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The UK housing market and the monetary policy transmission mechanism: An SVAR approach

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Abstract

I estimate an eight variable structural vector autoregression (SVAR) model of the UK economy based upon that of Kim and Roubini [Kim, S., Roubini, N., 2000. Exchange rate anomalies in the industrial countries: a solution with a structural VAR approach. J. Monet. Econ. 45(3), 561–586] for the purpose of investigating the role of the housing market in the transmission of monetary policy. Retail sales fall by just under 0.4% following a temporary positive 100 basis points shock to short-term domestic interest rates; inflation is also lowered. House prices fall by 0.75%. House price shocks increase consumption, the price level and interest rates. Combining the central estimates for interest rate and house price shocks suggests that house price movements can explain about one-seventh of the fall in consumption following an interest rate shock. A counterfactual simulation comes to a similar figure.

JEL classifications: E44; E52; R21

Keywords: Monetary policy; House prices; Structural VAR

1. Introduction

The level of household consumption spending depends on many factors: wealth, (lifetime) income and the real interest rate are among the most important. Whilst there has been a lot of discussion of the wealth effects due to the large gains and subsequent fall

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of stock markets in the last ten years (for an international study see IMF, 2002; or, for the US, Ludvigson and Steindel, 1999), there has been less discussion of the wealth effects of gains in the housing market. The UK has seen very rapid house price growth over recent years: prices rose by over 15% in 2003, over 25% in 2002, and over 10% in 2001 according to the Halifax House Price Index. In 1995 total household wealth in the UK was £3134 billion, 35% of which was real estate (Banks and Smith, 2000) and only 9% was in the form of direct stock holdings. The relative amount of household wealth held in real estate suggests more attention should be devoted to the wealth effects caused by rising house prices. All in all, when the rapid house price growth of the last ten years is coupled with the fact that housing wealth is levered through mortgages, the effects of house price growth on net wealth are potentially large. For the US, Maki and Palumbo (2001) find that the propensity to consume out of household net wealth is between 3% and 5%, which has had substantial effects on the US economy. Case et al. (2005) also find that housing wealth is more important that stock market across a number of developed economies.

As with other assets, house prices are affected by changes in interest rates. If house prices are influenced by interest rates and consumption depends on housing wealth, there is a channel of monetary policy transmission through house prices. This paper estimates the proportion of changes in consumption and prices that can be attributed to changes in housing wealth. That is, the paper attempts to set an upper bound on the overall importance of housing wealth and housing market related credit imperfections in the UK monetary transmission mechanism. In the empirical part of this paper I employ a two-stage approach: firstly estimating the response of house prices to an interest rate shock, and then estimating the response of consumption to a house price shock. Under the assumption that consumption reacts in the same way to changes in housing wealth regardless of the cause of the change in house prices, the estimates of the two responses can be combined to give an estimate of the proportion of the consumption response to interest rates that can be attributed to changes in housing wealth. The two-stage approach has an advantage over other approaches whereby a different model is estimated for each element of the transmission mechanism. I find that changes in house prices following a monetary shock account for about 15% of changes in consumption and also contribute to price changes. I also estimate a counterfactual simulation which leads to a similar value.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the literature on monetary policy and the housing market. Section 3 gives a description of the data. Section 4 details the structural vector autoregression (SVAR) model used to investigate the role played by house prices. Section 5 discusses the results. Section 6 concludes.

2. The housing market and monetary policy

Fig. 1 shows a simplified schematic of the monetary transmission mechanism through the housing market. As Maclennan et al. (2000) note,[1] there are both direct and indirect ways in which monetary policy may be transmitted through the housing market. The main *direct effect* is an income or cash flow effect: when the interest rate rises, the interest burden of any outstanding debt rises and after-housing-costs disposable income falls. How this

[1] See also HM Treasury (2003).

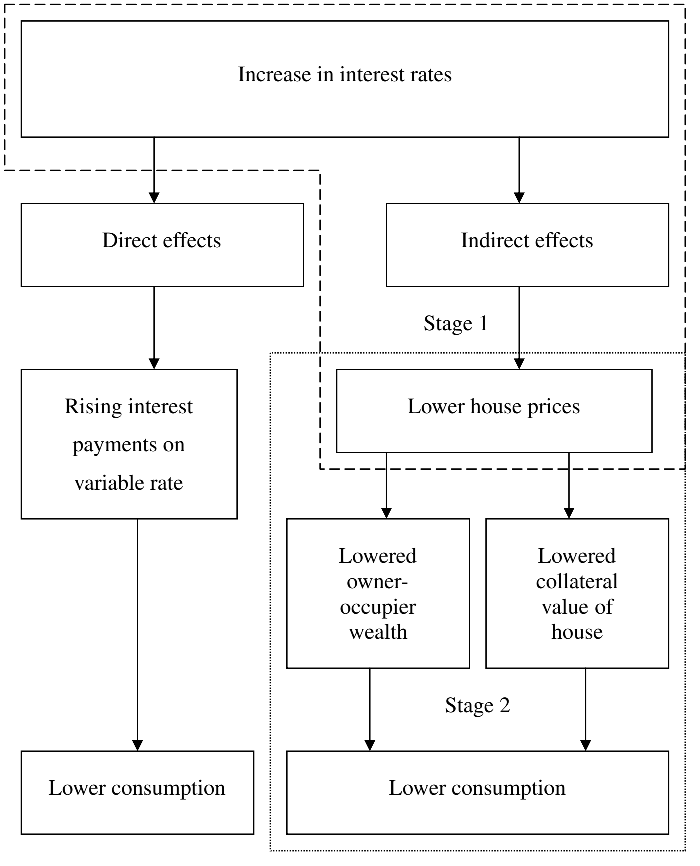

Fig. 1. Simplified schematic of the monetary transmission mechanism through the housing market.

affects consumption depends on how fast mortgage interest rates change following a monetary policy contraction. This depends on the proportion of variable rate mortgages to total mortgages and also upon the proportion of renegotiable rate mortgages (confusingly called fixed rate mortgages in the UK) and the duration of the fixed interest period—the shorter the duration of the fixed period the sooner interest rate changes are going to affect household disposable incomes. The size of the income effect also depends on what proportion of household income is consumed. Clearly, if households consume all of their current income and are limited in their ability to borrow, increasing the burden of interest payments will reduce disposable income and current consumption. This can be gauged by looking at household savings ratios—households that save a large proportion of the after-housing-costs disposable income are clearly less constrained than those who do not.

The *indirect effects* are wealth effects and credit channel effects. This paper will concentrate on these indirect effects. Increases in real house prices give individuals more assets to spend throughout their lifetimes. Hence they should increase their consumption because of this increase in wealth. A credit channel of monetary transmission works as follows: higher interest rates reduce housing wealth and households' access to credit through lower collateral levels. Credit constrained households must reduce their consumption spending following a fall in house prices (see Bernanke and Blinder, 1988; Bernanke and Gertler, 1995, for more on the credit channel). Iacoviello and Minetti (2007) suggest that households are likely to be more strongly affected than firms through both the balance sheet and lending subchannels[2] of the credit channel. This follows from the observation that households have a much more limited choice of alternative sources of finance once banks and building societies are accounted for than firms do. If house prices are affected by monetary policy and there is imperfect substitutability between mortgages and other forms of finance for households, then the necessary conditions for the existence of a credit channel of monetary policy transmission through the housing market are met. If the majority of a households' net worth is the value of their house, and these values are volatile, then they are particularly exposed to a balance sheet mechanism. For the lending subchannel, Iacoviello, and Minetti claim that the volatility (and hence riskiness of loans secured on them) of house prices means that negative monetary policy shocks will cause banks to shift the supply of loans away from housing.[3]

The two stages of the indirect channels are shown in Fig. 1. First, rising interest rates lower house prices, then lower house prices depresses consumption. Some studies provide us with estimates of the first stage, others with estimates of the second. A selection of these is presented in Table 1. Other studies use counterfactual simulations to estimate the effects of house prices in the transmission mechanism and are also taken up in the table. Since the estimation section of this paper will also concentrate on these three parts I will separate the survey of the literature into them too, where possible.

2.1. *The effect of monetary policy on house prices*

So how does monetary policy affect house prices? Theoretically, it can affect both the supply of (construction) and the demand for houses. Malpezzi and Maclennan (2001) estimate the long-run price elasticity of supply for new houses in the UK and the US. Depending upon the methodology employed they get different ranges for the elasticities. In general, though, those for the UK are lower; for the postwar period they produce estimates of between 6 and 13 for the US and between 0 and 1 for the UK. Clearly the short run elasticity of supply will be lower than this—approximately zero for the UK. Therefore, house prices are demand determined in the short run. For the remainder of this paper I will focus solely on the demand side effects of monetary policy.[4]

[2] The balance sheet channel focuses on the financial worth of borrowers. Borrowers with lower net worth will have less access to funds. The lending channel focuses on lenders' financial status—because loans and securities are not perfect substitutes lenders will reduce loan supply following a contraction in monetary policy. Households are more susceptible to this reduced loan supply because they are very limited in the available other sources for finance.

[3] This follows from the standard debt contract whereby borrowers increase the risk of their projects in response to higher interest rates. Because the total loss of the borrower is limited to the value of the collateral they have put up whilst there is no upper bound on the profits, the expected (mean) return on a project is increasing in its level of risk. In other words, the upper tails (highly successful project outcomes) of the distribution of the project's payoff will go to the borrower; the lower tails (unsuccessful outcomes) are covered by the lender. Hence, riskier projects will still offer a positive expected return to the borrower after rising interest rates have made the safer project have a negative expected return. See Bernanke and Gertler (1995) for more.

[4] I also estimated models with housing supply variables, but these did not change the results. Hence, it appears empirically appropriate to treat short-run housing supply as fixed. The results from this, and other alternative model specifications, are available in a supplementary materials document, which can be found at http://www.cpb.nl/eng/research/sector3/data/supplementarymaterial.pdf.

Theory suggests monetary policy will affect the demand for housing. Firstly, as with other assets, house prices are sensitive to the return available on other financial assets such as bonds. If the return available from holding bonds increases (interest rates rise) asset holders will transfer some of their portfolio into bonds and away from other assets including housing. This will lower house prices until the returns from holding the different asset classes is equalized after accounting for differing risks. Secondly, demand for housing is negatively related to interest rates because interest payments represent a major part of the cost of buying a house. Thirdly, the amount someone is willing and able to pay for a house is directly linked to the affordability of the initial interest payments. As Rosen (1984) explains, households are limited by their current income to what they can borrow. Over time, as real wages rise and inflation slowly eats away the real value of the outstanding debt, the burden of interest payments becomes less and less. Current interest rates are important determinants of house prices.[5] One further way in which monetary policy can lower house prices is by increasing the burden of variable interest rates to such an extent that the house needs to be sold to pay back the principal, or the house is reposed.

The responsiveness of UK house prices to monetary policy has been studied by, among others, Aoki et al. (2002). They use a recursive VAR to estimate the effects of monetary policy shocks on the housing market in the UK and find that UK house prices are 0.8% lower five quarters after a 50 basis points interest rate shock. This is a similar response to that of durable goods consumption. Giuliodori (2005) also uses the VAR methodology and finds a range of responses with house prices falling by between 1.5% and just over 2% following a 100 basis points shock for 3 VAR specifications. For an open economy specification including the nominal DM exchange rate he finds the response to be lower at about 0.7%.

Iacoviello (2002) estimates a structural VAR model for six European countries using the identification scheme of King et al. (1991): the model is estimated in error correction form and the shocks are separated into permanent and transitory components. He finds that house prices in the UK fall by up to 1.5% following a 50 basis points tightening of monetary policy. Using forecast error variance decompositions he finds that the single most important factor driving house prices in the UK are aggregate demand shocks.

Iacoviello and Minetti (2007) also use VARs to examine the credit channel of monetary policy through the housing market. They use three different Vector Error Correction Models (VECM) and a VAR for each of four different European countries.[6] The first VECM is used to identify responses to a monetary policy shock that can be considered

[5] To illustrate this point consider the following scenario. A potential house buyer (agent) has an (real) income of £25,000 per year and wishes to borrow £100,000 to buy a house worth £100,000. The real interest rate is 2%. In the first month the income of the agent is £2083 (ignoring taxes for simplicity). If inflation is zero the nominal interest rate is 2% (which I assume to be fixed on a yearly basis). If the agent does not repay any capital the monthly expenditure on the mortgage payments in the first month is £167, which is easily affordable. However, as inflation rises and nominal interest rates rise, the first month's payment rises. If inflation is 23% the payment will be £2083—if inflation is 50% it will be £4333. The only way the agent could afford the higher nominal rate is to borrow immediately against the rising value of the house. This, in general, is not possible. The nominal interest rate is clearly important in determining the initial affordability of a mortgage for a given house value. As Iacoviello (2004, p. 315) puts it: "Moreover, actual lending criteria in the mortgage market are such that the borrower's income, besides collateral value, is a limiting factor in affecting the borrowing capacity of the agents and their ability to cash in equity gains."

[6] Finland, Germany, Norway, and the UK.

Table 1
Empirical studies of the role of house prices in the UK monetary transmission mechanism

Study	Conclusions	Shock to...	Responses	Variables	Method (Identification)	Period
The effect of monetary policy on UK house prices						
Aoki et al. (2002)	In combination with Aoki et al (2004), DSGE model only fits data with financial accelerator through housing	50 Basis points short term interest rate	0.8% Fall in house prices, 0.8% fall in durable consumption, 0.1% Fall in non-durable consumption	Output, inflation, oil prices, real broad money, short term interest rates, consumption (durable vs non-durable), house prices, housing investment	VAR—Choleski with policy rate last	1975Q2–1999Q4
Iacoviello (2002)	Monetary policy has a significant effect on house prices	50 Basis points short term interest rate	1.5% Fall in house prices	GDP, real money, real house prices, short-term interest rate, inflation	VAR—KPSW approach	1973Q1–1998Q3
Giuliodori (2005)	House prices play a major role in the transmission mechanism	100 Basis points money market shock	GDP Fall 0.3%–0.4%, consumption fall 0.5%, real house prices fall 0.7% or 1.8% (depending on the model)	CPI, GDP, consumption, RHPI (detr), money market rate	VAR—Choleski decomposition	1979Q3–1998Q4
Iacoviello and Minetti (2007)	Bank lending channel and maybe balance sheet channel	70 Basis points interbank rate shock	Output fall 0.25%, house price fall 0.7–1% (depending on the model)	House price index, 3 month interbank, housing loans, total loans, spread (treasury bill—building societies rate), loans mix (non-depository inst./total)	VAR—KPSW approach	1978Q1–1999Q4

The effect of UK house prices on consumption						
Chirinko et al. (2004)	House Price shocks have bigger effects than equity shocks	1.5% House price shock	GDP rises by 0.4%	GDP, CPI, exchange rate, 3 month money market rate, nominal value privately owned houses, equity, (plus exogenous: world trade, com, US interest rates)	SVAR—non-recursive contemporaneous restrictions	1979Q4–1998Q4
Case et al. (2005)	Housing wealth effects are larger than stock market wealth effects	10% House price shock	Consumption rises by 0.6%	Consumption, income, housing wealth, stock market wealth	Panel data	Annual: 1978–1999
Counterfactual studies						
Aoki et al. (2004)	DSGE model only fits data when financial accelerator through housing market is switched on	50 Basis points short term interest rate	No financial accelerator: consumption rises by 0.56%, house prices by 0.48%. With financial accelerator: consumption rises by 0.66%, house prices by 0.99%	VAR from Aoki et al. (2002)	Calibrated DSGE model to VAR model in Aoki et al. (2002)	VAR from Aoki et al. (2002)
Giuliodori (2005)	As above	100 Basis points money market shock	With no role for house prices, the consumption response falls from 0.5% to 0.2%	As above	Within the same VAR as above, set all correlations with house prices to zero	As above

a benchmark to compare the rest against. They use a second VECM to look at the spread between mortgage and risk free rates. The third and fourth models look at the external finance mix (that is, the proportion of housing loans by "non-banks") of households. The third VECM looks to see if the mix is affected by policy shocks. The final VAR looks at the effect of shocks to the mix on the economy. Change in the mix can be interpreted as changes in the relative supply of loans from banks and non-banks. They find that house prices fall by 0.7–1% following a 70 basis points interest rate shock and conclude that there is evidence of a bank-lending channel and maybe also a balance-sheet channel. Further studies of the effects of interest rates on house prices can be found in Hendry (1984), Meen (1990),and Muellbauer and Murphy (1997).[7]

2.2. The effects of house prices on consumption

To establish an indirect housing market channel of monetary policy one needs to show not only that monetary policy affects house prices, but also that these changes in house prices affect consumption, and in consequence, output. Kennedy and Anderson (1994) list four factors that predict a low sensitivity of consumption to house prices. They are: high transactions costs, low loan-to-value ratios, a low level of owner-occupation and a high proportion of households in the market rented sector (as opposed to social housing). Low transactions costs make housing wealth more liquid. The more liquid housing wealth is, the more it will be spent. The more highly levered household wealth is, the greater the effect on net wealth of changes in asset prices. Hence, low loan-to-value ratios predict smaller responses of consumption to changing house prices. The more owner–occupiers there are in an economy, the more agents there are whose net wealth depends on the value of their home. Market rental prices move in line (at least to some degree) with house prices more than those in the social rented sector. If house prices rise, market rents should rise lowering consumption of households in the market rented sector. One way in which housing wealth can be spent, and therefore affect the rest of the real economy, is through mortgage equity withdrawal. Mortgage equity withdrawal is defined according to Davey (2001, p. 100) as:

> "Mortgage equity withdrawal (MEW) occurs when lending secured on housing increases by more than investment in the housing stock."

As house prices go up, homeowners can increase their borrowing that is secured against their properties. The terms offered on mortgages are often much better than those terms offered on unsecured loans due to asymmetric information. Davey reports that 64% spent some of their withdrawn equity within the first 6 months.

Although the case for a housing wealth effect seems, at first sight, clear-cut, it is not necessarily the case. Maclennan et al. (2000) note that increased house prices are bad for those in the rented sector for two reasons: higher future rents, and a higher price for becoming an owner–occupier. They argue that if wealth effects are smaller for landlords than for owner–occupiers, other things being equal, a high proportion of owner–occupiers will make the housing wealth effect on consumption larger. Overall, the evidence suggests that the effect of increases in house prices upon consumption is positive.

[7] Lastrapes (2002) estimates a VAR for US real house prices and money supply shocks. He finds that real house prices increase by up to 0.7% following positive shocks to the money supply of about 0.8%.

> "Simple life-cycle consumer theory suggests that a rise in real house prices believed to be long-lasting has both a positive wealth effect on non-housing consumption, and negative income and substitution effects,... Plausible estimates of the latter effects, in the UK and other studies, e.g. Meen (1993), suggest elasticities in the region of −0.5. The positive wealth effects will therefore dominate for owner–occupiers." (Maclennan et al., 2000, p. 59).

The response of output or consumption to house price shocks has been studied by, among others, Chirinko et al. (2004). They use an SVAR for 13 countries and find that the cumulative effect on UK consumption is a rise of about 0.7% one year after a 1% shock to house prices. The peak response following a 1.5% shock to house prices is a 0.4% rise in GDP.

Case et al. (2005) estimate regressions relating consumption to income and wealth measures for 14 countries.[8] They find that, although the results depend to a small degree upon the econometric specification, the evidence of a stock market effect on consumption is weak whereas that of the housing market is significant. This is in line with levered nature of housing wealth and the relatively small value of direct equity holdings. For the UK, they find that a 10% rise in house prices results in consumption rising by 0.6%. Iacoviello (2004) derives an aggregate Euler equation for consumption and shows that, if households are limited in their ability to borrow by the value of their homes, house prices should enter a correctly specified aggregate Euler equation for consumption. He also shows that changes in US house prices have significant effects on current US consumption.

2.3. Counterfactual approaches

The counterfactual approach involves taking an estimated model and removing the estimated effect of house prices on consumption or output to infer the role played in the transmission mechanism by house prices. Aoki et al. (2004) develop and calibrate a dynamic general stochastic equilibrium (DGSE) model of the economy to try to explain the VAR estimates from Aoki et al. (2002). Only with a financial accelerator channel switched on do they manage to approximate the responses from the VAR model. Using a shock of −50 basis points to interest rates, they find that consumption rises by 0.56% and house prices by 0.48% following the shock when there is no financial accelerator. When the financial accelerator is switched on in a model typifying the regulated conditions in the UK mortgage market in the early 1980s, the consumption response rises to 0.66% and the house price response to 0.99%. When the regulations in the model are removed the responses are 0.75% and 0.45%, respectively. As with most other DGSE models, the peak responses all occur at the time of the shock. The common finding from VAR models (and ad hoc experience), however, is that there is a lag between the shock and the response. Nonetheless, these DGSE estimates can still be useful as a guide for assessing the responses generated from VAR models.

Giuliodori's (2005) VAR study also estimates the effects of real house price shocks on consumption. For the UK, he finds a significant consumption increase following a real house price shock. Giuliodori also measures the importance of house prices in the trans-

[8] Belgium, Canada, Denmark, Finland, France, Germany, Ireland, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK, and the US.

mission mechanism by simulating a model containing consumption when consumption does not respond directly to house prices (a so-called counterfactual VAR); that is, the coefficients of contemporaneous and lagged house prices in the consumption equation are set to zero. The peak consumption response to a monetary contraction is about 0.5% in the unrestricted setting but only about 0.2% in the restricted model. Further estimates with exogenous house prices come to a similar proportion of consumption decreases due to falling house prices.

3. The data

I use eight variables to model the dynamics of the transmission mechanism: prices, retail sales, a short term interest rate, money supply, the house price index, the nominal exchange rate, commodity prices, and the Federal Funds Rate.[9] The sample period is from January 1987 until May 2003; hence, Muellbauer and Murphy's (1997) finding of a structural break in the UK house prices series following the deregulation of the housing market in the early 80s should therefore not affect the results of the current study greatly.[10] The data are all from the International Financial Statistics database at the IMF except retail sales and prices from the UK Office of National Statistics, house prices from the Halifax Bank,[11] and commodity prices from the Commodity Research Bureau. The short-term domestic interest rate used to represent the stance of monetary policy is the interbank rate. Money supply is narrow money, M0. As proxy for consumption I have taken retail sales.[12] The price index used is the retail price index minus mortgage interest payments, RPIX. The house price index used in this study is the index from The Halifax. The interbank rate and the Federal Funds Rate enter the model in levels, the rest enter in logarithms.

Tables 2 and 3 show the results of tests for the orders of integration and cointegration of the time series. All of the series except RPIX and M0 appear to be I(1); RPIX and M0 appear to be I(2). Depending upon which test is used, the order of cointegration is either 4 or 5/6. Since our primary focus is on the short-run dynamics of the system I will rely upon the Sims et al. (1990) result whereby an unrestricted VAR in levels correctly estimates the

[9] I have also estimated two 9 variable models, one including both consumption and industrial production and one also including housing starts to proxy for the supply of housing. The responses were virtually identical to those shown here. See the supplementary materials document of footnote 4 for these models.

[10] McCarthy and Peach (2002) look at the effect of monetary policy on the housing market in the US. Like the UK, the US also liberalised the market for mortgages around 1980. They estimate a recursive VAR to see if the responses to shocks have indeed changed over the sample period. They conclude that there are qualitative changes since 1986 with the effects on investment occurring later and the response of mortgage rates greater since the liberalisation. This is in line with less quantity rationing and more price rationing of mortgaging.

[11] The Halifax index has several advantages over some other available house prices series. Firstly the index attempts to measure the price of a typical house over time on a like-for-like basis by assigning value to characteristics of houses. The index of the Land Registry, on the other hand, is a simple weighted average; increases in that index are in part due to quality improvements such as the installation of double-glazing and are not such a good measure of pure windfall wealth gains. Furthermore, by recording the value at the time the financial arrangements are agreed, the index is more up-to-date than that of Office of the Deputy Prime Minister.

[12] The R^2 between quarterly consumption and quarterly retail sales is 0.91, which suggests that it is a reasonable proxy given that consumption is not available at a monthly frequency and my wish to have as many degrees of freedom as possible.

Table 2
Integration tests

Series	ADF		KPSS		AIC lags
	Test statistic	5% Critical value	Test statistic	5% Critical value	
CRB	−1.90	−2.86	1.16	0.463	1
CRBD12	−2.37	−1.94	0.07	0.463	12
FFR	−1.60	−2.86	2.38	0.463	5
FFRD12	−1.81	−1.94	0.08	0.463	12
RS	1.22	−2.86	2.73	0.463	7
RSD12	−1.49	−1.94	0.45	0.463	12
RSD12D	−5.50	−1.94	0.07	0.463	12
RPIX	−1.89	−2.86	1.71	0.463	12
RPIXD12	−1.27	−1.94	1.08	0.463	12
RPIXD12D	−4.71	−1.94	0.10	0.463	11
M0	2.56	−2.86	2.01	0.463	11
M0D12	−0.07	−1.94	0.76	0.463	12
M0D12D	−6.25	−1.94	0.07	0.463	12
INT	−1.41	−2.86	7.57	0.463	1
INTD12	−3.14	−1.94	0.11	0.463	12
ERM	−2.62	−2.86	1.27	0.463	1
ERMD12	−3.51	−1.94	0.06	0.463	12
RHPI	−1.26	−2.86	0.52	0.463	12
RHPID12	−0.86	−1.94	0.28	0.463	12
RHPID12D	−6.96	−1.94	0.09	0.463	11

The table shows the results of augmented Dickey–Fuller test for stationarity of each time series. The Kwiatkowski et al. (1992) test results are also shown. CRB is the commodity research bureau commodity prices, FFR is the Federal Funds Rate, RS is retail sales, RPIX is the price level, M0 is the narrow money supply, INT is the Interbank Rate, ERM is the nominal market exchange rate vis-à-vis the US dollar, and RHPI is the real house price index. D12 indicates that the series has been seasonally differenced, D12D indicates that the series has been seasonally differenced and then first differenced. Conclusions regarding the level of integration were based on these results as well as other (not shown) specifications.
Note: Tests for series in levels include seasonal dummies, those for seasonal differenced series do not.

dynamics of the system taking into account whatever cointegration may be present and estimate the model in levels.[13]

4. The model

VAR models[14] as proposed by Sims (1980) are an alternative to large scale macroeconometric models and do not rely on "incredible" identifying assumptions. The original

[13] Since Phillips (1998) shows that impulse responses from VARs in levels are inconsistent at long horizons, and Faust and Leeper (1998) show that small mistakes in specifying the cointegrating relations will affect the short-run parameters, the safest approach appears to be estimating the model in levels and only focussing on the short horizon responses.

[14] Whilst some authors, notably Maclennan et al. (2000) are sceptical with regards the suitability of VAR models for studying housing markets because they do not capture the non-linearities present in UK house price series, the use of the VAR methodology in the current paper allows direct comparison with the numerous other studies that have used VAR models as shown in Table 1. Furthermore, Iacoviello and Minetti (2007) argue that since their VARs are consistent with the descriptive evidence of, among others, Diamond and Lea (1992), VAR models are at least qualitatively useful for investigating housing phenomenon.

Table 3
Johansen test for cointegration

r	Intercept included		Intercept and time trend included	
	Statistic	p-value	Statistic	p-value
0	354.8	0.000	274.3	0.000
1	217.2	0.000	186.9	0.000
2	136.3	0.000	119.4	0.037
3	89.3	0.004	85.7	0.080
4	56.6	0.028	57.6	0.150
5	33.7	0.070	33.1	0.337
6	15.4	0.208	15.9	0.509
7	5.9	0.203	6.5	0.416

Test of the Null Hypothesis of cointegrating rank $= r$ against the alternative $= r+1$.

atheoretical VARs used a Choleski decomposition to get impulse responses; a Choleski decomposition implies a causal ordering that may itself be incredible if the researcher wishes to look at the effects of more than just monetary shocks. Structural VAR (SVAR) models explicitly provide an economic or informational rationale behind the restrictions necessary to identify monetary and other shocks (see Bernanke, 1986; Sims, 1986; Blanchard and Quah, 1989). VAR studies of the monetary transmission mechanism using the Choleski decomposition usually rely on partial identification. With partial identification only one of the underlying structural shocks is identified—in this case the monetary policy shock. Partial identification is achieved by ordering the other variables in the VAR either side of the interest rate equation. This is equivalent to saying that all those variables ordered before the interest rate respond contemporaneously to, but have no contemporaneous effect themselves on monetary policy. Those ordered after the interest rate do not respond to monetary policy immediately; monetary policy does react contemporaneously to them, though. This is problematic when interest rates and other financial variables such as exchange rates and house prices, which are assumed to be jointly determined, are included in a model. Furthermore, relying on partial identification means that only one shock can be studied per model; another model is needed to look at identified house price shocks. In other words, each model only looks at one half of the transmission mechanism.[15]

The model presented here allows both stages to be looked at in a single model. The structure of the model is based upon that of Kim and Roubini (2000). The choice of the Kim and Roubini model is also driven by the result that, as Grilli and Roubini (1996 p. 858) put it, ‘‘the structural VAR approach appears to be quite successful in explaining all the puzzles that plagued the recent literature on the effects of monetary policy in closed and open economies.’’ I amend the model slightly to include house prices. To understand the model it will be useful to summarize the VAR modeling process. In VAR modeling one first estimates the reduced form as an autoregression as in (1).

$$Y_t = A(L)y_t + u_t \tag{1}$$

Here, $A(L)$ is a finite order lag polynomial and u_t is the vector of reduced form errors. The aim is to be able to say what effect changes in one variable have on the other variables; this cannot be done with the model estimated in (1) because the errors are not independent

[15] See Christiano et al. (2001) for more discussion of partial identification.

of each other. To do so requires that one identify the structural form of the model wherein each element in the error term is contemporaneously uncorrelated with the others. Eq. (2) shows the structural form of the model in moving average form with $B(L)$ an infinite order lag polynomial;[16] (3) shows the connection between the vector of (orthogonalized) structural shocks, e_t, and the reduced form errors. Here, B_0 is the structural lag polynomial at lag zero.

$$B(L)y_t = e_t \tag{2}$$

$$e_t = B_0 u_t \tag{3}$$

Eqs. (4)–(6) shows the connections between the reduced form and the structural form.

$$B(L) = B_0 + B^{+}(L) \tag{4}$$

$$A(L) = -B_0^{-1}B^{+}(L) \tag{5}$$

$$\Sigma = B_0^{-1}\Lambda B_0^{-1} \tag{6}$$

Eq. (4) splits the infinite order lag polynomial from the structural form into the contemporaneous correlations (i.e., the correlations at lag zero), B_0, and the correlations at all strictly positive lags, $B^{+}(L)$. Eq. (5) maps each reduced form coefficient matrix onto its structural form counterpart. This can be done simply if the researcher knows the B_0 matrix of contemporaneous correlations. B_0 is identified through the unrestricted covariance matrix of the reduced form, $\Sigma = E(u_t u_t')$, and the diagonal covariance matrix of the structural form, $\Lambda = E(e_t e_t')$, as in (6). This, unfortunately, does not uniquely identify B_0—there are many matrices that satisfy (6). In order to identify the structural form of the model the researcher must place additional restrictions somewhere in the model. Since the primary interest of this study is in short and medium term responses, I use contemporaneous restrictions on the B_0 matrix to identify the shocks as in (7). This avoids any potentially serious mis-specification problems associated with long-run restrictions (Faust and Leeper, 1997).

$$\begin{bmatrix} e_{\mathrm{Com}} \\ e_{\mathrm{FFR}} \\ e_{\mathrm{RS}} \\ e_{\mathrm{RPIX}} \\ e_{\mathrm{MD}} \\ e_{\mathrm{MS}} \\ e_{\mathrm{ER}} \\ e_{\mathrm{RHPI}} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21}^0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31}^0 & 0 & 1 & 0 & 0 & 0 & 0 & b_{38}^0 \\ b_{41}^0 & 0 & b_{43}^0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{53}^0 & b_{54}^0 & 1 & b_{56}^0 & 0 & 0 \\ b_{61}^0 & b_{62}^0 & 0 & 0 & b_{65}^0 & 1 & b_{67}^0 & 0 \\ b_{71}^0 & b_{72}^0 & b_{73}^0 & b_{74}^0 & b_{75}^0 & b_{76}^0 & 1 & 0 \\ 0 & 0 & 0 & 0 & b_{85}^0 & b_{86}^0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{\mathrm{Com}} \\ u_{\mathrm{FFR}} \\ u_{\mathrm{RS}} \\ u_{\mathrm{RPIX}} \\ u_{\mathrm{M}} \\ u_{\mathrm{R}} \\ u_{\mathrm{ER}} \\ u_{\mathrm{RHPI}} \end{bmatrix} \tag{7}$$

Here, e_{Com} is a commodity price shock, e_{FFR} is a Federal Funds shock, e_{RS} is a retail sales shock, e_{RPIX} is a price level shock, e_{MD} is a money demand shock, e_{MS} is a money supply shock, e_{ER} is an exchange rate shock, and e_{RHPI} is a real house price shock. The reduced form errors are denoted similarly except with u_{M}, a money stock error, and u_{R}, an interest rate error. Kim and Roubini base their identification strategy upon a model

[16] This is the model that describes the underlying economic structure.

of the macro-economy based upon optimising agents developed by Sims and Zha (2006); so do I. Hence, it will be instructive to explain the salient features of the identification strategy.[17]

The structural model is composed of several blocks. Rows 1 and 2 measure the external pressures on the economy. As Kim and Roubini, (p. 568) explain, "By including the oil price, we control for current systematic responses to (negative) supply shocks and inflationary pressure." I use a broad commodity price index instead of the oil price for this. I also include the Federal Funds Rate as a foreign interest rate in the model. This follows Grilli and Roubini (1995) who argue persuasively that, for the G7 countries, the US acts as "leader" and the other countries are "followers" in setting monetary policy.[18]

Rows 3 and 4 comprise the domestic goods market equilibrium and the large number of zero restrictions in these rows is consistent with a model exhibiting nominal rigidities.[19] Commodity prices do, however, enter this block and the rationale behind this follows from a cost mark-up rule for prices as is common in the theoretical literature. Furthermore, house prices enter row 3 to allow aggregate demand to vary contemporaneously with house prices.[20]

Money demand is shown in row 5 and money supply in row 6 of the B_0 matrix. Following the discussion in Sims and Zha, I assume that monetary policy does not respond contemporaneously to consumption or prices simply because the data is not available contemporaneously. Central banks can forecast current consumption and prices from the available data and use these to guide policy. Including the actual price and consumption values contemporaneously in the reaction function is equivalent to saying that the central bank always forecasts these variables perfectly. In our model, the interest rate equation includes lagged values of all variables, which can be viewed as containing an implicit forecast of the current period consumption and prices. Whilst it is also true that a central bank has many more sources of data to base these forecasts upon than one could possibly hope to include in a VAR, the most important variables in constructing this forecast are likely to be the lagged values of consumption and prices themselves. I prefer to approximate the information set that the central bank uses to forecast current values than to assume they always forecast the variables exactly. Lagged values of consumption and prices are in the information set of the central bank in our model.[21] For the other variables, the Bank of England can respond contemporaneously to those variables that are available contemporaneously: commodity prices, money, and the exchange rate. I also assume that the central bank does not respond contemporaneously to house price move-

[17] Various alternative empirical specifications for the housing market have been tested. That is, leaving the basic Kim and Roubini model unchanged I estimated the model with alternative zero restrictions in the last row and column. My conclusions are robust to these alternative empirical specifications of the housing market. See the supplementary materials document of footnote 4 for these models.

[18] Without controlling for US rates, open economy VARs often suffer from both the price puzzle and the exchange rate puzzle. The price puzzle is the term given to an estimated increase in prices (or inflation) following a positive interest rate shock and is a common finding of VAR studies. The exchange rate puzzle is the corollary finding for the exchange rate: a fall following a positive interest rate shock.

[19] The dynamic stochastic general equilibrium model of Sims and Zha (2006) generates inertial output and prices of this type. Nominal rigidities of this sort are common in DGSE models.

[20] I have also estimated models with no contemporaneous response of aggregate demand to house prices. The conclusions were robust to this alteration. See the supplementary materials document of footnote 4 for these models.

[21] See McCallum (1999) for more discussion on the (un)observability of current output and prices for a monetary policy rule.

ments. Again, whilst the central bank can react to the general level and speed of change of house prices through the lagged values, it seems unlikely that the central bank responds contemporaneously. To illustrate this point it is noteworthy that the December 2003 interest rate decision of the Bank of England was taken on 4 December whilst the December house price statistics from the Halifax were released on 6 January 2004.[22]

The money demand equation is standard in that it assumes money demand depends contemporaneously on real income and the opportunity cost of holding money. Contemporaneous portfolio adjustments from money to house prices are assumed to be negligible and are treated as zero.

The final two rows in the model are the exchange rate and house prices. The exchange rate serves two purposes: allowing the monetary authorities to take into account "the effects of a depreciation of their currencies on their inflation rates" and "controlling for the components of interest rate movements that are systematic responses to a depreciation of the domestic currency, we are more likely to identify the interest rate innovations that are true exogenous contractions" (Kim and Roubini p. 568). House prices are modeled as only reacting contemporaneously to domestic monetary variables.[23]

5. Results

The reduced form VAR model was estimated with 2 lags for all variables as suggested by the Akaike Information Criterion (AIC).[24] Full seasonal dummies, an intercept and a time trend were included. The restrictions in (7) were imposed and estimated by maximum likelihood using the scoring algorithm of Amisano and Giannini (1997).[25] The over-identifying restrictions imposed on the structural covariance matrix are not rejected in favor of the alternative hypothesis of the completely unrestricted reduced form covariance matrix at conventional confidence levels having a p-value of 0.622.[26]

Fig. 2 shows the responses of the domestic variables to a positive 100 basis points interbank rate shock. The dotted lines indicate 90% bootstrapped confidence intervals calculated using Hall's method with 1000 replications.[27] The responses are in line with the predictions of economic theory: consumption, prices, money and house prices fall, whilst the exchange rate appreciates. Retail sales display the commonly found hump shaped

[22] I have also estimated models allowing the central bank to react contemporaneously to house prices but this did not alter the conclusions regarding the importance of house prices in the transmission mechanism. See the supplementary materials document of footnote 4 for these models.

[23] The UK housing market is not entirely domestic; the top end of the market is quite international, especially in London. I have estimated alternative specifications allowing for a contemporaneous response of house prices to international variables but this did not alter the results. See the supplementary materials document of footnote 4 for these models.

[24] The Hannan-Quinn Criterion (HQ) and the Schwarz Criterion (SC) both suggested lag lengths of one. I chose to use the more general model suggested by the AIC despite the possibility that this was too many lags. As Lütkepohl and Krätzig (2004, p. 111) put it: "the AIC criterion (*sic*) asymptotically overestimates the order with positive probability, whereas [HQ and SC] estimate the order consistently under quite general conditions ...".

[25] The models were estimated using the JMulTi software package of Lütkepohl and Krätzig described in Lütkepohl and Krätzig (2004).

[26] As is often found with SVAR models most of the individual elements of the B_0 matrix are not statistically significant due to the high correlation among the series (see Kim and Roubini for further discussion).

[27] See Benkwitz et al. (2000) for a discussion of methods for bootstrapping confidence intervals and their associated problems.

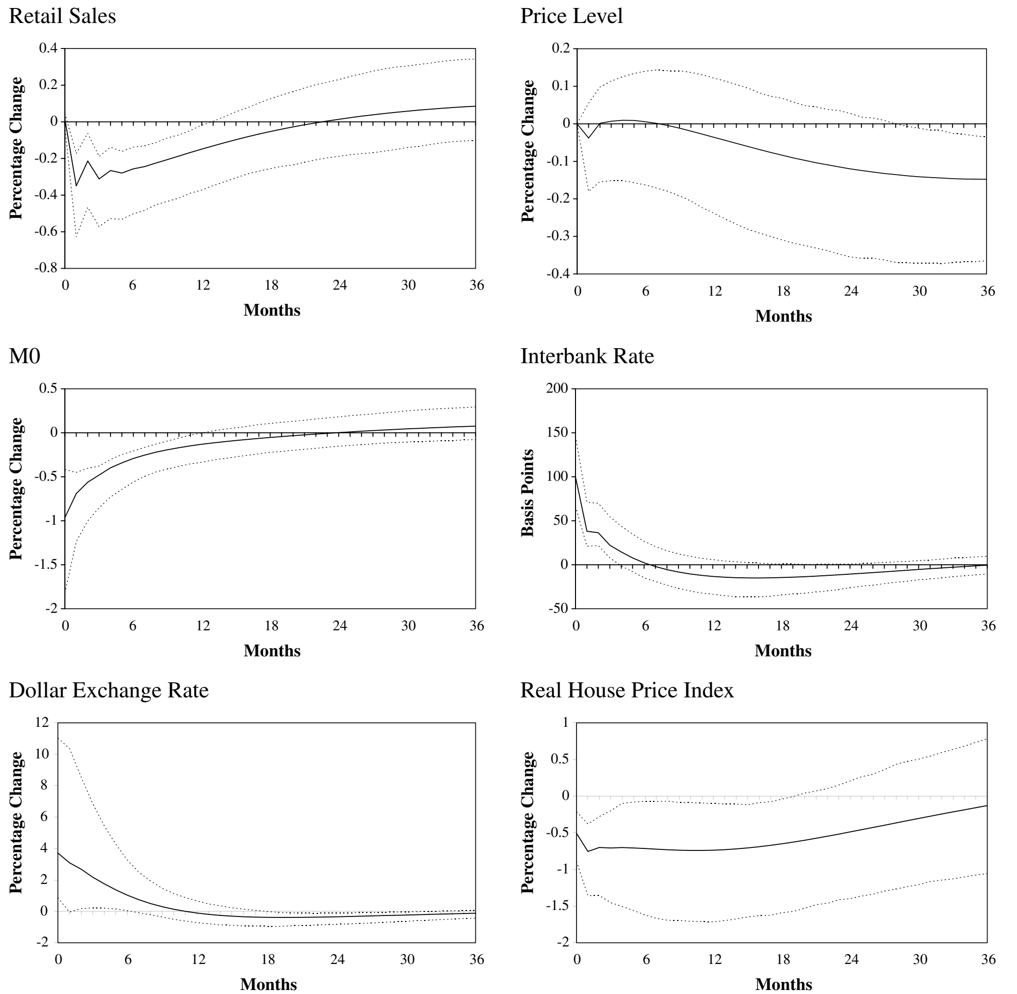

Fig. 2. 100 Basis points interbank rate shock. *Note:* Dashed lines are 90% bootstrapped confidence intervals calculated using 1000 repetitions of Hall's percentile method. The vertical axis represents the percentage deviation from the underlying path, except for the response of the interbank rate, which shows the change from the underlying path in basis points.

response with a peak effect of –0.33% occurring after 1 month; it remains around this level for 4 months before returning to baseline. This response is statistically significant at the 90% level as shown by the confidence intervals.

After a delay of about eight months, the price level slowly falls to 0.01 percentage points below baseline following the temporary interest rate shock. Money demand falls immediately following the increase in the opportunity cost of holding money before returning to baseline at around 18 months. The exchange rate response is large with a peak appreciation of just over 3.5% showing the volatility of the sterling exchange rate over the sample period. House prices fall immediately by 0.5% and reach their lowest point 1 month later at −0.75%.

In order to gauge the role played by house prices in the transmission mechanism we can look at the effects of a house price shock on consumption and prices and then see how

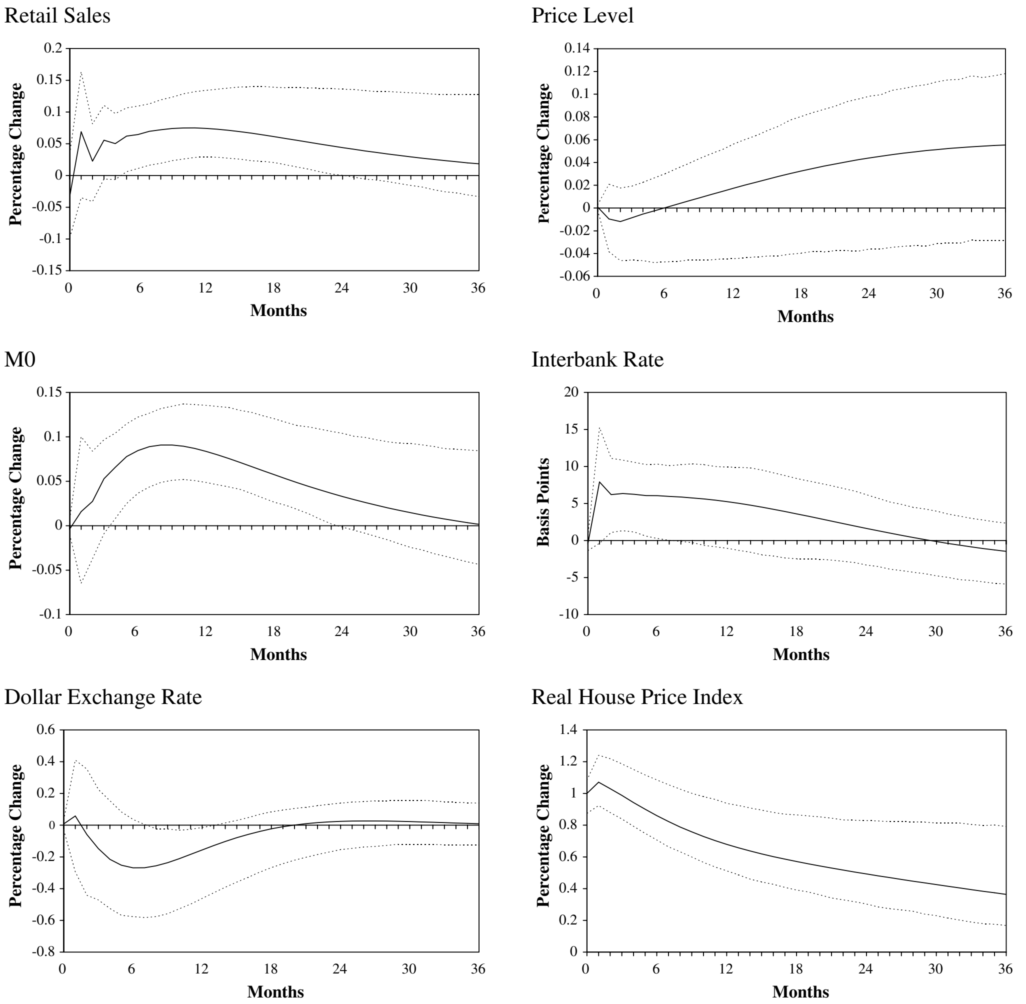

Fig. 3. 1% Real house price shock. *Note:* Dashed lines are 90% bootstrapped confidence intervals calculated using 1000 repetitions of Hall's percentile method. The vertical axis represents the percentage deviation from the underlying path, except for the response of the interbank rate, which shows the change from the underlying path in basis points.

much house prices fall following a monetary shock. Under the assumption that consumption responds in the same way to changes in house prices whatever the cause of the change in house prices, combining these two responses can give us an idea of the importance of house prices in the mechanism. Fig. 3 shows the responses to a 1% positive shock to real house prices. The peak response is 0.07%, which is in line with the estimate of Case et al. (2005) and only slowly moves back towards the baseline. The interest rate responds immediately, rising by up to 7 basis points.[28] Perhaps this is in anticipation of the effect of the

[28] Whilst this may not seem a large response, one should bear in mind that house prices in the UK have risen hugely as detailed in the opening paragraph of this paper.

house price shock on prices; the central estimate of the price level response rises by up to 0.06%. The central estimates of the key responses (consumption, prices, and interest rates) are all of the expected sign as has already been noted.[29]

By combining the central estimates for the responses to the monetary and the house price shocks—a 1% real house price shock raises consumption by 0.07% and house prices fall by 0.75% following a monetary policy shock—it can be inferred that about 0.05–0.055% points (or about 15%) of the fall in consumption in Fig. 2 is due to changing house prices. This is an estimate of the combined role of a housing wealth–effect channel and a housing credit channel.

5.1. Forecast error variance decompositions

Fig. 4 shows variance decompositions for retail sales, the interbank rate and real house prices. Initially, retail sales shocks are the most important cause of variations in retail sales. After 18 months the domestic price level and the US Federal Funds Rate become more important. Domestic monetary shocks, as represented by interbank rate and M0 shocks, account for very little of the forecast error in retail sales. Likewise, real house prices also do not appear to be an important driving factor for retail sales.

The variance decomposition for the interbank rate gives us an idea of the variables in the model that the Bank of England reacts to most when setting interest rates. The largest proportion of variance after two years (31%) is attributable to the Federal Funds rate; although money supply shocks are also important throughout the three years. Retail sales, the price level and house prices combined account for only 14% of the observed variation in the interbank rate at the two year horizon.

Real house prices are largely self determined to begin with, although as the horizon increases the other variables grow in importance. After three years the US Federal Funds Rate accounts for 33% of variation in house prices. That US interest rates play an important role for UK house prices whilst UK rates do not is in line with the Grilli and Roubini argument that the US acts as a leader. Unlike Iacoviello (2002), the proportion of house price variation attributable to aggregate demand shocks (as represented by retail sales) is low.

5.2. Counterfactual approach

The results discussed so far put the present study on the side of Case et al. (2005) in terms of the scale of the consumption response to house price shocks. In the overall transmission mechanism, the results detailed here ascribe a much smaller role for house prices than that suggested by the results of Chirinko et al. (2004) and Giuliodori (2005). In order to investigate why the estimates presented here are smaller, I calculated the proportion of the fall in consumption following the monetary shock that is due to house prices using a similar counterfactual approach employed by Giuliodori. This approach was pioneered by Sims and Zha (2006) and Ludvigson et al. (2002). The counterfactual approach shuts off the effects of house prices on consumption by setting to zero the cross correlations between

[29] I also estimated a model with commodity prices and the Fed Funds rate treated exogenously, which narrowed the width of the confidence intervals whilst leaving the responses virtually identical to those shown here. See the supplementary materials document of footnote 4 for this model.

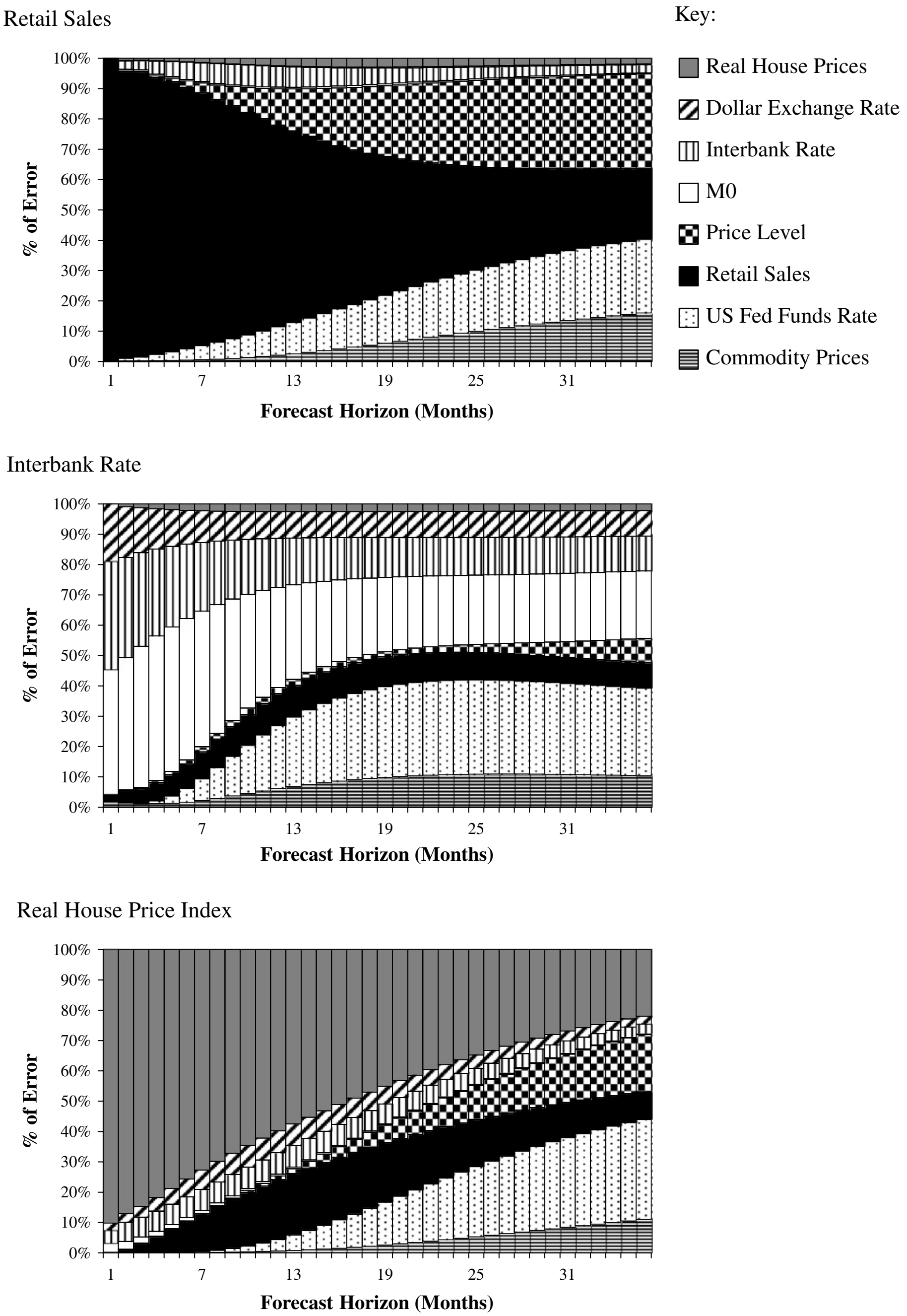

Fig. 4. Forecast error variance decompositions.

consumption and house prices in the consumption equation of the structural model. That is, the b_{38}^{L} (where $L = 0, 1, 2$) parameters are set to zero in each of $B(L)$ matrices in Eq. (2), whilst leaving the other parameters as originally estimated. Then the impulse responses are

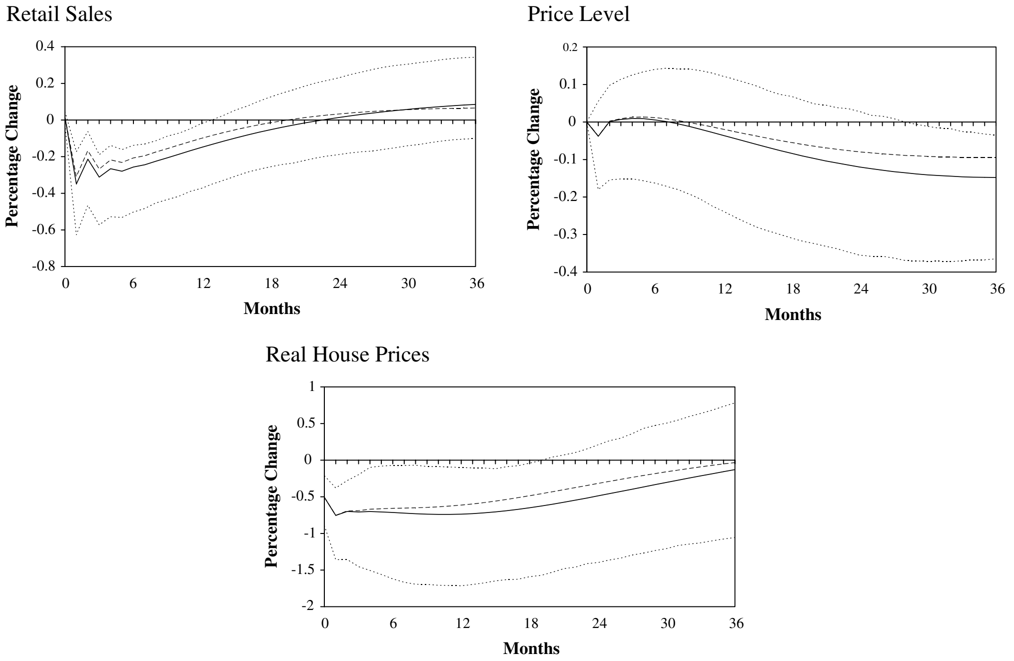

Fig. 5. 1% Interest rate shock—housing shut off. *Note:* Dashed lines are 90% bootstrapped confidence intervals calculated using 1000 repetitions of Hall's percentile method. The vertical axis represents the percentage deviation from the underlying path.

recalculated and compared and the difference between the counterfactual impulse response and the baseline impulse response is attributed to the house price—consumption channel.[30] Clearly this technique is subject to the Lucas critique: if consumption did not depend on house prices, the Bank of England would have reacted differently over the sample period and our monetary policy shocks would be different. Since we are not looking to say what would happen if consumption did not depend on house prices, but rather what proportion of the response that we see in the sample under study is estimated to come through house prices, the Lucas critique is not so strong. Therefore, although we report the results, they should be taken as a form of circumstantial evidence rather than a smoking gun.

The results of the counterfactual approach are shown in Fig. 5. Shutting off the housing wealth effect reduces the impact of a monetary policy shock on consumption, the price level, and real house prices. The peak response of consumption falls from −0.35 to 0.31 and the reduction in prices is also slightly smaller smaller. The counterfactual simulation attributes about 12% of the response of consumption to a monetary policy shock to falling house prices, which is also much smaller than that reported by Giuliodori. It is unclear

[30] Giuliodori utilises a different definition of shutting-off the house price channel. He sets all of the cross correlations involving house prices to zero; that is the last row and column of each of the $B(L)$ matrices. In order to check the sensitivity of my conclusions to this differing definition I also calculated the Giuliodori version and my conclusions were unchanged. See the supplementary materials document of footnote 4 for a comparison of the two definitions.

why my results differ so sharply from those of Giuliodori; inspection of table indicates that the key differences is Giuliodori's use of the Choleski decomposition and the earlier sample period that includes the period before the major liberalization of the UK mortgage market. However, it may also be due to my use of monthly data where I have had to proxy consumption with retails sales, although Christiano et al. (1999) report that monthly and quarterly VAR models of the monetary transmission mechanism lead to similar outcomes. The proportions I find are also in line with those of Aoki et al. (2004). Further investigation of the causes of the differences is not possible because the sample period of the data used in this study do not extend as far back as Giuliodori's and because results from an 8 variable VAR estimated on the reduced degrees of freedom available from quarterly data would not be reliable. The values estimated by the counterfactual approach are also in line with those estimated using the two-step procedure reported above. The effect of monetary policy shocks on real house prices is also slightly reduced.

6. Conclusions

I estimated an 8 variable structural VAR model for the UK based upon Kim and Roubini (2000) to investigate the role played by house prices in the transmission mechanism of monetary policy. By estimating a structural VAR with an economic interpretation to each of the structural shocks, the model I have estimated can generate both monetary policy shocks and house price shocks within the same model. This has the advantage that the identified house price shocks are, by construction, not correlated with the monetary policy shocks. Estimating different models for looking at monetary policy and house price shocks may suffer from this problem.

Evidence from impulse responses suggests that housing wealth does play a role, although not as large as suggested by some other authors. For both a two-step approach and for a counterfactual simulation we estimate that about 12–15% of the drop in consumption following a contractionary monetary policy shock works through changes in house prices; the uncertainty surrounding these point estimates is large so should only be taken as a guide. The comparable estimate of Giuliodori (2005) attributes about 60–70% of changes in consumption to house price movements. My results do not preclude the housing market playing an important role in the monetary transmission mechanism because of the direct effects that work through interest payments on mortgages, but the results presented here do not support the claims that the credit and wealth channels of monetary policy transmission account for most of output variation in response to monetary policy.

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