DEAKIN
UNIVERSITY AUSTRALIA

Faculty of Business and Law
School of Accounting, Economics and Finance

School Working Paper

ECONOMICS SERIES

SWP 2009/22

An SVAR Analysis of Monetary Policy Dynamics and Housing Market Responses in Australia

IKM Mokhtarul Wadud
Omar HMN Bashar
Huson Joher Ali Ahmed

An SVAR Analysis of Monetary Policy Dynamics and Housing Market Responses in Australia

IKM Mokhtarul Wadud[ℜ]

Omar HMN Bashar[♣]

Huson Joher Ali Ahmed[♠]

Abstract: This paper examines the impact of monetary policy and a range of sector-specific and macroeconomic shocks on the Australian housing market using quarterly data for a period of 1974-2008. The paper develops a structural vector autoregressive (SVAR) model based on contemporaneous restrictions to analyse the dynamics of these shocks. The results indicate that supply of new houses in Australia rises with higher real house prices; and that house prices rise and fall with higher inflation rate and interest rate, respectively. Dynamics of the impulse responses reveal significant effect of monetary policy on new house constructions, real house prices, material costs and inflation. Results also suggest that housing output, real house prices and interest rates respond significantly to shocks to housing supply, housing demand and to a number of other variables. These results are expected to shed some lights on the current policy environment pertaining to the Australian housing sector.

Keywords: Monetary transmission, Housing market, Structural VAR

JEL Classification: R31, E52, E62, C51

[ℜ] School of Accounting, Economics and Finance, Deakin University, Pigdons Rd., Waurn Ponds, Geelong, Victoria 3217, Australia. Tel +61 3 52272051, Email: Mokhtarul.wadud@deakin.edu.au

[♣] Corresponding author. School of Accounting, Economics and Finance, Deakin University, Pigdons Rd., Waurn Ponds, Geelong, Victoria 3217, Australia. Tel +61 3 52272132, Email: Omar.bashar@deakin.edu.au

[♠] School of Accounting, Economics and Finance, Deakin University, Pigdons Rd., Waurn Ponds, Geelong, Victoria 3217, Australia. Tel +61 3 52273381, Email: huson.aliahmed@deakin.edu.au

1. Introduction

Monetary transmission effect on the housing sector has been an outstanding issue and a major area of interest to researchers in recent years. The role the housing sector in any economy and the welfare implications of improved housing affordability have been well documented in the literature (Mishkin, 1996, 2007; Fry et al., 2009; Vargas-Silva, 2008; McCarthy and Peach, 2002). However, the effects of policy strategies on the housing market do not seem to be readily predictable in view of differences in response patterns of various sector specific and macroeconomic variables. In particular, the effects of monetary policy on the housing market have been subject to scrutiny due to the existence of a number of direct and indirect transmission channels (Mishkin, 2007). Housing is generally considered as more interest-sensitive than the economy as a whole and the degree of such sensitivities can vary through time and across countries (Berger-Thomson and Ellis, 2004). Over the last few decades, the Australian housing sector has expanded significantly with high price and demand growth, much unlike many other developed economies of comparable socio-economic setting including the UK, Canada and the US. The consequences of high price growth in Australian housing sector have been observed in terms of declining age-specific home ownership rates for younger households from the 1970s and increased affordability problems.[1] Yates (2008) suggested that an effective solution to housing affordability problems lie in addressing the underlying demand and supply factors as well as in directing policies to increase the supply of affordable rental housing. To assist with home ownership and to promote residential investment, the Australian Federal government and the state governments made concerted efforts in the form of concessions provided by the governments and public expenditure to support housing.[2]

While high house price growth and the government's fiscal measures to support the housing sector in Australia have been of some concerns, the monetary transmission in Australian

[1] From 1960 to 2006, real house prices increased at an average rate of 2.7 per cent per annum, outweighing the 1.9 per cent per annum growth in per household real income (Yates, 2007 & 2008). Otto (2007) suggested that the growth in real house prices could be attributed to the combined effect of the growth in per household real incomes and the growth in number of households.

[2] Estimates reveal that the total government expenditure on housing and community increased more than ten times in 2009 over its 1974 levels. Some of the major government policies included introduction of a new capital gain tax in 1985, a concessionary arrangement in the existing capital gain tax in 1999 and The first home owners grant (FHOG) in July 2000, funded by both the Federal and the state governments, to compensate for increases in building and housing costs associated with the implementation of the goods and services tax (GST) Despite the apparent appeal of the FHOG, the scheme has been criticised by some authors as the scheme tends to increase the house prices and distort equitability (Wood et al, 2006).

housing has been subject to limited research. In view of the strategic impact of monetary policy on house prices, affordability of housing and housing output driven by the market dynamics, much of the underlying behaviour of the Australian housing market could be explained through the monetary policy transmission mechanism. The Reserve Bank of Australia (RBA) pursued monetary contraction in the 1970s and in the 1980s, followed by phases of expansions beginning from the early 1990s. Over the 2000s, the RBA continued its inflation targeting strategies with a view to stabilising the economy.[3] For the Australian housing market though, while the reduced interest rates lowered the costs of borrowing boosting demand; high growth of house prices adversely affected the home buyers. In addition, there seems to be perceived disruption in the Australian monetary transmission mechanism in recent years, with the commercial banks inadequately responding to the RBA's reduced interest rates. However, the overall efficacies of monetary policies are discernible through the transmission of the monetary shocks affecting a range of housing market factors including demand, supply, material cost and prices (Mishkin, 2007).

Despite a plethora of studies available examining the housing market response to a variety of fiscal measures (Wood et al., 2006; Wood, 1999; Yates, 2008; Dvornak and Kohler, 2003), there seems to an absolute dearth of studies addressing issues of monetary transmission in Australian housing. A major contribution to the monetary transmission and housing literature in the Australian context known to date has been made by Fry et al. (2009). However, this study was limited to examining the wealth and monetary policy effect on the overvaluation in Australian housing and equity markets. In this paper, we attempt to exclusively analyse the Australian housing with a broader set of objectives and by integrating the monetary transmission mechanism with a number of housing market and macroeconomic variables.

The major objectives of the study are: Firstly, to examine the dynamic effects of monetary policy on the house prices and housing output in Australia; Secondly, to analyse the major factors explaining housing demand and supply; Thirdly, to analyse the reaction of monetary policy to the housing market shocks; and Fourthly, to examine how shocks to various macroeconomic variables affect house prices and housing output. Hence, this study

[3] The RBA adopted its inflation targeting policies in the 1990s during the monetary expansion of the decade. To weather the impact of the global financial crisis, the RBA reduced its cash rate target to 4.25 per cent by the end of 2008 and to 3.25 per cent in 2009. The RBA raised interest rates from around 8 to 10 per cent in the 1970s to about 18 per cent by the end of the 1980s. This was followed by monetary expansions as the RBA lowered interest rates from about 11 per cent in the early 1990s to about 5 per cent by the end of the century.

essentially adopts a more holistic approach compared to the Fry et al. (2009) study, by examining the dynamics of a number of sector specific, macroeconomic and policy variables using a simple housing market model. We develop a structural vector autoregressive (SVAR) model for Australian housing and analyse the effect of monetary policy, inflation and a number of other market factors. The approach entails an examination of the policy efficacies including those revealed through the monetary transmission channels as well as an analysis of the dynamic interdependence and contemporaneous relationships involving a range of macroeconomics and housing market variables. In particular, the model developed herein disentangles the effects (external, demand and supply shock, monetary policy shock, fiscal policy shocks) in a structural form with an emphasis on analysing how monetary transmission affects house price, housing demand, housing supply, raw material cost, inflation and exchange rate through various channels.

The results indicate that in the short run the supply of new residential houses increases with the increase in real house prices. Also, the real house price increases with higher inflation rate, and falls with higher interest rate. Evidences from the impulse responses show that a contractionary monetary shock significantly affects number of new houses, real house prices, material costs, housing output, inflation rate and interest rates. Also, shocks in housing demand, housing supply, inflation rates, material costs and exchange rates significantly affect housing output. Further, real house prices respond significantly to shocks in real output, housing supply and housing demand. Significant responses of the interest rates are also observed to shocks to inflation rate, government expenses, housing demand, housing supply, material costs and foreign interest.

The rest of the paper is structured as follows: Section Two discusses the theoretical and empirical literature on monetary transmission effect on housing market. The model based on a structural VAR framework used in this study has been presented in Section Three. Section Four discusses the empirical findings and Section Six concludes highlighting some implications of our results.

2. Monetary transmission effect and the housing market

Mishkin (1996) provides a comprehensive analytical framework on how the effects of monetary policy are transmitted through various channels. These channels show the direct effects on the user cost on housing capital, expectations of future house-price movements, and housing supply; as well as the indirect impact on housing output through standard wealth effects, credit-channel effects on consumer spending, and credit-channel effects on housing demand. Figure 1 provides a diagrammatic representation of the direct and indirect transmission channels of monetary policy affecting the housing market.[4]

One of the direct effects of monetary policy is transmitted on to the user cost on housing, defined as an opportunity cost of occupying a house rather than renting. If the opportunity cost of owning a house is lower than renting, demand for housing activities is likely to decline.[5] A simple analogy that can be drawn out of this context is that when monetary policy raises the short-term rate, long-term rate also tends to rise driven by expectations of future increase in the short-term rate; and hence, the average mortgage rate also raises leading to higher user cost of capital on housing (Figure 1). Therefore, there will be a fall in demand for housing, which in turn would lead to a decline in housing construction and prices thereby lowering aggregate demand in the economy (Mishkin, 2007).

The expected real rate of appreciation in housing price provides another way for monetary policy to affect housing activity. As pointed out earlier, the tightened monetary policy softens housing price because the demand for housing decline through user cost of transmission. To illustrate further, expectation of tightening monetary policy may likely lead to much lower real rate of house price appreciation through rising user cost of housing, subsequently leading to lower demand for housing activities. Case and Shiller (2003) have emphasized that changes in these expectations can have an effect on the user cost of capital and thus on housing demand.

---

[4] Note that Figure 1 is a concise representation of the broad picture of monetary transmissions mechanism as it shows the transmission channels affecting the housing sector only and not the macroeconomic variables.

[5] The user cost of housing is illustrated through the following equation:

$$\boldsymbol{UC} = \mathrm{P}h\,[\{(1\text{-}t)i - \pi^{e}\} - \{\pi_{h}^{e} - \pi^{e}\} + \delta],$$

where Ph is the relative purchase price of new house, $\{(1\text{-}t)i - \pi^{e}\}$ is the after tax real mortgage rate as a form of cost of borrowing, $\{\pi_{h}^{e} - \pi^{e}\}$ is real house price appreciation, δ is the depreciation rate for housing, i is the mortgage rate, π_{h}^{e} is the expected rate of appreciation of housing price and π^{e} represents the expected rate of inflation. Therefore, user cost of capital on housing depends on two important parameters namely after tax real interest rate and expected appreciation of housing price.

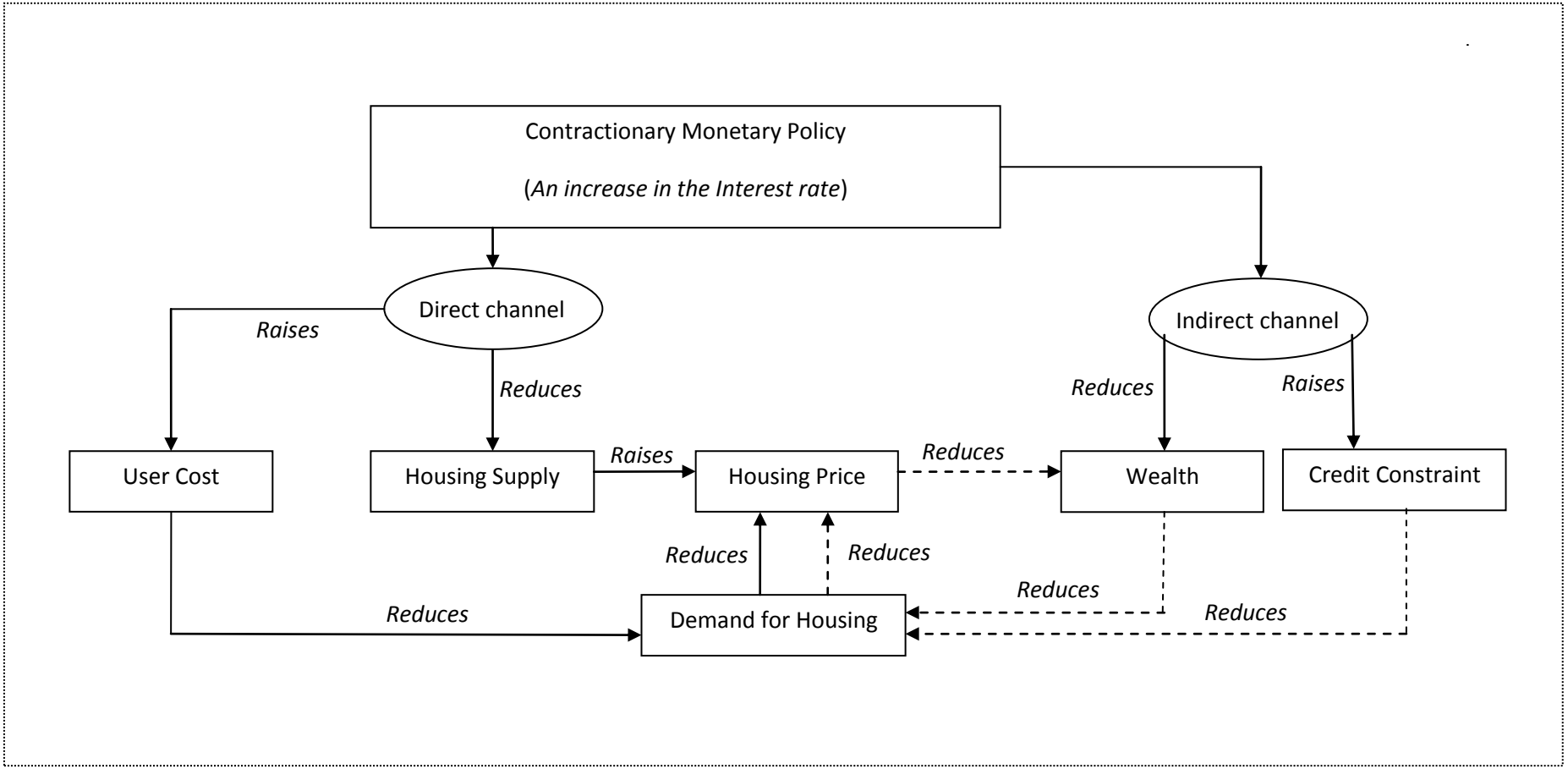


Figure 1: Monetary Transmission Channels and the Housing Market

From the supply side perspective, any increase in short term interest rate may have an immediate impact on housing construction cost, thereby housing output. Thus any increase in policy interest rate is likely to influence housing activities. These types of arguments are supported by McCarthy and Peach (2002).

It is understandable that the fall in real house prices due to lower demand for housing as a result of contractionary monetary policy will lead to a decline in asset (wealth) for individuals. The fall in individuals' wealth (negative wealth effect) would further reduce housing demand leading to lower housing prices (Figure 1). In turn, individuals' wealth too declines lowering household consumption and demand for housing.

Households might be credit constrained which may affect housing demand[6]. Credit-constrained households are those whose expenditure exceeds their revenue. Therefore, any increase in short-term rates leads to interest burden of the households and reduces their cash flow. Mishkin (2007) suggests that the relationship leads to two possible credit channels. The first channel is through which the nominal, and not just real, interest rate can affect housing demand. Higher nominal rates, even when real interests rates remain unchanged, reduce current cash flow due to increase in mortgage rate will lower after interest and tax income as results lowering cash flow. Hence subsequent decline in the demand for housing will be expected. From credit channel perspective, the central problem that limits the demand and supply of housing is the result of tight credit market due to asymmetric information between potential house buyer and financial institution (Mishkin, 2007). Lenders are reluctant to make loans because they have difficulties identifying the credit worthiness of the borrower. This can be analysed from two perspectives. Firstly, the lenders are reluctant to extend the loan to prospective home loan borrower as they lack information on credit worthiness of the borrower. Secondly, once loan is extended, the borrower might undertake activities that may undermine the ability to repay the loan on time.

[6] For details on credit channel and monetary policy shocks see Bernanke and Gertler (1995).

Review of the empirical studies

There has been a vast literature on modelling housing market and various transmission mechanisms, especially in the developed economies. For the US housing market, a number of studies examined the demand shocks (Jarocirinski and Smets, 2008) and supply shocks (Ludvigson et al., 2002 and Baffoe-Bonnie, 1998). In a recent study, Vargas-Silva (2008) examined the impact of monetary policy shocks on the US housing market. Malpezzi and Maclennan (2001) estimated the long-run price elasticity of supply for new houses in the UK and the US. They estimated that in the post-war period, the price elasticity ranged between six to 13 percent for the US and between zero to one percent for the UK housing markets. Clearly, the short run elasticity of supply was lower for the UK housing market, implying that house prices are demand-driven in the short run.

Aoki et al. (2004) examined the responsiveness of UK house price to monetary policy shocks using VAR by including output, inflation, oil prices, real broad money, short term interest rate, consumer durable, and housing investment. Their findings suggest that an increase in the short term rate by 50 basis points leads to 0.8% fall in house price, and similar increase in short rate leads to 0.1% fall in price for non-consumer durable. In a similar study, Iacoviello (2002) estimated the structural VAR model for 6 European countries using identification of King et al. (1991) model. The study found that the house prices in UK fall by up to 1.5% following a 50 basis points tightening of monetary policy. However, the most important factor that was found to be affecting the house price was the aggregate demand shock.

Iacoviello and Minetti (2008) used a VAR model to examine the credit channel of monetary policy through the housing market. In their study, four different vector error correction models (VECM) and a VAR for each European market were used. They first developed a VECM to identify response to monetary policy shocks. The second VECM was used to look at the spread between mortgage rate and risk free rate; while the third and the fourth models were used to examine the external finance mix of house loan (bank and non-bank). The findings suggested that the house price decline between 0.7 to 1 per cent following 70 basis point increase in short interest rate. In a more recent study, Elbourne (2008) adopted a structural VAR model to understand the effect of change in monetary policy on consumption behaviour.[7] Using a two-step approach and a counterfactual simulation, Elbourne (2008)

[7] Elbourne (2008) used the model Kim and Roubini (2000) by including housing price.

suggested that about 12-15% of the drop in consumption on a contractionary monetary policy shock is channelled through changes in house prices.

For the Australian housing sector, Abelson et al. (2005) developed and estimated a long-run equilibrium model that shows the real income determinants of house prices and an asymmetric error correction model to represent house price change in the short run. In a related study, Dvornak and Kohler (2007) addressed the question of how changes in stock market wealth and housing wealth affect consumption expenditure in Australia. Their findings suggest that housing wealth and stock market wealth have a significant effect on consumption. Otto (2007) examined the standard economic factors to explain the growth of real house price in Australia and suggested that the variable mortgage rate is one of the important variables that affect the growth rate of house price of the capital cities in Australia. As mentioned earlier, the effect of monetary policy on housing market has been examined by Fry et al. (2009). Using a SVAR model, their estimates involved identifying the relative effect of wealth and monetary policy causing overvaluation in the Australian housing and equity markets. Their findings suggest that while the wealth effects from portfolio shocks in equity markets have been important drivers for overvaluation in Australian housing, the effects from monetary policy have been trivial. Their also found that the some of the important factors driving the overvaluation of Australian housing include the housing shocks arising from housing demand, the goods market shocks arising from aggregate demand and the aggregate supply shocks. They showed that the overvaluation in pre-2006 period is dominated by the housing demand shock while the overvaluation in post-2006 period is dominated by goods market shocks transmitting through changes in aggregate demand and aggregate supply.

In this paper, we have used a structural VAR model of Australian housing market with a view to examining the effect of monetary policy through user cost, expected price appreciation, housing output, and credit channels. This paper also evaluates the contemporaneous relationship and shock transmission mechanism involving a number of other variables including housing demand, housing supply and costs, thereby shedding further lights on Australia's housing policy environment. Hence, on empirical grounds, the scope and policy implications emanating from the study are expected to surpass those of Fry et al. (2009). Further, this study provides additional insights for the Australian housing market compared to Elbourne's (2008) study. While Elbourne (2008) examined the price shocks in the UK housing market, the market forces behind such shocks were not identified. In this study, price

shocks are clearly separated to have originated from demand and supply of Australian housing.

3. Econometric Modelling

The structural VAR modelling requires a prudent choice of variables for inclusion in the model reflecting the theories and the empirical objectives. Hence, in the VAR model we mainly included the variables that play crucial role in Australian housing market. In particular, a demand and a supply equation for Australian housing market have been specified in order to determine these important variables. A Structural VAR has the following general form:

$$\mathbf{A_0 Y_t = A_1(L) Y_t + B\varepsilon_t} \qquad [1]$$

Here $\mathbf{Y_t}$ represents *n*-vector relevant variables; $\mathbf{A_0}$ and $\mathbf{B}$ are *n x n* matrices; and $\mathbf{A_1(L) = \sum_{i=1}^{q} A_{1i} L^i}$ represents matrices polynomial in the lag operator with $\mathbf{A_{1i}}$ being an *n x n* matrix. $\boldsymbol{\varepsilon_t}$ is an *n*-vector of serially uncorrelated, zero mean structural shocks with an identity contemporaneous covariance matrix, $\mathbf{\sum_{\varepsilon} = E[\varepsilon_t \varepsilon_t'] = I}$. These structural shocks, among others, include housing demand shock, housing supply shock and monetary policy shock.

Provided that $\mathbf{A_0}$ is nonsingular, solving for $\mathbf{Y_t}$ yields the reduced form of VAR representation:

$$\mathbf{Y_t = A_0^{-1} A_1(L) Y_t + A_0^{-1} B\varepsilon_t}$$

or $$\mathbf{Y_t = C(L) Y_t + u_t} \qquad [2]$$

where $\mathbf{C(L) = A_0^{-1} A_1(L)}$

and $\mathbf{u_t = A_0^{-1} B\varepsilon_t}$

or $\mathbf{A_0 u_t = B\varepsilon_t}$ [3]

As the contemporaneous effects are not directly estimated in reduced form VAR, these effects (if any) are supposed to be included in the VAR residual terms. Thus, the residual series described by the vector $\mathbf{u_t}$ may be correlated with each other due to the contemporaneous effect of the variables across equations, although they are still presumed to be white noise.

Equation [1] is the structural model of the VAR. The reduced form represented in [2] is more familiar. The main technique involved here is to estimate equation [2] and recover the parameters and the structural shocks, $\boldsymbol{\varepsilon_t}$ in [1] from these estimates. Having identified the structural shocks, we can then find the impulse response of a variable to a one-time shock to any variable included in the model.

The main problem with this approach is of identification since the number of parameters that need to be estimated in the structural model is larger than that of the estimated reduced form model. In order to solve the identification problem, restrictions are typically imposed on the elements of $\mathbf{A_0}$ and/or **B.** In our analysis, we use the contemporaneous relations in the Australian housing market, the monetary policy reaction function and the domestic and external sectors of the Australian economy in general to impose these restrictions.

The housing market model

Based on the discussions in previous two sections, we introduce following simple model for housing in Australia:

$$h_t^s = \alpha_1 mc + \alpha_2 rhp + b_{hs}\varepsilon_t^{hs} \quad [4.1]$$

$$h_t^d = \beta_1 ry_t + \beta_2 rhp_t + \beta_3 r_t + \beta_4 \pi_t + \beta_5 fr_t + \beta_6 rg_t + \beta_7 ex_t + b_{hd}\varepsilon_t^{hd} \quad [4.2]$$

$$h_t^s = h_t^d \quad [4.3]$$

where h_t^s = supply of housing, h_t^d = demand for housing, ***mc*** = housing material costs, ***rhp*** = real house price, ***ry*** = real GDP in Australia, ***r*** = short term nominal interest rate, π = inflation rate, ***fr*** = foreign interest rate, ***rg*** = real net government spending for housing, and ***ex*** = nominal exchange rate against the US dollar. Variables are expressed in VAR

residual form and all variables except r, π, and fr are in log form.[8] Here ε^{hs} and ε^{hd} represent housing supply and demand shocks, respectively.

Re-writing the equilibrium condition in [4.3] as $h_t^s = h_t^d = h$ and inverting [4.2], we may re-write the housing market equations as,

$$h_t = \alpha_1 mc_t + \alpha_2 hpr_t + b_{hs}\varepsilon_t^{hs} \quad [5.1]$$

$$rhp_t = \gamma_1 fr_t + \gamma_2 ry_t + \gamma_3 \pi_t + \gamma_4 rg_t + \gamma_5 r_t + \gamma_6 h_t + \gamma_7 ex_t + \tilde{b}_{hd}\varepsilon_t^{hd} \quad [5.2]$$

In the above model, the first equation postulates that real house price and housing raw material costs are the main determinants of housing supply in Australia. Housing demand, on the other hand, is assumed to be determined by the real income level, real house price, domestic and foreign interest rates, the inflation rate, government's net spending on housing and the exchange rate.

A higher material cost is expected to reduce the housing supply, whereas an increase in real value of houses would increase the supply of new houses. A higher income level would increase the housing demand, whereas an increase in house price would decrease the demand for housing. The effect of changes in the interest rate on housing demand may not be predicted directly. While higher interest rate is expected to reduce housing demand; demand may actually increase during the impact period if people perceive this increase in the interest rate as a signal for further increase in the rate in the future. Similarly, effect of foreign interest rate on housing demand is indeterminate. An increase in the foreign interest rate increases the returns on investment in alternative assets, which may lead to a reduction in domestic housing demand. However, foreign residents may find Australia a more attractive place to buy a house if the Australian interest rate is lower compared to the foreign interest rate, in which case, domestic demand for housing may increase. A higher level of Govt. Spending on housing is expected to increase housing demand. Like demand for any other goods, housing demand is expected to decline when inflation goes up. Currency appreciation reduces the prices of imported goods, which may increase consumers' purchasing power and hence demand for housing.

[8] These reduced form variables essentially form the vector $\mathbf{u_t}$. Details of each of the variables are presented in section 4.2.

The SVAR System and Data Description

The above model of housing market assumes that variables that influence housing demand and supply are exogenous to ***h*** and ***rhp***. But as a matter of fact, these variables may also be affected by housing supply and demand. Also note that the above equations are in residual form where the lag effects were removed from the equations. In order to explore the dynamics of the relationships and to capture the endogeneity of the variables, here we have introduced a Structural VAR model. In the VAR system we have included the variables that are important for the Australian housing market. As suggested by [5.1] and [5.2], the structural VAR system includes following nine variables[9]:

RY, Π, RG, R, MC, H, RHP, EX, FR

where

RY = Real GDP (at 1989-90 prices)

Π = Quarterly CPI inflation

RG = Real Govt. Expenditure on housing and community (at 1989-90 prices)

R = 90-day Bill Rate (quarterly average)

MC = An index for cost of materials used in housing (1989-90 =100)

H = Number of private sector housing approvals.

RHP = Real house Price Index adjusted for CPI (1989-90 = 100)[10]

EX = Exchange Rate in terms of the US dollar per unit of Australian Dollar.

FR = the US Federal Funds Rate

All variables except for *Π, R* and *FR* are expressed in natural logarithms. Quarterly data covering the period 1974Q2 – 2008Q4 have been used for the VAR estimation. The Reserve Bank of Australia (RBA) and Australian Bureau of Statistics (ABS) were the main sources of data. All data are seasonally adjusted. Wherever possible, seasonally adjusted data have been collected from the main source. We have used Census X-12 method on raw data that were not seasonally adjusted in the main source.

Following standard practice we include the variables in their levels (or log-levels) in the VAR model despite the fact that most of these variables are nonstationary. The main problem with

[9] We have used the capital letters to denote the variables. Note that in Equations 4.1 – 5.2, we used small letters to represent the reduced forms of these variables.

[10] The price index of established homes was only available from the ABS sources from the Q2, 1986. For period prior to 1986, we used the CPI housing figures.

using nonstationary variables in a VAR model is that the standard errors of the coefficients are not estimated precisely, however, VAR coefficient estimates will still be unbiased. As inference of the reduced form VAR coefficients is not our prime objective, and given the usefulness of the VAR coefficients due to their unbiasedness, there is no point transforming the variables to induce stationarity.

The whole VAR system can be decomposed into four separate blocks; namely, the domestic goods market block, the policy block, the housing market block and the external block. Goods market equations are represented by equations of ***RY*** and Π. Policy equations are described by ***RG*** and ***R***, as they are directly affected by policy actions of fiscal and monetary authorities, respectively. The housing market block comprises ***H, RHP*** and ***MC***. Finally, ***FR*** and ***EX*** are included to represent the external effects.

For choosing the lag order of the VAR system, we primarily looked at criteria like Akaike Information Criterion (AIC), Final Prediction Error (FPE), Hannan-Quinn Criterion (HQC) and Schwarz Criterion (SC). For a maximum of 10 lags, AIC suggests 10 lags, FPE suggests 2 lags, and HQC and SC suggest a lag order of one. We have chosen a lag order of two, as this was found to be the minimum lag at which residuals in each equation satisfied the white noise property. As Australia is a small open economy, it is unlikely that an Australian variable would affect the US interest rate. Considering this, we included only the own lags in the equation for ***FR***. The Feasible Generalized Least Squares method has been used to estimate this VAR system with asymmetric lag orders.

Identification

Once we estimate the VAR system, the next step is to impose restrictions on the contemporaneous relations between the reduced form VAR residuals and the structural shocks (as described by [3]). Our identification scheme is based on equation [5.1] – [5.2] as well as monetary policy reaction function and the structure of the Australian economy. This can be represented in matrix form as:

$$\begin{bmatrix} 1 & & & & & & & & \\ x & 1 & & & & & & & \\ x & x & 1 & & & & & & \\ x & x & x & 1 & & & & & \\ x & x & x & & 1 & & & & x \\ x & x & x & & x & 1 & & & x \\ & & & & & -\alpha_1 & 1 & -\alpha_2 & \\ -\gamma_1 & -\gamma_2 & -\gamma_3 & -\gamma_4 & -\gamma_5 & & -\gamma_6 & 1 & -\gamma_7 \\ x & x & x & x & x & & x & & 1 \end{bmatrix} \begin{bmatrix} fr \\ ry \\ \pi \\ rg \\ r \\ mc \\ h \\ rhp \\ ex \end{bmatrix} = \begin{bmatrix} x & & & & & & & & \\ & x & & & & & & & \\ & & x & & & & & & \\ & & & x & & & & & \\ & & & & x & & & & \\ & & & & & x & & & \\ & & & & & & x & & \\ & & & & & & & x & \\ & & & & & & & & x \end{bmatrix} \begin{bmatrix} \varepsilon^{fr} \\ \varepsilon^{ry} \\ \varepsilon^{\pi} \\ \varepsilon^{rg} \\ \varepsilon^{r} \\ \varepsilon^{mc} \\ \varepsilon^{hs} \\ \varepsilon^{hd} \\ \varepsilon^{ex} \end{bmatrix} \quad [6]$$

As mentioned before, variables in the left hand side of the system represent relevant residuals obtained in the reduced form VAR (reduced form representation of the variables). On the right hand side of the system, the nine structural innovations (**ε'**s*)* basically represent shocks to the foreign interest rate, domestic output, inflation, govt. spending on housing, monetary policy, housing material costs, housing supply, housing demand and the exchange rate, respectively.

In the above system of equations, the seventh and eighth equations simply represent the contemporaneous relations in the housing market described by [5.1]-[5.2]. For other equations we use '*x*' to denote the coefficients to be estimated. The first four variables are assumed to affect housing demand and/or supply, without any feedback effect, i.e., these variables are not assumed to be affected by housing demand or supply. These four variables are arranged recursively with the order appeared in [6]. We experimented with alternative orderings for these four variables; however, the results were largely similar to what we obtained and reported in this paper. Note that we have not attempted to disentangle the aggregate demand and supply shocks, as this is not consistent with our main objective.

The specification of the fifth equation deserves some explanation, as this represents the monetary policy reaction function. Here we have assumed that the Australian Central Bank reacts (by changing the interest rate within the same quarter) to the movements in inflation and to the changes in real output level. It is also assumed that the domestic interest rate is affected contemporaneously by the foreign interest rate and the exchange rate. To maintain the interest parity, domestic interest rate may move in the same direction of the movement in the foreign interest rate within the same quarter. Changes in the exchange rate may affect the

future expected exchange rate, which in turn may contemporaneously affect the domestic interest rate.

The sixth equation shows that the raw material costs in the housing market depend contemporaneously on domestic and foreign interest rates, real aggregate output level, inflation and the exchange rate. The last equation exhibits that the exchange rate depends on all the variables included in the model except house price and raw material costs.

4. Results

The estimated coefficients of the housing market model presented by (5.1) and (5.2) are reported in Table 1. Note that the relevant standard errors are given in parentheses. The estimated parameters in [6] are presented in Table A.1 in the Appendix.

Table1: Estimated Coefficients in the Housing Market Model

	h_t	RHP_t
α_1	-0.6037 (0.8443)	
α_2	1.5037* (0.6830)	
γ_1		0.0582 (0.1548)
γ_2		0.0444 (0.1770)
γ_3		-0.7529** (0.2450)
γ_4		0.0022 (0.0043)
γ_5		0.5913* (0.0023)
γ_6		-0.0517 (0.0868)
γ_7		0.0490 (0.0352)
b_{hs}	0.0496** (0.0034)	
$\tilde{b}_{hd}$		0.0170** (0.0023)

Note: Figures in parentheses are the relevant standard errors.
** Significant at the 1 percent level.
* Significance at the 5 percent level.

In Table 1, the coefficients for *real house price* in the first equation; and for the *domestic interest rate* and *inflation rate* in the second equation are found statistically significant. It is thus evident that in the short run real house price is the main determining factor for the number of new houses built in Australia. The positive significant value of α_2 confirms that the supply of new residential houses increases with the increase in real value of houses in the impact period. The material costs appear to exert expected negative impact on the housing supply. However, such effects are very insignificant, which implies that changes in material costs would not affect the supply of new houses in Australia. While this result is a bit anomalous on theoretical grounds, it is perceivable that empirically, growth in the construction of the new houses in Australia has not relied significantly on changes in the material costs, thereby limiting shifting of the housing supply function.

The estimates of the equation of the real house price show that the real house price increases with the inflation rate, which suggests that nominal house price increases by more than proportionately compared to an increase in the general price level. The real house price decreases with an increase in the interest rate significantly in the contemporaneous period. This finding suggests that a contractionary monetary policy may have immediate dampening effect on housing demand. Note that the estimated parameters of both the housing supply and demand shocks are highly significant. However, the housing supply shock is found more volatile than the housing demand shock, as the standard deviation of the housing supply shock (0.0496) is found much larger than the standard deviation of the housing demand shock (0.0170).

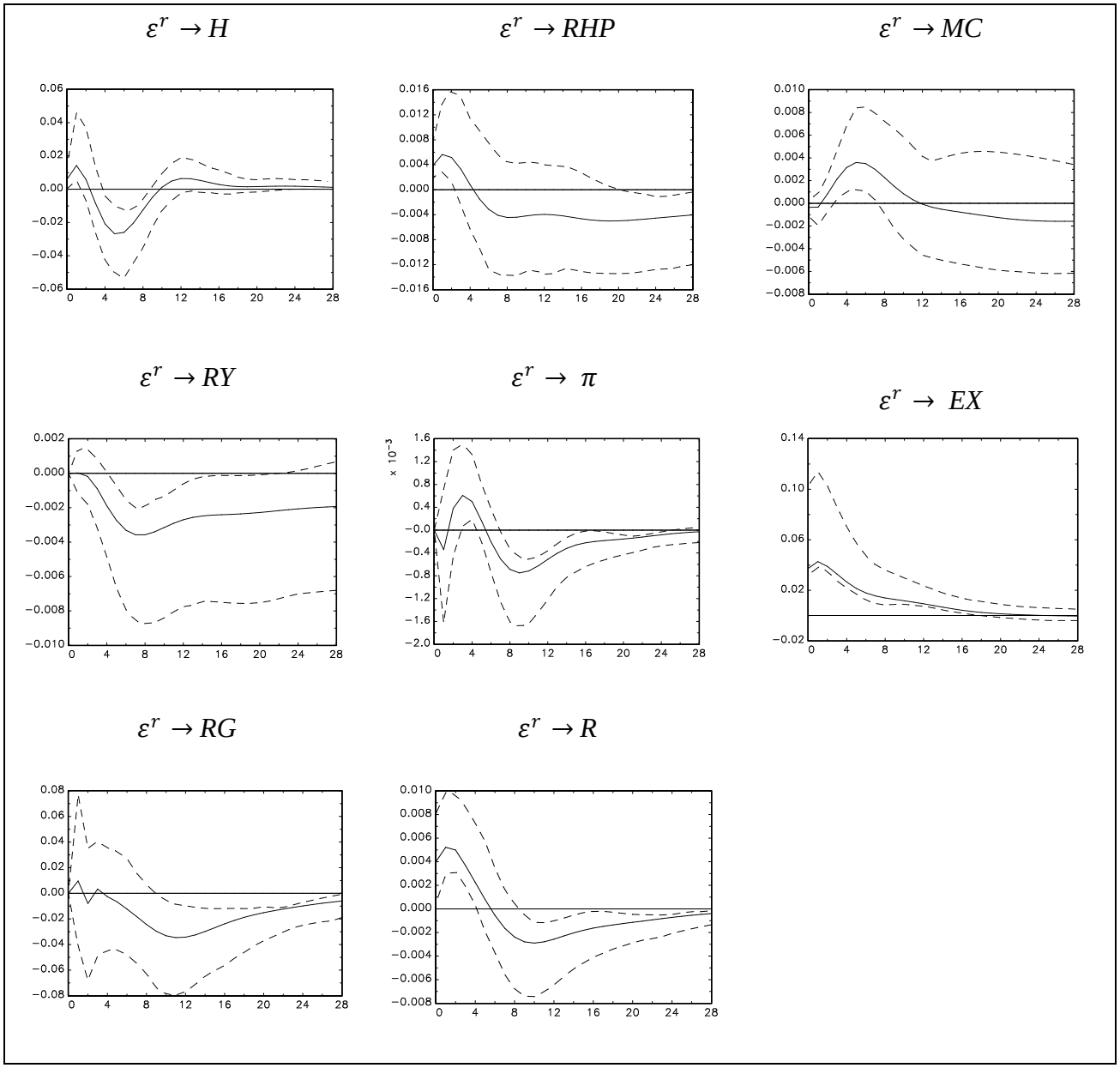
In order to examine the dynamic changes in the number of new house approvals and real house price in response to various macro shocks including the monetary policy shocks, we have estimated various impulse response functions, which are discussed in the following sections. These impulse response functions have been grouped based on shock (for monetary policy) and impulses (for other variables).

The Monetary policy shocks

We first examine the impulse responses due to monetary policy shocks, since such shocks are of significant interest to assess policy dynamics in the housing market. Figure 2 shows the impulse response functions of the interest rate shocks (contractionary monetary policy) on the

range of variables affecting the Australian housing market. As shown in the figure, a contractionary monetary shock immediately increases the number of new houses followed by a gradual decline about a year or so, lasting for a couple of years before the effect fades away.

Figure 2: Effects of Contractionary Monetary Policy



Note: The dotted lines represent the upper and the lower bands of 95% bootstrapped confidence intervals computed using 1000 repetitions of Hall's percentile method.

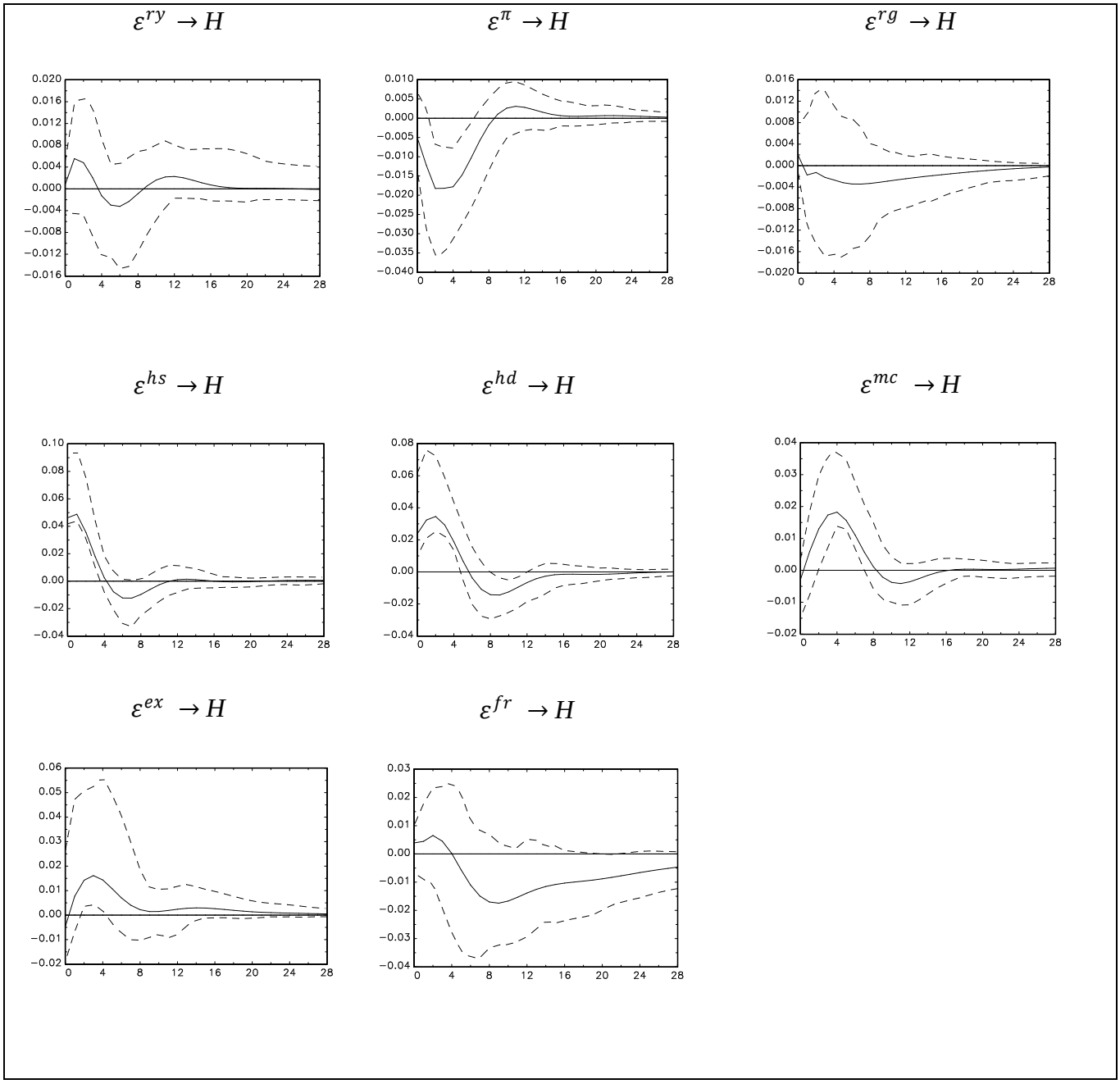
Note that despite their short lived nature, both these fluctuations are significant. The initial increase in the number of new houses could reflect the effect of expectations of further monetary contraction, positive wealth effects due to price increases with higher demand,

ongoing building contracts etc., which primarily imply increased housing output along the housing supply function. Once the impacts of these factors are realised, the housing output declines significantly, as an anticipated outcome of the monetary contraction. For similar reasons, monetary shock causes an instantaneous and significant increase in the real house prices within a year before the prices decline (Figure 2). For the UK housing market, Elbourne (2008) found that real house prices fall immediately due to monetary policy shock. Although the initial response of the real house prices in Australia contradicts with that of the UK, it is important to realise that increased house prices is typical of Australian housing market and any instantaneous increase in prices could be affected by expectations on further increases in interest rates, which in turn would put upward pressure on the real house prices. Over a longer time frame though, precisely after the 8th quarter following the shock, as shown in Figure 2, the real house prices in Australia tend to decline, presumably reflecting lower housing demand due to the user cost transmission mechanism (Case and Shiller, 2003).

The costs of materials also increase significantly with monetary policy shocks between four to eight quarters prior to their dissipations. Much of the rise in the material costs could be attributable to increased rental costs of construction equipments and reduced supply by firms producing building materials prompted by fall in investments. The responses of real output due to contractionary monetary policy shock are also well pronounced in Figure 2, as real output declines significantly with reduced aggregated demand lasting for about three years. In line with these output changes, the inflation rate also declines significantly between two to four years responding to the monetary contraction. The response of the exchange rates follows a predicted pattern, with appreciation in the Australian dollars due to increased interest rates and resultant capital inflow from overseas. While the exchange rate appreciations gradually dissipate, the process sustains for a prolonged period of about five years (Figure 2). Elbourne (2008) found similar response patterns of exchange rate to monetary shock for UK housing market. The effects of government expenditure on housing and community seem to remain trivial for a couple of years after which such responses are significantly negative and slowly tend to revert to neutrality over the next six to seven years. Essentially, this phenomenon indicates the decline in government expenses aligned with monetary contractions and the transmitted reduction in aggregate demand and economic growth, which tends to erode away over time. Lastly, the effect of monetary contraction on interest rates seems to be mostly significant. The immediate response of the interest rates is positive with the rates rising for more than a year following the policy shock. The response

eventually becomes negative and gradually weakens over years, much alike the response pattern of the public expenditure on housing.

Figure 3: Impulse Responses of Housing Output



Note: The dotted lines represent the upper and the lower bands of 95% bootstrapped confidence intervals computed using 1000 repetitions of Hall's percentile method.

The dynamics of the housing output, real house prices and interest rates

We will now examine how the other shocks may affect housing output, real house prices and the interest rates. Impulse response functions of the number of new houses to various shocks other than the monetary shocks are presented in Figure 3. It is observed that the output shock and the Govt. spending shock have insignificant effects on the number of new houses built. Both housing demand and supply shocks have an immediate positive impact on the housing output and the significant positive effects last for about four quarters. It is evident from the figure that these two shocks have only temporary impacts on housing construction.

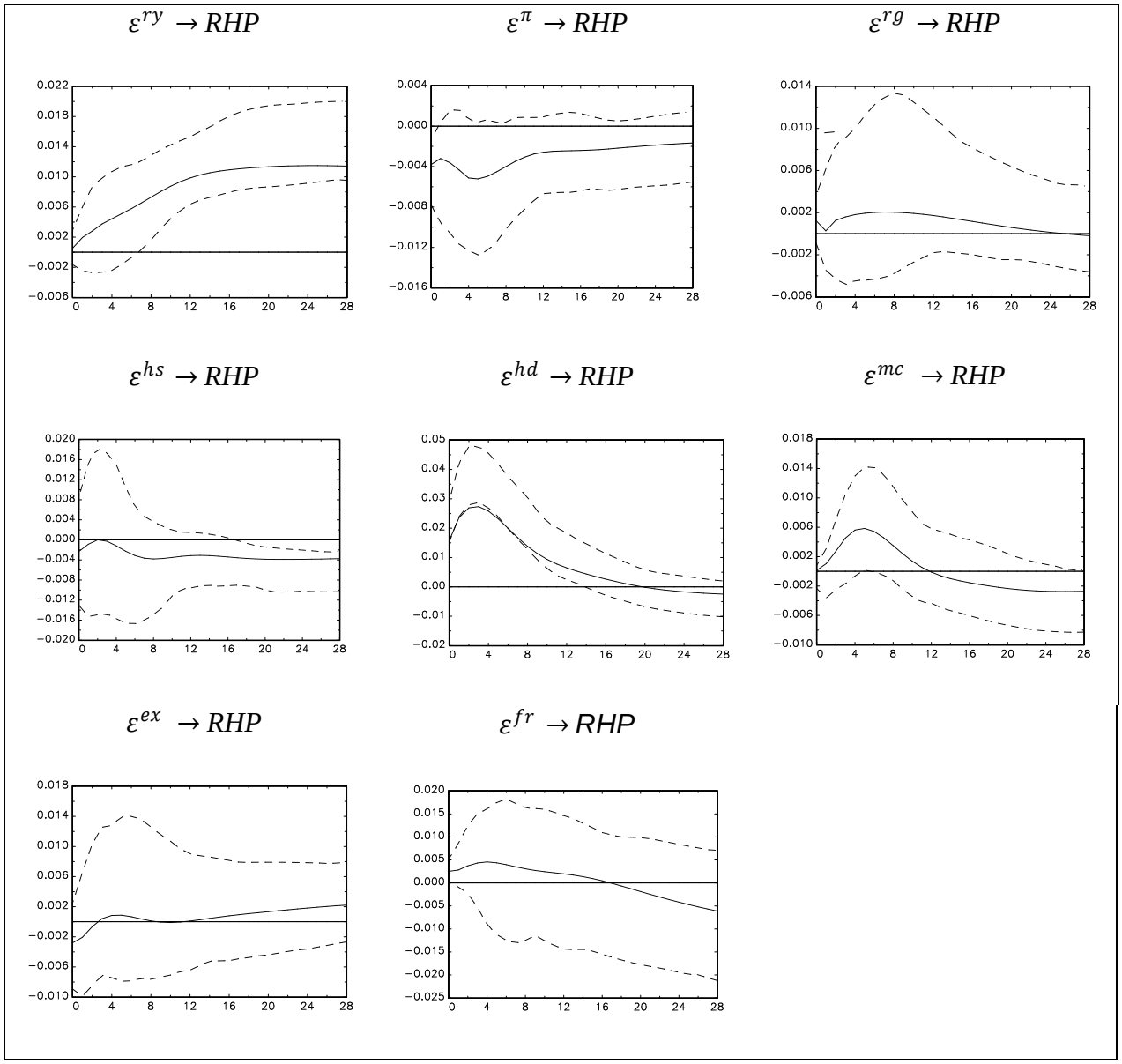
A onetime positive shock to inflation starts to influence the housing output adversely in the second quarter of the shock and the significant negative effect persists until the end of the 7th quarter. Although we didn't explicitly identify aggregate demand and supply shocks, it is apparent that the inflation shock we specify here can be comparable to an adverse supply shock. An adverse supply shock will reduce the real economic activity including the building of new houses in the economy[11].

It is interesting to observe that a positive shock to housing material costs increases the number of new houses significantly after two quarters of the shock and the effects remain significant for about five more quarters. One explanation for this is that higher material costs may reflect higher quality materials used in the housing construction. The exchange rate shock appears to have a brief significant effect on housing construction. An appreciation of Australian currency makes the imported housing materials of same quality cheaper, which may in turn increase the number of new houses built. Lastly, housing output responses to shocks in foreign interest rates seems to be insignificant (Fig. 2).

Figure-3 gives impulse responses of real house price to the various shocks. With a onetime shock in real output, the real house price increases immediately. This growth is significantly positive after the 8th quarter and stabilises at around 1 per cent after about three years. Such responses appear to be consistent with theories, since increased real output induces to higher

[11] In appendix A.1, Figure A.1a shows the impulse response functions of real output to various shocks. The negative response of output to an inflation shock confirms the idea that the identified inflation shock is dominated by the adverse supply shocks.

Figure 4: Responses of real house prices to various shocks



Note: The dotted lines represent the upper and the lower bands of 95% bootstrapped confidence intervals computed using 1000 repetitions of Halls' percentile method.

consumption demand (e.g., spending for housing) leading to increased real house price. The inflation shock, on the other hand, has negative and insignificant impact on real house price. As we know that higher price level or expectation about higher future price levels raises interest rate. This may lead to lower purchasing power, and as a consequence, demand for housing will decline putting downward pressure on the real house prices.

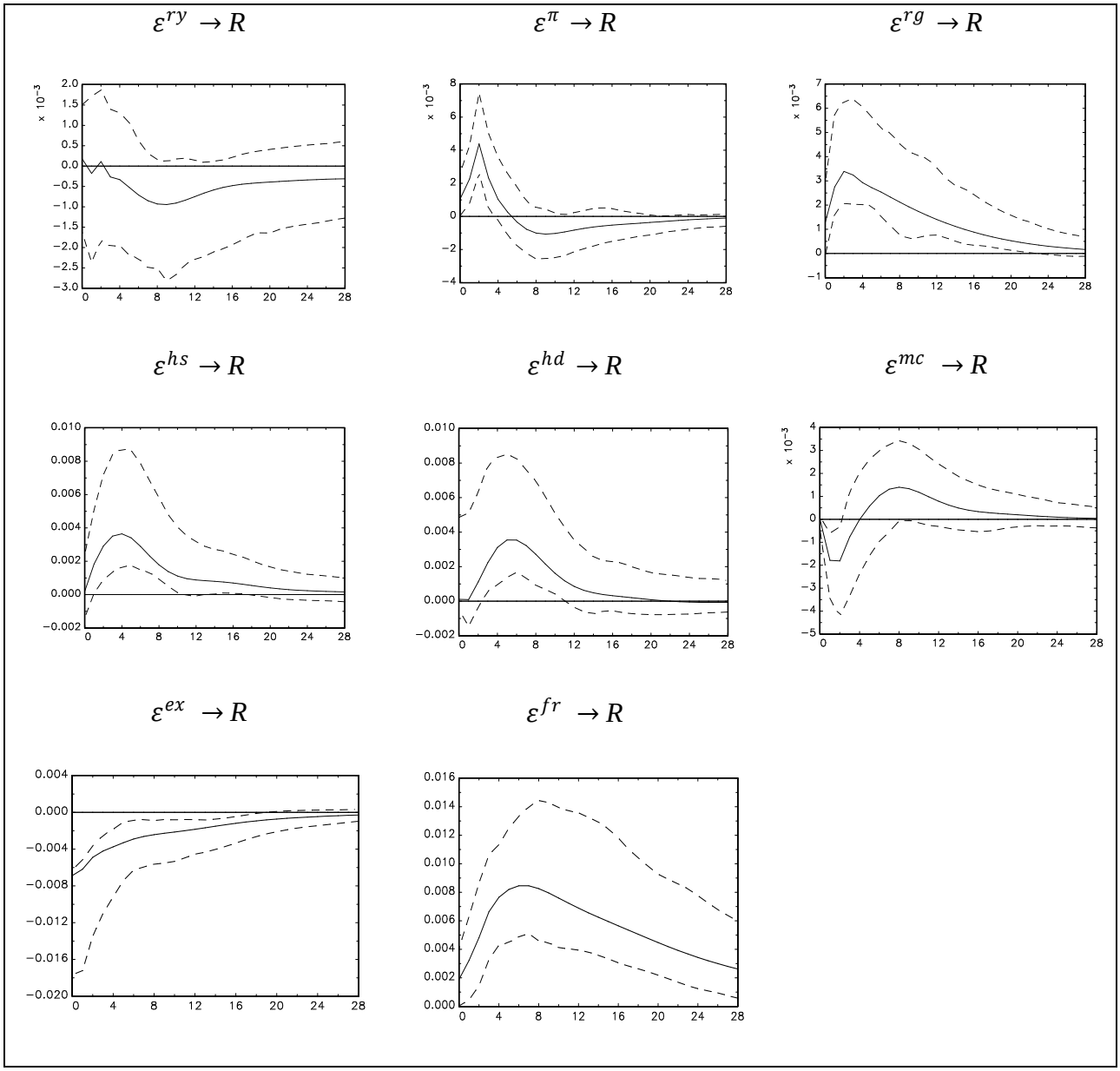
Figure 4 also shows that the fiscal policy shock represented by the shock to the government expenditure exerts negligible impact on the real house prices. The government spending on housing and community create greater demand for housing, and hence may put upward pressure on the real price. We document a positive impact on real house price though it is not statistically significant.

The housing supply shock has insignificant and negative impact on real house prices. However, real house prices tend to decline significantly after about four years. It is perceivable that increased housing supply through outward shift in supply curve for housing puts downward pressure for real price of housing. Conversely, the demand shock significantly raises the real house price, which lasts for about 12 quarters. A cursory look at the graph reveals that the magnitude of the demand shock on the house prices is rather large compared to the other shocks, with the rate of price growth rising close to 3 per cent by the 4^{th} quarter.

Material cost is expected to be a significant price determinant, as per standard theoretical predictions. Our findings suggest that there is a positive impact of material cost shocks on real house price up to quarter 12. However, such responses of the house prices appear to be mainly insignificant, except for the 6^{th} quarter or so. Over a longer term, there appears to be some dampening (but insignificant) effect on the house prices. Overall, real house prices in Australia seem to be largely insensitive to shocks in the material costs. This is consistent with general observation in Australia that house price rises significantly more than the increase in average household income, house building construction cost and average rent. Finally, both the exchange rate shock and foreign interest rate shock pose little impact on real house prices, which implies that the exchange rate is not a fundamental determinant of house prices in Australia.

With its inflation targeting strategy adopted in the early 1990s, the RBA changes the official cash rate if the inflation rate goes beyond the range of 2-3 percent. Various short and long term interest rates are supposed to change in line with the changes in official cash rate; however, there are other factors that may also contribute to the movements in interest rates. In particular, we would like to see if the interest rates are affected by the shocks stemming from the housing market.

Figure 5: Interest rate responses to various shocks



Note: The dotted lines represent the upper and the lower bands of 95% bootstrapped confidence intervals computed using 1000 repetitions of Hall's percentile method.

Figure 5 shows the impulse response functions of the short term interest rate to various macroeconomic and housing market shocks. A positive shock to the aggregate output level does not appear to have any significant effect on the interest rate. The interest rate tends to decline somewhat notably between eight to 10 quarters only, which is an expected response to higher real output. A onetime shock to inflation leads to immediate significant increase in the interest rate, rising up to about 0.4 per cent. The interest rate keeps on rising significantly for about a year followed by

insignificant declines (Figure 5). The immediate and significant rise in the interest rates due to an inflationary shock reflects the RBA's inflationary targeting strategies as well as possible increases in the money demand.

A shock stemming from Govt. spending on housing has a strong significant effect (positive) on the interest rate, which persists for about 20 quarters. This finding has an important policy implication; higher govt. spending increases the money demand leading to quite persistent increase in interest rates, however, as we have pointed out in the previous subsection, this Govt spending plays very little role in boosting the housing market.

It is observed that a housing market shock, irrespective of whether it is coming from demand or supply sides, increases the interest rate. In both cases, the interest rate starts to increase significantly after one or two quarters of the shocks and the positive responses persist for abbot 10-12 quarters. It is understandable that interest rate rises due to a housing demand shock through the increase in demand for housing loans. However, the increase in the rate to a housing supply shock is relatively hard to rationalize. One possible explanation may be that higher level of housing constructions generates additional income for the people in the housing industries; which in turn increases aggregate demand and the interest rate. A positive shock to the raw material costs initially decreases the interest rate significantly.

A higher material cost is comparable to an adverse supply shock, which may lead to an increase in inflation and aggregate output level. The interest rate may decline if the Central Bank reacts to lower inflation and the output level. In line with the interest parity condition, it is observed that a positive shock to the foreign interest rate increases the domestic interest rate immediately and this effect is significant and quite persistent. A positive shock to the exchange rate (appreciation) appears to have long-lasting negative effect on the interest rate. The main reason for this may be that an appreciation of the currency causes the future expected appreciation, which in order to fulfil the interest parity condition, leads to reduction in the domestic interest rate. The effect of one period positive shock to foreign interest rate on the domestic interest rate also seems to be significant (Figure 5). Domestic interest rate seems to rise significantly responding to a shock in the foreign interest rate over the entire span of time presented in the figure (about seven years), with increased growth rate up until the 8^{th} quarter. This is an expected outcome since higher interest overseas would raise domestic interest rate slowing capital outflow thereby maintaining interest rate parity.

5. Conclusions

This study develops an econometric model for Australian housing market and examines the monetary transmission effects on the housing market by estimating a 9-variable SVAR model. The identification scheme used in this paper disentangles the effects of various macroeconomic, housing market and policy shocks while examining the role of these shocks in Australian housing market and the overall Australian economy.

The housing market model based on the contemporaneous relations shows that the short term interest rate is the main determinant of real house prices in Australia. The quantity of new houses constructed is primarily affected by the inflation rate and real house prices. The evidence from impulse responses suggests that a contractionary monetary shock immediately increases the number of new houses followed by a significant negative effect on housing construction for about a year or so, before the effect fades away. A positive monetary policy shock is also observed to significantly raise material costs and real house prices for a short period of time. These results suggest that a contractionary monetary policy shock initially increases the housing demand reflecting public's expectation for further increase in the future interest rates and house prices. However, in the long run, the contractionary policy dampens the housing demand and ultimately causes the real house prices to decline. The robustness of our identification scheme is evident from the conventional patterns observed in the responses of aggregate output, inflation, the exchange rate, the interest rate and government spending on housing to the identified monetary policy shock.

An important finding of this study is that the RBA tends to react to the shocks stemming from housing market. This is evident from the finding that the short term interest rate increases following both housing demand and supply shocks and decreases to a positive shock to housing material costs. Apart from the monetary policy shock, a number of other shocks are found to significantly affect real house prices and housing output in Australia. Real house prices are influenced positively by the shocks originated from housing demand and aggregate real economic activities and negatively by housing supply shocks. In this regard, the effects of real output and housing supply shocks are found to be more persistent compared to the effect of a housing demand shock. While both housing demand and supply shocks positively affect the constructions of new houses, a shock to inflation is found to be adversely affecting the housing output. The shock to the Government spending for housing appears to have very insignificant effect on housing market activities.

References:

Abelson, P., Joyeux, R., Milunovich, G., Chung, D., 2005. Explaining house prices in Australia: 1970-2003. Economic Record 81 (special issue), S96-103.

Aoki, K., Proudman, J., Vlieghe, G., 2004. House prices, consumption, and monetary policy: a financial accelerator approach. Journal of Financial Intermediation 13 (4), 414-35.

Baffoe-Bonnie, J., 1998. The dynamic impact of macroeconomic aggregates on housing prices and stock of houses: a national and regional analysis. The Journal of Real Estate Finance and Economics 17 (2), 179-97.

Berger-Thomson, L., Ellis, L., 2004. Housing construction cycles and interest rates, Reserve Bank of Australia Research Discussion Paper No. 08.

Bernanke, B., Gertler, M., 1995. Inside the black box: the credit channel of monetary transmission. Journal of Economic Perspectives 9 (4), 27-48.

Case, K. E., Shiller, R. J., 2003. Is there a bubble in the housing market? Brookings Papers on Economic Activity 2, 299-342.

Dvornak, N., Kohler, M., 2007. Housing wealth, stock market wealth and consumption: a panel analysis for Australia. Economic Record 83 (261), 117-30.

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

Fry, R. A., Martin, V. L., Voukelatos, N. 2009. Overvaluation in Australian housing and equity markets: wealth effects or monetary policy? CAMA Working Paper No. 10.

Iacoviello, M., 2002. House prices and business cycles in Europe: a VAR analysis. Boston College Working paper No. 540.

Iacoviello, M., Minetti, R., 2008. The credit channel of monetary policy: evidence from the housing market. Journal of Macroeconomics 30(1), 69-96.

Jarocinski, M., Smets, F. R., 2008. House prices and the stance of monetary policy. Federal Reserve Bank of St. Louis Review 90 (4), 339-66.

Kim, S., Roubini, N., 2000. Exchange rate anomalies in the industrial countries: a solution with structural VAR approach. Journal of Monetary Economics 45(3), 561-86.

King, R., Plosser, C., Stock, J., Watson, M., 1991. Stochastic trends and economic fluctuations. American Economic Review 81(4), 819-40.

Ludvigson, S., Steindel, C., Lettau, M., 2002. Monetary policy transmission through the consumption-wealth channel. Federal Reserve Bank New York Economic Policy Review 8 (1), 117–33.

McCarthy, J., Peach, R. W., 2002. Monetary policy transmission to residential investment. Federal Reserve Bank of New York Economic Policy Review 8 (1), 139-58.

Malpezzi, S. and Maclennan, D., 2001. The long-run price elasticity of supply of new residential construction in the United States and the United Kingdom. Journal of Housing Economics 10 (3), 278-306.

Mishkin, F. S., 1996. The channels of monetary transmission: lessons for monetary Policy. NBER Working Paper No 5464.

Mishkin, F. S., 2007. Housing and the monetary transmission mechanism. NBER Working Paper No 13518.

Otto, G., 2007. The growth of house prices in Australian capital cities: what do economic fundamentals explain? Australian Economic Review 40 (3), 225-38.

Vargas-Silva, C., 2008. Monetary policy in the US housing market: a VAR analysis imposing sign restrictions. Journal of Macroeconomics 30 (3), 977-90.

Wood, A. G., 1999. Home-owner residential property taxes and their burden on net personal wealth: an empirical study for Australia. Urban Studies 36 (2), 239-54.

Wood, A. G., Watson, R., Flatau, P., 2006. Microsimulation modelling of tenure choice and grants to promote home ownership. Australian Economic Review 39 (1), 14-34.

Yates, J., 2007. Affordability and access to home ownership: past, present and future? *Research Report No. 10*, Australian Housing and Urban Research Institute, Sydney.

Yates, J., 2008. Policy forum: housing affordability: what are the policy issues? The Australian Economic Review, 41 (2), 200-14.

Appendix

Table A.1: Estimated Structural coefficients

Estimated $\mathbf{A_0}$ *Matrix*

1.0000								
-0.1410 (0.0703)	1.0000							
0.1073 (0.0555)	-0.0042 (0.0665)	1.0000						
1.8148 (3.0255)	-4.7012 (3.5761)	-4.3024 (4.5928)	1.0000					
-0.3222 (0.1900)	-0.0667 (0.1750)	-0.2672 (0.2433)		1.0000				0.3278 (0.3493)
0.0181 (0.0447)	0.0030 (0.0513)	0.1367 (0.0662)	0.0001 (0.0012)	0.0884 (0.0530)	1.0000			-0.0014 (0.0098)
					0.6037 (0.8443)	1.0000	-1.5037 (0.6883)	0.0000
-0.0582 (0.1548)	-0.0444 (0.1770)	0.7529 (0.2450)	-0.0022 (0.0043)	-0.5913 (0.2308)		0.0517 (0.0868)	1.0000	-0.0490 (0.0352)
1.6310 (2.2058)	-0.1692 (0.8915)	1.0487 (1.8830)	0.0464 (0.0424)	-9.4367 (9.9234)		0.0558 (0.1843)		1.0000

Figures in parentheses are relevant standard errors.

Estimated B *Matrix*:

0.0100 (0.0006)								
	0.0083 (0.0005)							
		0.0064 (0.0004)						
			0.3459 (0.0209)					
				0.0162 (0.0131)				
					0.0049 (0.0003)			
						0.0496 (0.0034)		
							0.0170 (0.0023)	
								0.0857 (0.0682)

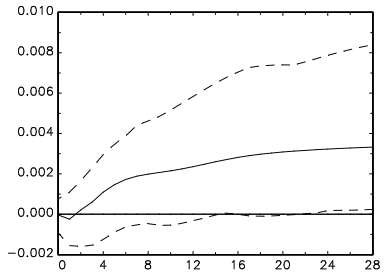
Figures in parentheses are relevant standard errors.

Test for overidentified model: Chi^2 (5): 4.1312 , Prob: 0.5307

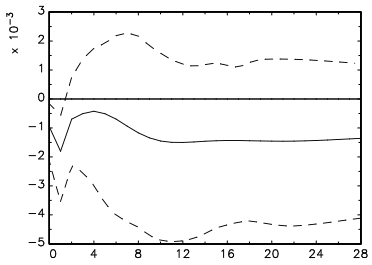
Figure A.1: Impulse responses of supplementary variables.

A.1a: Material costs (MC)

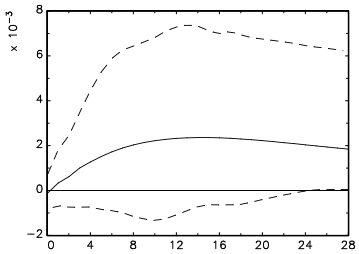
$\varepsilon^{ry} \rightarrow MC$



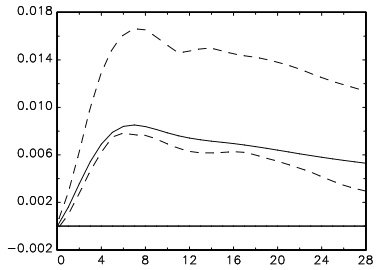
$\varepsilon^{\pi} \rightarrow MC$



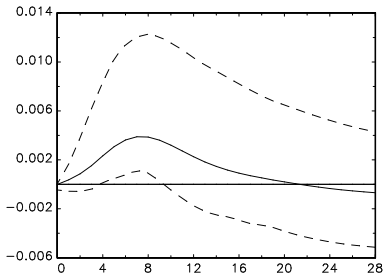
$\varepsilon^{rg} \rightarrow MC$



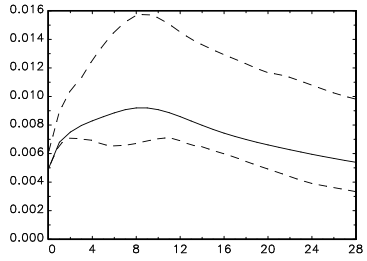
$\varepsilon^{hs} \rightarrow MC$



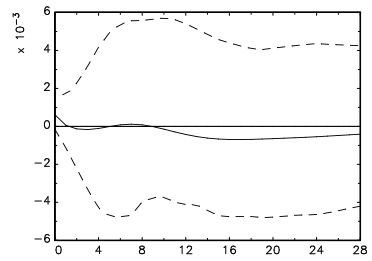
$\varepsilon^{hd} \rightarrow MC$



$\varepsilon^{mc} \rightarrow MC$



$\varepsilon^{ex} \rightarrow MC$



$\varepsilon^{fr} \rightarrow MC$

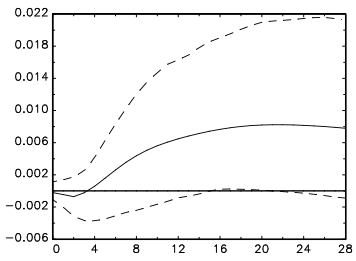


Figure A.1: Impulse responses of supplementary variables (Continued)

A.1b: Real output (RY)

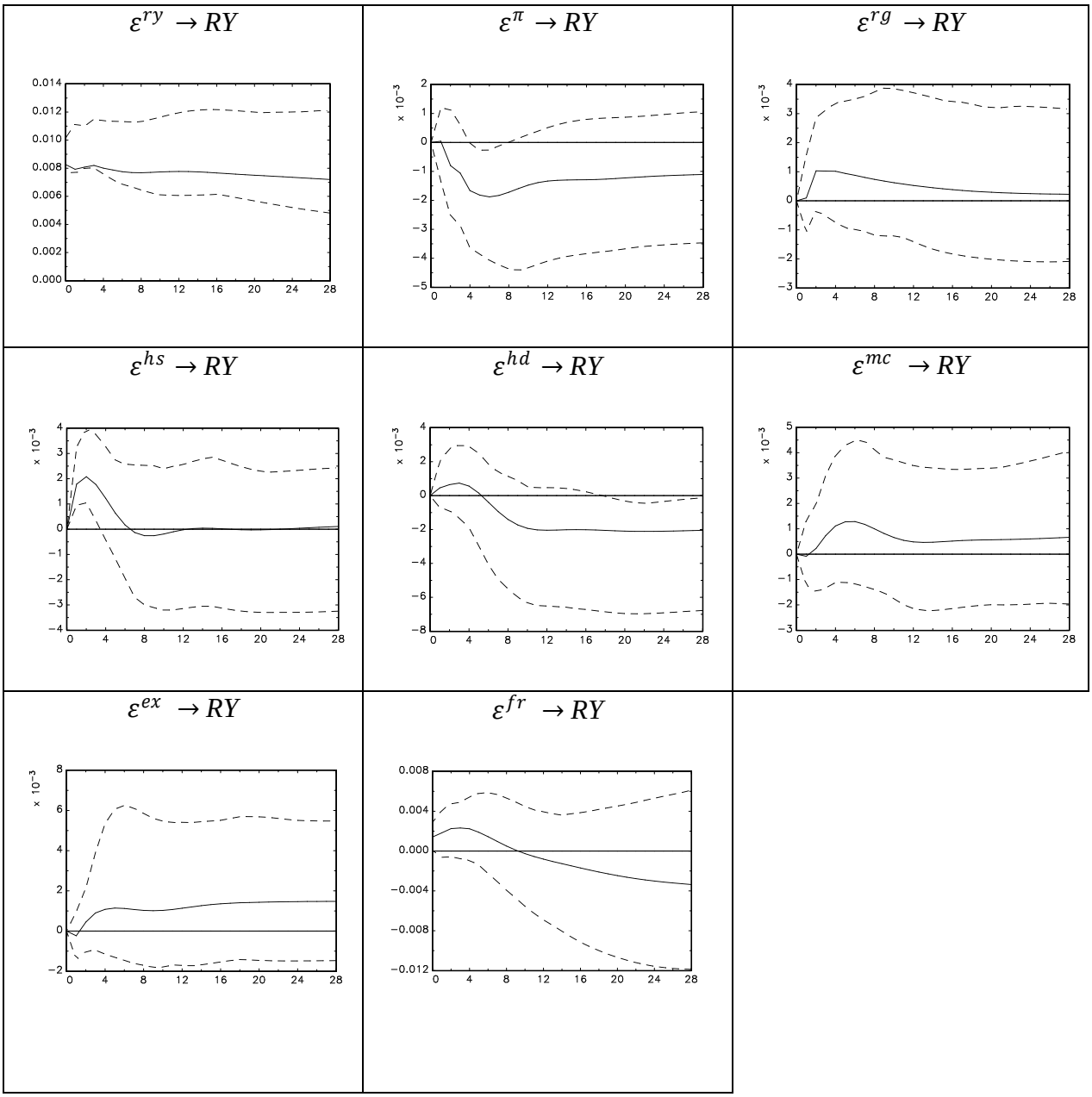
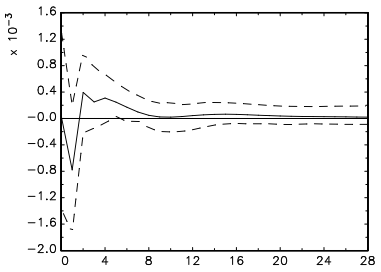


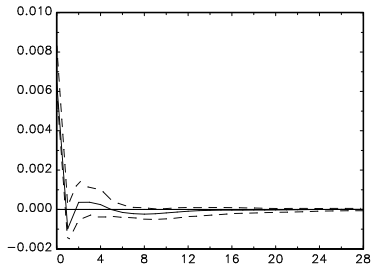
Figure A.1: Impulse responses of supplementary variables (Continued)

A.1c: Inflation rates (π)

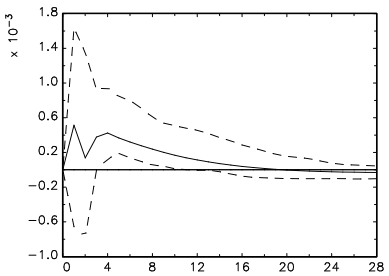
$\varepsilon^{ry} \rightarrow \pi$



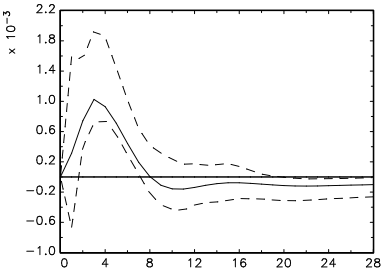
$\varepsilon^{\pi} \rightarrow \pi$



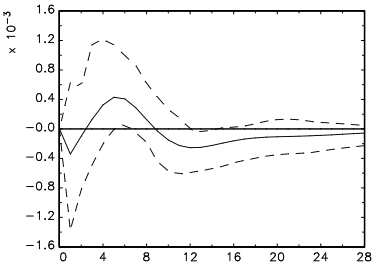
$\varepsilon^{rg} \rightarrow \pi$



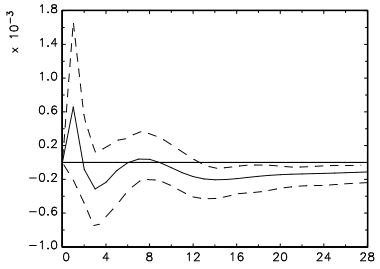
$\varepsilon^{hs} \rightarrow \pi$



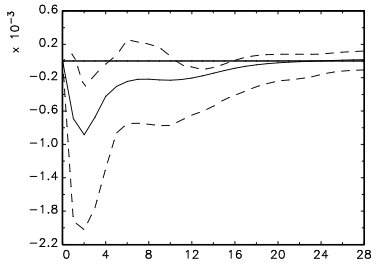
$\varepsilon^{hd} \rightarrow \pi$



$\varepsilon^{mc} \rightarrow \pi$



$\varepsilon^{ex} \rightarrow \pi$



$\varepsilon^{fr} \rightarrow \pi$

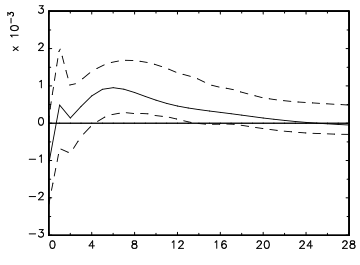
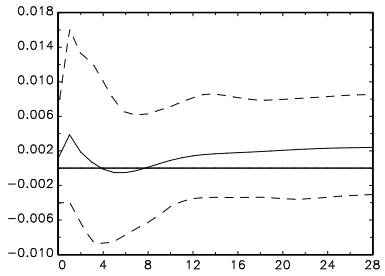


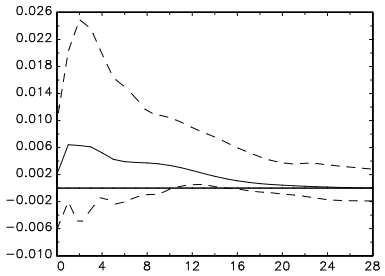
Figure A.1: Impulse responses of supplementary variables (Continued)

A.1d: Exchange rates (EX)

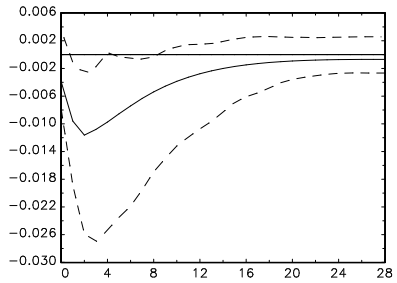
$\varepsilon^{ry} \rightarrow EX$



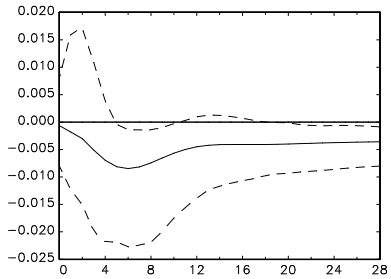
$\varepsilon^{\pi} \rightarrow EX$



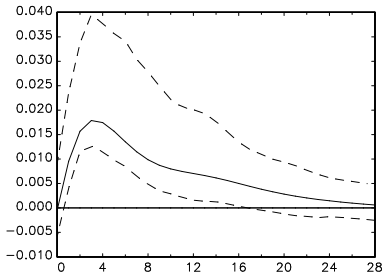
$\varepsilon^{rg} \rightarrow EX$



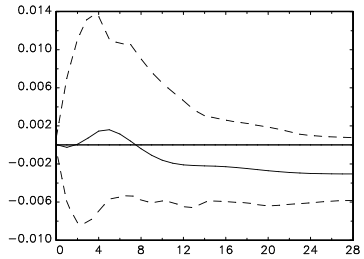
$\varepsilon^{hs} \rightarrow EX$



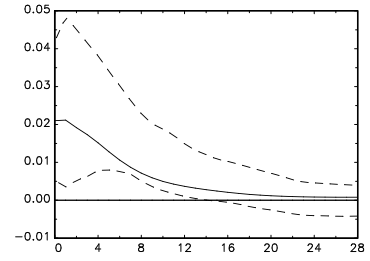
$\varepsilon^{hd} \rightarrow EX$



$\varepsilon^{mc} \rightarrow EX$



$\varepsilon^{ex} \rightarrow EX$



$\varepsilon^{fr} \rightarrow EX$

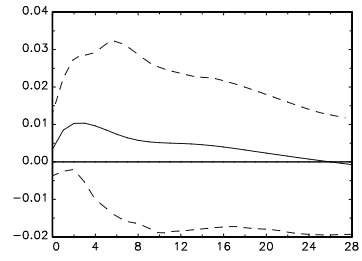
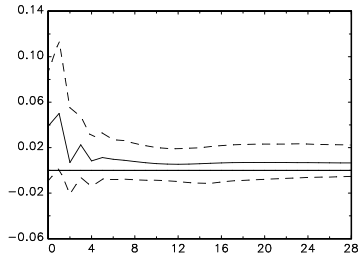


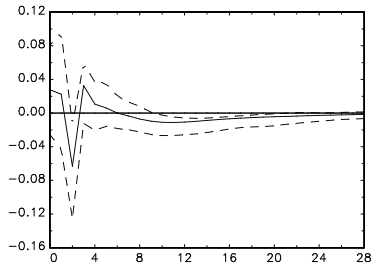
Figure A.1: Impulse responses of supplementary variables (Continued)

A.1e: Government expenditure (RG)

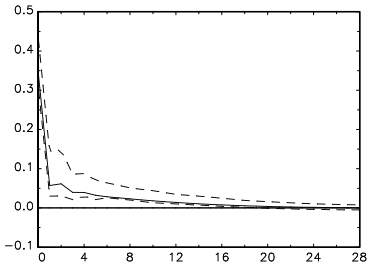
$\varepsilon^{ry} \rightarrow RG$



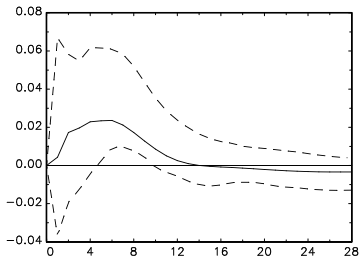
$\varepsilon^{\pi} \rightarrow RG$



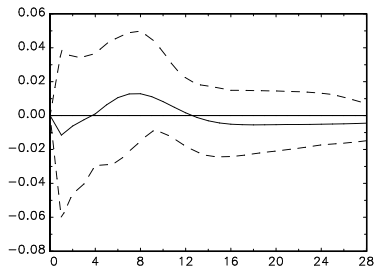
$\varepsilon^{rg} \rightarrow RG$



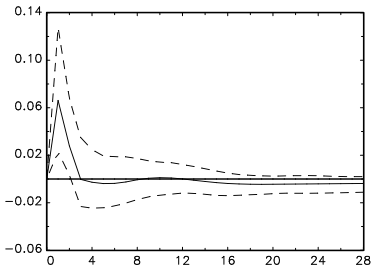
$\varepsilon^{hs} \rightarrow RG$



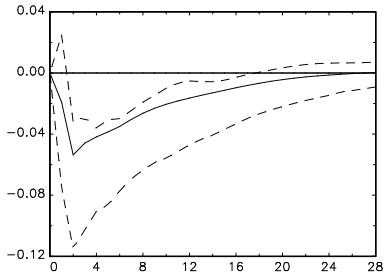
$\varepsilon^{hd} \rightarrow RG$



$\varepsilon^{mc} \rightarrow RG$



$\varepsilon^{ex} \rightarrow RG$



$\varepsilon^{fr} \rightarrow RG$