	( )	( )	(0.507)	(0.232)	(0.887)	(0.404)	(0.769)	(0.000)
CONST	-21.857	1.34	13.74	4.466	28.516	1033.298	90.235	-42.932
	(0.002)	(0.059)	(0.001)	(0.357)	(0.002)	(0.011)	(0.198)	(0.038)

Note: The first row for each lag variable indicates the coefficient estimate. The second row for each lag variable indicates the p-value. Some estimators have zero restrictions as seen by the dashed lines.

Appendix G
Estimation statistics for A_0

Table G.1: ML test for overidentification

Log Likelihood	-192.488
LR Test:	5.0177
Prob	0.7557

Structural VAR is over-identified with 8.0000 degrees of freedom

Figure G.1: Estimated standard errors for A_0

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0035 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0037 & 0 & 0 & 0 & 0.1606 & 0 & 0 & 0.0142 \\ 0.004 & 0 & 0.0829 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.8157 & 0 & 0 & 2.2125 & 0 & 0 \\ 0.7092 & 0.3963 & 0 & 0 & 1.4105 & 0 & 1.4061 & 0 \\ 0.2233 & 5.7689 & 22.7854 & 4.2448 & 25.2785 & 49.115 & 0 & 0 \\ 0 & 0 & 0 & 0.2702 & 0 & 0.3311 & 0 & 0 \end{bmatrix}$$

Appendix H
Counterfactual impulse responses

Figure H.1: Direct effect counterfactuals

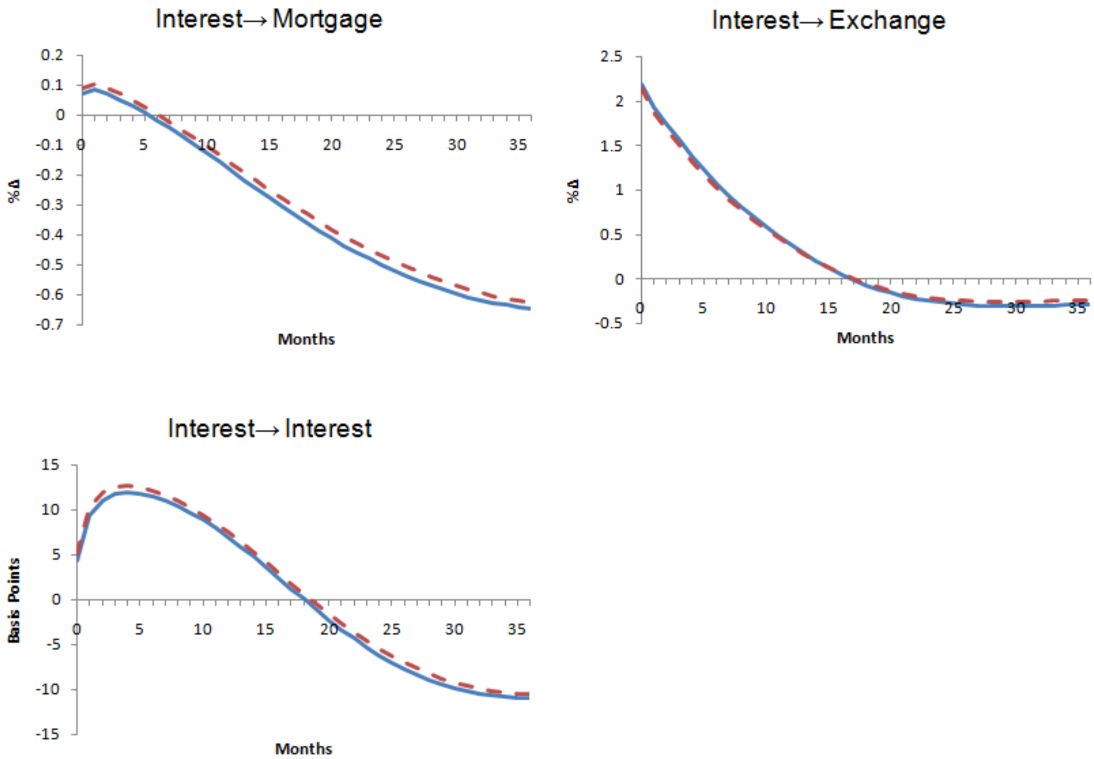
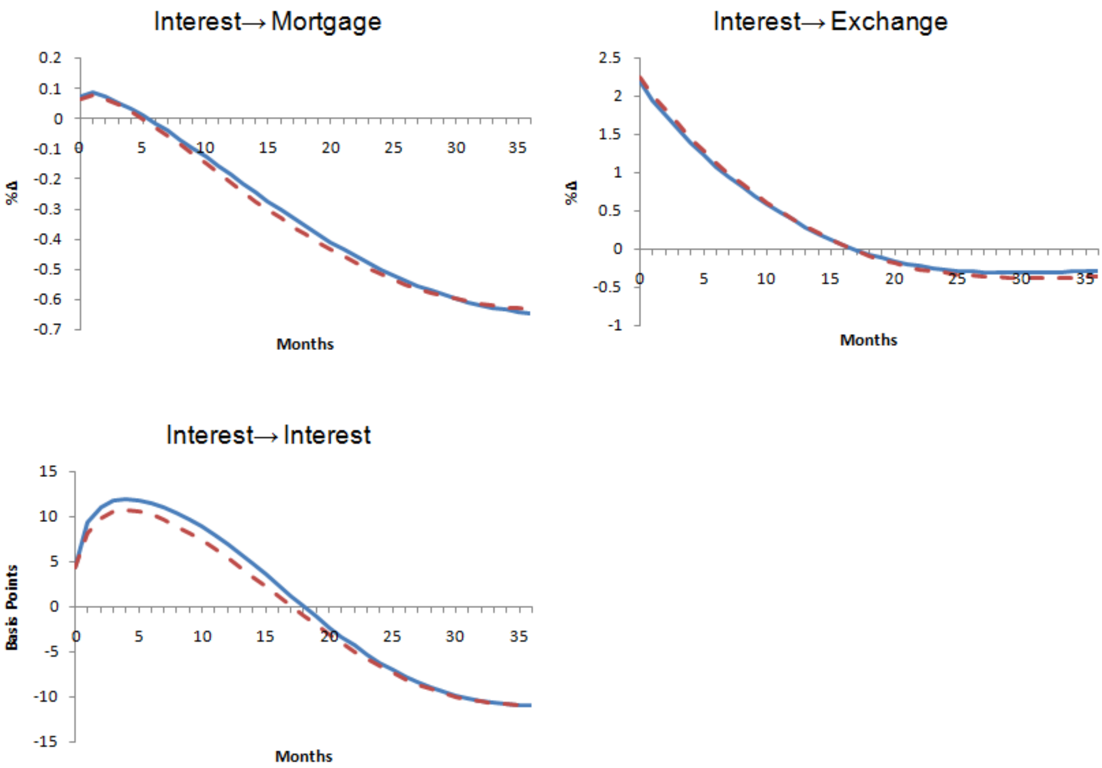


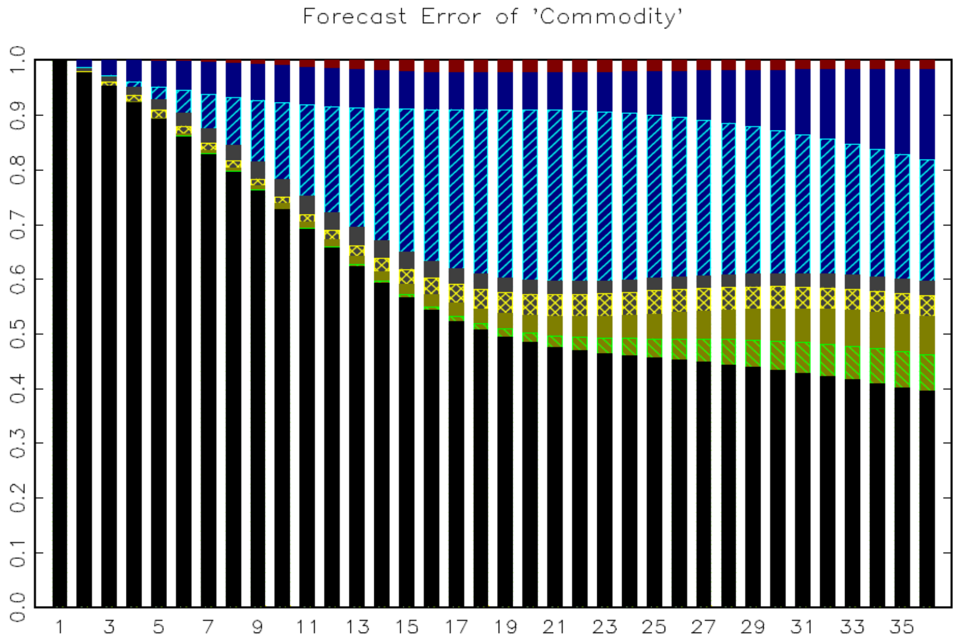
Figure H.2: Indirect effect counterfactuals

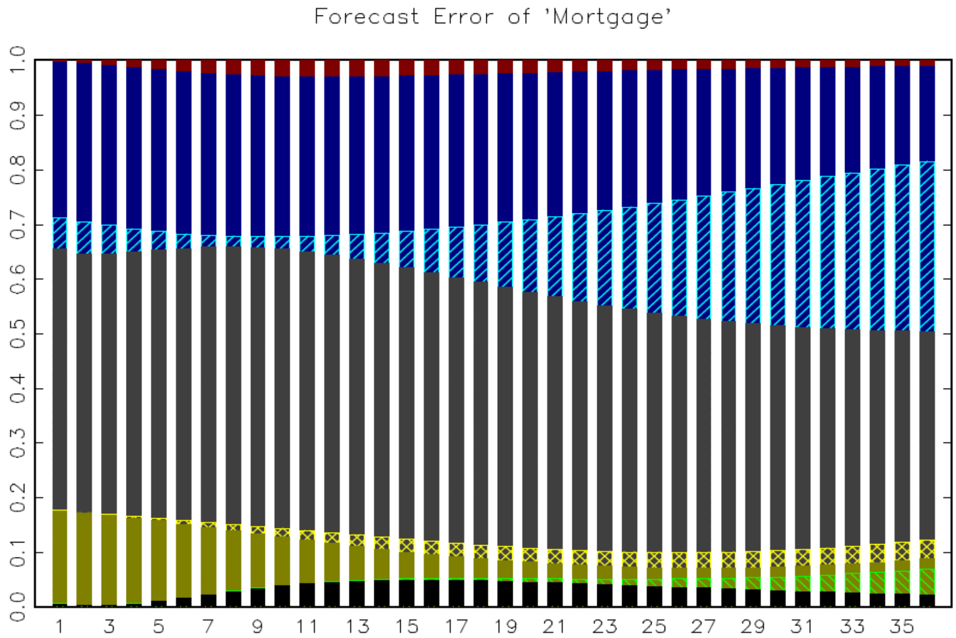


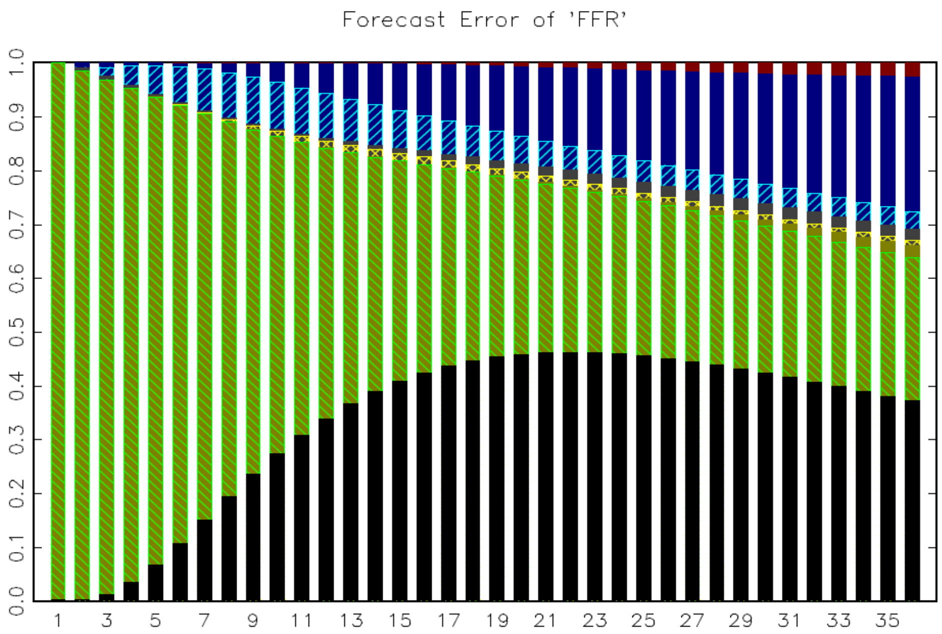
Appendix I

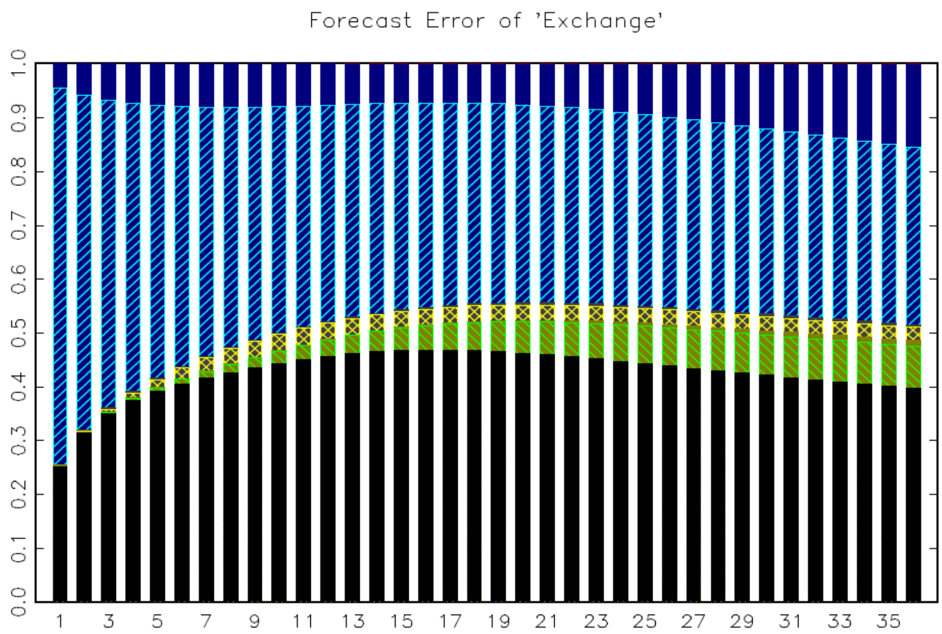
Forecast error variance decompositions

Figure I.1: FEVD





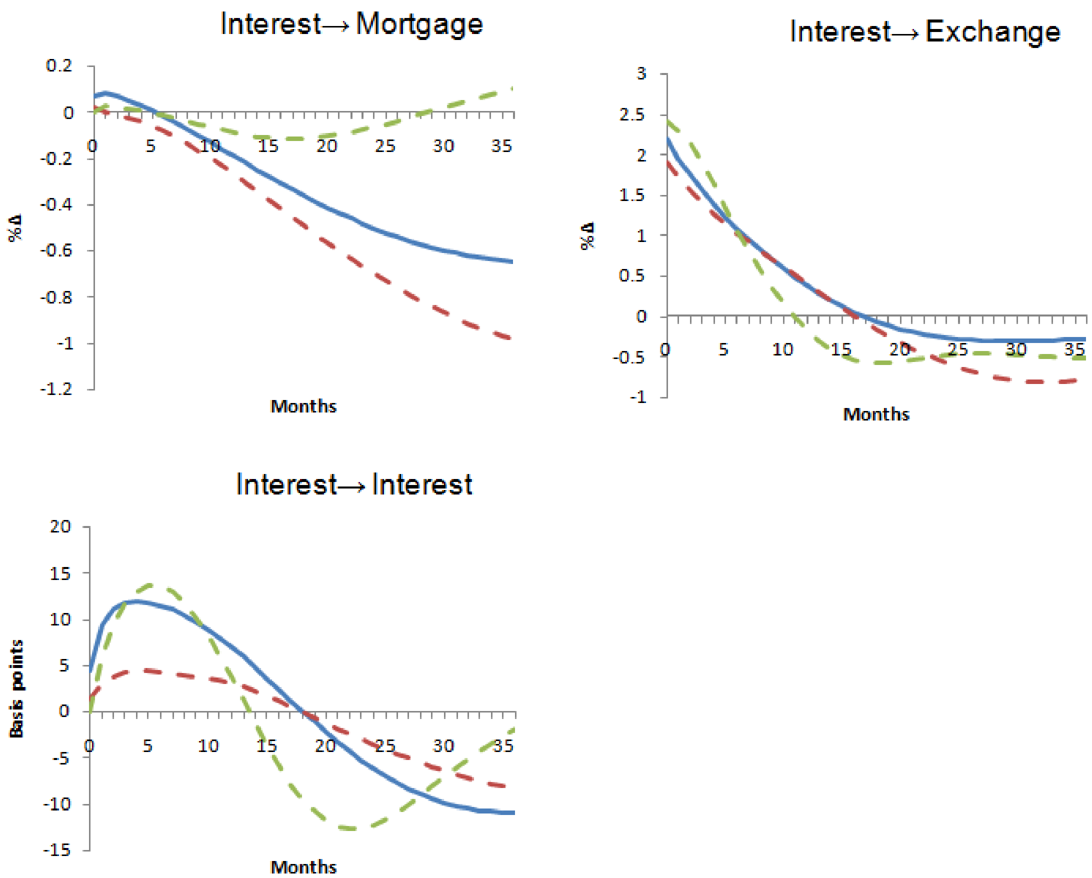

Forecast Error of 'FFR'
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35


Forecast Error of 'Exchange'
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35

Appendix J

Breakpoint test impulse responses

Figure J.1: Impulses responses



Bibliography

Ando, A. and F. Modigliani (1963). The" life cycle" hypothesis of saving: Aggregate implications and tests. *The American economic review 53*(1), 55–84.

Belsky, E. (2004). *Housing wealth effects: housing's impact on wealth accumulation, wealth distribution and consumer spending.* Joint Center for Housing Studies, Harvard University.

Bernanke, B., M. Gertler, and S. Gilchrist (1994). The financial accelerator and the flight to quality. Technical report, National Bureau of Economic Research.

Bernanke, B. S., A. S. Blinder, et al. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review 82*(4), 901–21.

Bernanke, B. S., J. Boivin, and P. Eliasz (2004). Measuring the effects of monetary policy: a factor-augmented vector autoregressive (favar) approach. Technical report, National Bureau of Economic Research.

Bernanke, B. S. and M. Gertler (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives 9*(4), 27–48.

Bjrnland, H. C. and K. Leitemo (2005, May). Identifying the Interdependence between US Monetary Policy and the Stock Market. Memorandum 12/2005, Oslo University, Department of Economics.

Brischetto, A., G. Voss, et al. (1999). *A structural vector autoregression model of monetary policy in Australia.* Citeseer.

Cooray, A. et al. (2002). The fisher effect: A review of the literature. Technical report, Macquarie University, Department of Economics.

Craine, R. and V. L. Martin (2008). International monetary policy surprise spillovers. *Journal of International Economics 75*(1), 180–196.

Cuche, N. A. and M. K. Hess (2000). Estimating monthly gdp in a general kalman filter framework: evidence from switzerland. *Economic and Financial Modelling 7*(4), 153–194.

Cushman, D. O. and T. Zha (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary economics 39*(3), 433–448.

DiPasquale, D. and W. C. Wheaton (1994). Housing market dynamics and the future of housing prices. *Journal of urban economics 35*(1), 1–27.

Dufty-Jones, R. and D. Rogers (2015). *Housing in 21st-Century Australia: People, Practices and Policies*. Ashgate Publishing, Ltd.

Eichanbaum, E. and L. Charles (1995). Some empirical evidence on the effects of shocks to monetary policy on exchange rate. *The Quarterly Journal of Economics*, 975–1009.

Elbourne, A. (2008, March). The UK housing market and the monetary policy transmission mechanism: An SVAR approach. *Journal of Housing Economics 17*(1), 65–87.

Faust, J. and E. M. Leeper (1997). When do long-run identifying restrictions give reliable results? *Journal of Business & Economic Statistics 15*(3), 345–353.

Gerlach, S., K. Assenmacher-Wesche, et al. (2008). Financial structure and the impact of monetary policy on asset prices. Technical report, Center for Financial Studies (CFS).

Gerlach, S. and F. Smets (1995). The monetary transmission mechanism: evidence from the g-7 countries.

Giannini, C. et al. (1991). Topics in structural var econometrics. Technical report.

Gospodinov, N., A. M. Herrera, and E. Pesavento (2013). Unit roots, cointegration and pre-testing in var models.

Kelly, J.-F., J. Hunter, C. Harrison, and P. Donegan (2013). Renovating housing policy. *Grattan Institute, Melbourne*.

Kim, S. and N. Roubini (2000). Exchange rate anomalies in the industrial countries: A solution with a structural var approach. *Journal of Monetary Economics 45*(3), 561–586.

Knoll, K., M. Schularick, and T. M. Steger (2014). No price like home: Global house prices, 1870-2012.

Kohler, M., A. Rossiter, et al. (2005). *Property owners in Australia: a snapshot*. Citeseer.

Kohler, M., M. Van Der Merwe, et al. (2015). Long-run trends in housing price growth.

Mishkin, F. S. (1996). The channels of monetary transmission: lessons for monetary policy. Technical report, National Bureau of Economic Research.

Mishkin, F. S. (2007). Housing and the monetary transmission mechanism. Technical report, National Bureau of Economic Research.

Romer, C. D. and D. H. Romer (1989). Does monetary policy matter? a new test in the spirit of friedman and schwartz. In *NBER Macroeconomics Annual 1989, Volume 4*, pp. 121–184. MIT Press.

Rowley, S. and R. Ong (2012). Housing affordability, housing stress and household wellbeing in australia.

Sims, C. A. (1992). Interpreting the macroeconomic time series facts: The effects of monetary policy. *European Economic Review 36*(5), 975–1000.

Sims, C. A., A. J. Rolnick, and W. E. Weber (1986). Are forecasting models usable for policy analysis. In *Quarterly Review, Federal Reserve Bank of Minneapolis.* Citeseer.

Sims, C. A., J. H. Stock, and M. W. Watson (1990). Inference in linear time series models with some unit roots. *Econometrica: Journal of the Econometric Society*, 113–144.

Sims, C. A. and T. Zha (2006, April). Does Monetary Policy Generate Recessions? *Macroeconomic Dynamics 10*(02), 231–272.

Stroebel, J. and J. Vavra (2014). House prices, local demand, and retail prices. Technical report, National Bureau of Economic Research.

Woodford, M. (2008). How important is money in the conduct of monetary policy? *Journal of Money, credit and Banking 40*(8), 1561–1598.

Yates, J. (2008). Australia's housing affordability crisis. *Australian Economic Review 41*(2), 200–214.